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Balkan-Atlı, Nur

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Basic Biographical Information

Nur Balkan-Atlı was born in 1953 in Aydın, Turkey After graduating from Robert College, she went to Paris and studied prehistory, anthropology, and ethnology at Sorbonne University. She received her M.A. and Ph.D. with a dissertation titled *The Neolithization of Anatolia* from the Sorbonne University in 1985. Atlı was assigned as a specialist to the Prehistory Department of İstanbul University in 1987 and was promoted to Assistant Professor in 1995 and then Professor in 2000.

Major Accomplishments

Nur Balkan Atlı's major field of study is the Paleolithic period of prehistoric archaeology and lithic technologies. Since 1995, she has mostly focused on the obsidian beds and working areas in the Cappadocia region in Turkey. After working in El Kown, Qdeir (Suriye), Cafer Höyük (Malatya), and Aşıklı Höyük (Aksaray) on excavations, she started an ongoing study through the Cappadocia Obsidian Research Project. She is connected to the French Institute of Anatolian Studies and is a researcher and a member of the monitoring committee.

Nur Balkan Atlı is also a foreign member of the French CNRS Archiorient Group, a local consultant of the European Commission INCO-MED Programme, and a member of the American Research Institute of Turkey and similar scientific institutions. She currently serves on the editorial board of journals including "Anatolia Antiqua" and "Paliorién t." She has published the book *La Niolithisation de l'Anatolie* and numerous scientific articles.

Cross-References

► Art, Paleolithic
► Lithic Technology, Paleolithic

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Balme, Jane

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Basic Biographical Information

Prof. Jane Balme is an Australian archaeologist and leading researcher in the archaeology of Indigenous Australia.

She grew up mainly in Western Australia and following high school went to the University of Western Australia where she obtained her undergraduate degree in anthropology (1979). After working at the Western Australian Museum as a graduate assistant in archaeology, she enrolled in a Ph.D. at the Australian National University (ANU). Her Ph.D. research on Pleistocene fishery on the Darling River in western New South Wales was awarded in 1990.

Prof. Balme has also worked as a consultant to the National Parks and Wildlife Service of New South Wales and as a lecturer in the Archaeology and Palaeoanthropology Department at the University of New England. She is currently Professor in Archaeology and Associate Dean (Research) in the Faculty of Arts at the University of Western Australia.

Prof. Balme has worked on projects with Indigenous groups in north and western New South Wales, southern Arnhem Land, the Kimberley region of northwest Australia, and southwest Australia. Most of her work has been on the archaeology of Indigenous Australia, and she has a particular interest in the Pleistocene period, the symbolic evidence of early art and adornment, and the role that symbolic differentiation between populations may have played in the colonization of the continent. She has also published on gender organization in hunter-gatherer societies, archaeology education, and public perceptions of archaeology.

Major Accomplishments

Prof. Balme's research to date has been in three principal areas:

- Social behavior and organization in early Australian Indigenous groups (e.g., Balme & Beck 2002; Balme et al. 2009), including Pleistocene Australia (e.g., Balme 2000; Balme & Morse 2006)
- The development of gendered social organization, particularly in hunter-gatherer societies (e.g., Balme & Bowdler 2006; Balme & Bulbeck 2008; Bowdler & Balme 2010)
- Archaeology as a discipline (e.g., Beck & Balme 2005)

She has held major research grants, usually in collaboration with other researchers. In 2010, she received a major Australian Research Council Linkage Project grant, with Prof. Susan O'Connor, for the study into Lifeways of the First Australians in the Kimberley region. This project, working in collaboration with Traditional Owners, is using archaeological evidence to investigate the complexity of life in that area.

Prof. Balme has also contributed greatly to the Australian Archaeological Association (AAA), the professional body for Australian archaeologists. She has held several positions in AAA over the years, including secretary, and chair of the Australian National Committee for Archaeology Teaching and Learning.

Cross-References

- ▶ Beck, Wendy E.
- ▶ Bowdler, Sandra E.
- ▶ First Australians: Origins
- ▶ Gender, Feminist, and Queer Archaeologies: Australian Perspective
- ▶ Indigenous Archaeologies: Australian Perspective

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Bam: Archaeological and Social Investigations after the Earthquake

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Introduction

Bam is a desert city engaged in citrus and palm cultivation, whose residents dwelt in handmade mud-brick houses around an ancient citadel, which is a World Heritage Site (UNESCO 2005). It is located in the southern border of the Lut desert, in southeastern Iran. Despite this fringe location, it has traditionally served as a center for local trade. On the 26 December 2003, the city was reduced to ruins by an earthquake in only 12 seconds. Approximately 40,000 people died, 30,000 were injured (Tahmasebi et al. 2005), and 100,000 people made homeless (Mann 2005: 3). *Disaster ethnoarchaeology: Bam after the earthquake* was an ethnoarchaeological project aimed at recording this dramatic change (Dezhamkhooy & Papoli 2010; Papoli 2010; Papoli et al. 2011) (Fig. 1).

Key Issues/Current Debates/Future Directions/Examples

The project, which took place in five seasons from 2004 to 2007, was conducted by 40 archaeologists, 24 women and 16 men, Ph.D. candidates, and M.A. and B.A. students, all familiar with the local and cultural context and supported by the previous directors of the *Bam research foundation*. In the first four seasons, data gathering was based on an *ethnoarchaeological approach*. In the last season (2007), six ruined houses of different status and district were

Bam: Archaeological and Social Investigations after the Earthquake, Fig. 1 Bam citadel after earthquake

investigated by archaeological excavation. The main mission of the project was to discover the impact of the catastrophe on the intimate lives of the residents. In addition, the project also sought to understand from the strata how the settlement had previously been affected by Bam's inhospitable and unstable environment – drought, winds, and frequent earthquakes (see Mahalati 1988).

The lifeways of Bam and its immediate environment were surveyed in five categories: mortuary practices, material culture, population mobility, trade and market patterns, and domestic architecture. Data were gathered through observation and by questionnaires designed to record patterns of life before the earthquake. The recorded changes to everyday life were studied over the short, medium, and long term. Also recorded were accounts of the gradual return to normal conditions.

Recording damaged buildings was a key part of the archaeological inquiry. Bam's domestic architecture was first divided into three general architectural styles: modern (structures built on metal frames), semi-modern (plaster and clay mortar on metal frames), and traditional (made of mud brick). 673 houses and 383 destroyed shops (Fig. 2) were evaluated during the first three seasons. These buildings were classified by their degree of damage: destruction of decorations, destruction of walls and roofs, or total destruction. The state of the buildings was compared with the socioeconomic status of the occupants, by district. For example, it was shown that most casualties occurred in the traditional type of housing, most vulnerable to earthquake and occupied by the least wealthy.

The excavations of the six houses (Fig. 3) showed that most of them had already been searched to discover the remains of the dead and to remove valuable materials. Most of the furniture remained. Divisions recorded within the houses led to information about the use of space and the implied spatial imperatives of gender, class, and wealth. People of higher status had more private spaces such as bedrooms or divided spaces based on gender and age, while the less wealthy had more common spaces, such as one bedroom for all the family. Differences in status were evident in other material culture too. The last moments of the six families were reconstructed from the disposition of the surviving cultural material.

There were interesting differences between the archaeological findings and the statements made on the questionnaires, no doubt through a reluctance to admit to activities of which authorities may have disapproved – such as

Bam: Archaeological and Social Investigations after the Earthquake, Fig. 2 Buildings for recording (shops)

Bam: Archaeological and Social Investigations after the Earthquake, Fig. 3 A store room of the Hafezabadi House under excavation Trench 1

sexual practices, drinking, or even watching some satellite channels. The earthquake and the subsequent archaeological excavations opened up private spaces such as bedrooms, revealing intimacies of everyday life, love letters, and personal entertainment tools.

Since the investigators were themselves indigenous, their relations with Bam residents developed naturally. But the feelings of the archaeologists were nevertheless strongly affected by the roles they were obliged to adopt. International and national aid initiatives rapidly altered the circumstances, the attitudes, and the decisions of residents. In addition, the changing policies of the Iranian government were determinant, eventually bringing the project to an end.

Cross-References

▶ Cultural Heritage Site Damage Assessment
▶ Disaster Response Planning: Earthquakes

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Bamiyan Buddhas

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Introduction

The Bamiyan Buddhas were situated in the Hindu Kush mountains, in the central highlands of Afghanistan. They were the largest standing Buddhas in the world (Grun et al. 2004). The two main statues were built in 554 CE and 507 CE (Janowski 2011: 47) and were known in modern times as the West Grand Buddha and the East Grand Buddha. They were, respectively, 53 m and 38 m high (Grun et al. 2004: 178). The statues were carved into niches in the valley of Bamiyan, a center of Buddhist culture from the second century CE until the eighth century, and were part of a large complex of Buddhist temples, many of which still survive. The valley and the remains of the Buddhas are now a world heritage site (UNESCO 2003).

In March 2001, Afghanistan's effective government, the Taliban, destroyed the Bamiyan Buddhas in the face of huge international opposition and in defiance of international law (Francioni & Lenzerini 2003). Later discussion of the Buddhas centered on the stabilization of the larger site of Bamiyan and the possible reconstruction or restoration of the destroyed statues.

Definition

These two statues of the standing Buddha were located in the Bamiyan Valley, 200 kms northwest of Kabul, in the Hindu Kush mountain ranges, 2,500 m above sea level. The statues were carved directly into the cliff face. The geology of the cliffs consists of conglomerate and siltstone layers, with the siltstone being particularly vulnerable to the actions of water (Margottini 2004). The region experiences hot summers and very cold winters, and the freeze thaw cycle puts further pressure on the cliffs and the remains of the Buddhas.

The Western statue was the larger of the two. Before its destruction it was the largest standing Buddha in the world. It stood at 53 m high and was constructed in 554 CE. The Eastern statue was slightly smaller at 38 m and was built in 507 CE (Grun et al. 2004; Janowski 2011). A smaller statue of a seated Buddha was located between the Eastern and Western Great Buddhas, and it was destroyed as well.

In modern times the statues appeared to be without faces or arms. The lower legs of the larger Buddha were badly damaged in the seventeenth and eighteenth centuries by the moguls Shah Aurangzeb and Nadir Shah (Grun et al. 2004). The clearest ancient description of the statues is by Hsuan-Tsang, a Chinese monk who visited the site in 630 CE. He described the Buddhas as being gilded and decorated with precious stones. They also wore masks, and while the lack of facial features in modern times is often attributed to vandalism, it is possible that this was an original feature designed to accommodate the wooden masks (Cotter 2001). The statues were originally constructed by carving their rough shape into the cliffs. The intricate gowns of the Buddhas were shaped by applying stucco to the rough carving, and the lower arms were made of wood (Knobloch 2002).

The statues were sculpted in the Gandharan style that blends Greco-Roman artistic traditions with Indian and Buddhist religious art (Grun et al. 2004). This suggests that the building of the statues was initiated at an earlier time than radiocarbon dates given above would suggest. Grun et al. (2004) states that the building of the Buddhas was instigated by the Kushan Dynasty, who ruled the area from the first to the third century CE. The Western, larger statue represents Vairocana, the "Light Shining throughout the Universe" Buddha, and the Eastern, smaller statue Shakyamuni, "The Awakened One of the Shakya Clan" (AIIS 2004). The artistic style represented here is believed to have inspired other sites in China such as Dunhuang.

The Buddhas were first recorded in Western literature by Alexander Burnes in 1832 (Grun et al. 2004). The first archaeological work at the site was undertaken by the Delegation Arche´ologique Francaise en Afghanistan in the 1920s and 1930s. The French recorded the site, began preservation work on some of the murals, and produced the first guide book to the Bamiyan Valley (Grun et al. 2004). A number of Japanese and American researchers continued working at Bamiyan in the late twentieth century, recording details, completing a photographic survey, and preserving the great statues. Most research at the site was put to a halt with the Soviet invasion in 1979.

Key Issues/Current Debates/Future Directions/Examples

In March 2001 the Taliban regime of Afghanistan, which controlled Bamiyan at the time, destroyed the Buddhas. The destruction of the Buddhas was part of a systematic destruction of all images in Afghanistan that were considered to be idolatrous. While the Buddhas were not the only victims of this wave of destruction, they were the most visible, and their destruction has come to symbolize the violence of the Taliban regime (Centlivres 2008; Janowski 2011).

It is possible that the Taliban's actions were more politically than religiously motivated. In 2001 Afghanistan had been at war for more than 20 years, and the Taliban had begun pushing for full control of the nation. In 1999 the Taliban made a commitment to protect Afghanistan's cultural heritage (ICOMOS 2001) but by 2001 the United Nations had imposed a number of sanctions on the country and had refused to acknowledge the Taliban as the government of Afghanistan, despite their effective control of the country. In this volatile political environment, the destruction of the Buddhas can be interpreted as an assertion of power on the part of the Taliban, rather than an action that was motivated solely by religious beliefs (Francioni & Lenzerini 2003).

The destruction of the Bamiyan Buddhas by the Taliban led to a reconsideration of the nature of war crimes and crimes against humanity. Francioni and Lenzerini (2003) found that the destruction of the Buddhas differs from the usual destruction of cultural heritage during wars because of the careful documentation of the destruction and the lack of a clear military objective. Instead, it can be viewed as act of defiance of the United Nations and of the international community (Francioni & Lenzerini 2003: 620). From this viewpoint, the destruction of the Bamiyan Buddhas can be viewed as a planned action in a symbolic war between the Taliban and others.

In 2003 the United Nations inscribed the cultural landscape and archaeological remains of the Bamiyan Valley onto the World Heritage List (UNESCO 2003) under criteria i, ii, iii, iv, and vi. This area is currently listed as World Heritage in Danger. The inscription specifies the niches in which the Buddhas once stood, the sacred cave system, the remaining Buddhist art, and several other elements of the surrounding landscape as the main elements of the site (UNESCO 2003). Since the fall of the Taliban regime, the new Afghani government has attempted to preserve what remains of the Bamiyan Buddhas and their surrounds. The government has been working with UNESCO to stabilize the site, which is at risk due to natural process and the effects of the blasting that was done to destroy the Buddhas (Margottini 2004; Manhart 2004). Archaeological work has resumed at the site (Hammer 2010) and a systematic recording of the niches that remain has been undertaken, including computer and 3D modelling of the site (Grun et al. 2004).

When archaeologists visited the site in 2002, they discovered that the Buddhas had not been completely pulverized and that the remains were substantial and that reconstruction of the Buddhas was technically possible (Lawler 2002). Since this time there has been debate over what should happen at the site. UNESCO does not support reconstruction, campaigning for a stabilization of the remaining aspects of the site and the preservation and display of the pieces of the Buddhas in a museum context. Many local people and members of the Afghani government support full reconstruction on economic grounds; they believe the reconstruction of the Buddhas will promote tourism and give the country a much needed economic boost (Gall 2003). The discussion over what to do with the remains of the Buddhas has led to a reassessment of the ethics of restoration and reconstruction in the academic literature (Gall 2003; Manhart 2004; Centlivres 2008; Janowski 2011). The UNESCO 10th expert working group released its recommendation for the Bamiyan site in 2011. They found that "in view of the available scientific data and estimated financial requirement, a total reconstruction of either of the Buddha sculptures cannot be considered at the present time" (UNESCO 2011). However, this does not rule out reconstruction at some point in the future. The remains of the Buddhas are currently still in situ, at the foot of the niches in which they once stood.

Cross-References

- ▶ Middle East Archaeology: Sites, Texts, Symbols, and Politics
- ▶ UNESCO's World Heritage List Process
- ▶ Vandalism and Looting (Ethics)
- ▶ World Heritage List: Criteria, Inscription, and Representation
- ▶ World Heritage Objectives and Outcomes

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Ban Chiang: Agriculture and Domestication

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Basic Site Overview

Ban Chiang is a prehistoric settlement located in the northeastern part of the Khorat Plateau in Thailand. It came to prominence in the 1960s when elaborately decorated pottery vessels were found there. Excavations by Thai archaeologists then identified similar vessels in a cultural sequence that spanned the early Neolithic to the end of the Iron Age. The painted vessels were restricted to late Iron Age burials. These excavations coincided with claims based on the nearby site of Non Nok Tha that copper-based technology dated to the fourth millennium BCE which, if validated, would of necessity make Southeast Asia an independent center for the discovery of bronze casting.

Ban Chiang was soon to be almost entirely ransacked by looters, initially fed by visitors from a large, nearby American airbase. Appreciating the potential significance of this site, the University Museum of Pennsylvania and the Thai Fine Arts Department appointed Chester Gorman and Pisit Charoenwongsa to direct rescue excavations. Two small areas were identified where looters had not yet penetrated, and fieldwork took place in 1974 and 1975. The cultural sequence of both areas, when combined, began with burials containing ceramic vessels decorated with incised and impressed patterns that typify the Southeast Asian early Neolithic. These lay under further human graves assigned to the Bronze Age, although copper-based mortuary offerings were very rare indeed. With the Iron Age, grave goods included bimetallic spears with an iron blade and socketed bronze haft, glass beads, deeply incised clay cylindrical rollers, and bones from domestic pigs and dogs.

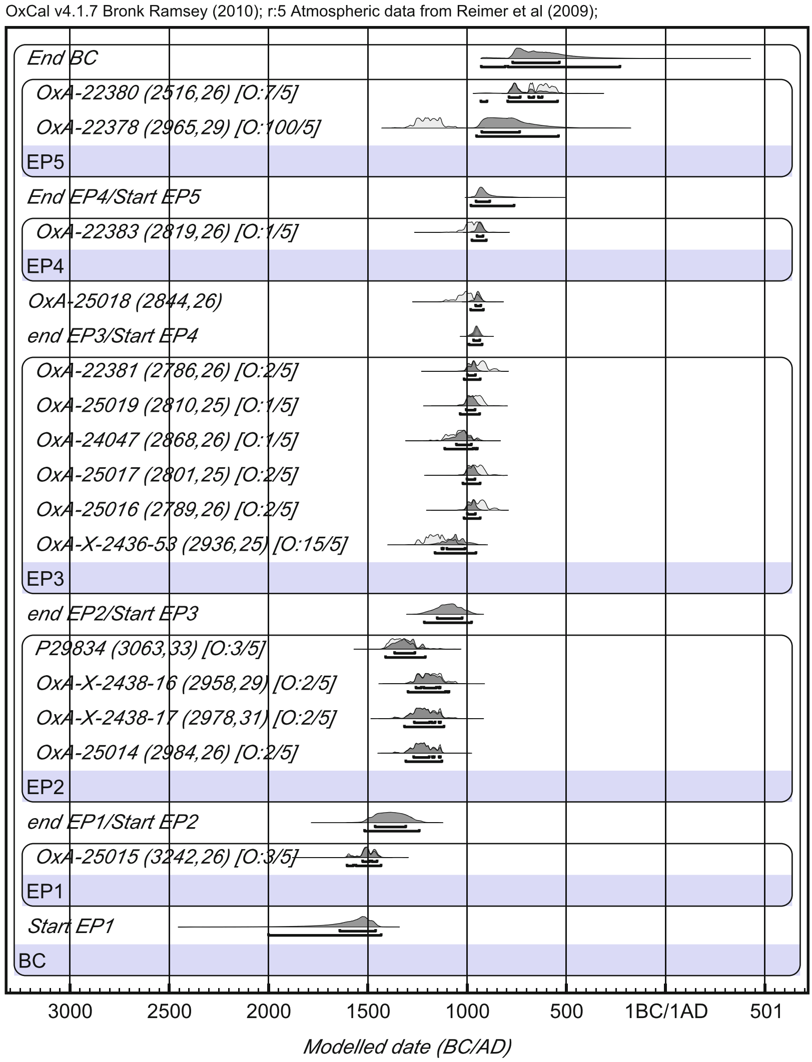
Evidence of Early Agriculture

Radiocarbon determinations were initially derived from charcoal which came from two principal sources. The majority of samples were accumulated from fragments of charcoal recovered from grave fill, while a few came from in situ hearths. Gorman and Charoenwongsa (1976) reported that these confirmed the startlingly early date for the initial Bronze Age at 3600 BCE and further claimed that iron forging was under way between 1600 and 1200 BCE. This divided scholarly opinion down the middle, and Ban Chiang became a *cause célèbre*.

The untimely death of Chester Gorman in 1981 led to the appointment of Joyce White to analyze and publish the results of the 1974–1975 excavations. Appreciating the internal contradictions in the charcoal-based chronology, she began first to reinterpret the results and then, with the advent of AMS dating of very small organic samples, turned to a new dating program that involved extracting and dating the rice chaff that had been used in prehistory to temper mortuary pots.

This experimentally involved three different pretreatments. The two most relevant involved dating either the actual fragments of rice teased out of the pot matrix or the organic fraction of the entire crushed potsherd. A problem arose when dates obtained from both pretreatments from the same pot or burial presented offsets of centuries or even millennia. In the event, White has proposed a new chronology for Ban Chiang derived from six crushed potsherd determinations and one from rice phytoliths. These, she has

Ban Chiang: Agriculture and Domestication, Fig. 1 The radiocarbon dates of human and pig bones from Ban Chiang. *EP1* early Neolithic, *EP2* later Neolithic, *EP3* early Bronze Age, *EP4–5* later Bronze Age



suggested, indicate initial settlement of the site by Neolithic rice farmers in the 3rd millennium BCE and the transition into the Bronze Age in 2000–1800 BCE (White 2008). This would mean that the inhabitants of Ban Chiang either themselves developed metallurgical capabilities or derived their knowledge from a source other than early Chinese states.

White and Hamilton (2009) have subsequently composed a model which identifies the source of the bronze casting tradition at Ban Chiang in the Seima-Turbino transcultural phenomenon of the Urals. Their proposed route for the passage of the necessary specialists covers at least 2,500 km of Western China.

There are problems with this proposal. The first is the reliability of their radiocarbon chronology based on ceramic tempers. Although prima facie, this seems a valid technique, since the rice chaff is most unlikely to have inbuilt age, it is now recognized that clay itself can contain up to 15 % of carbon, and this provides a spuriously early result. However, new methods for pretreating and dating bone, and then interpreting the results, provide a means of testing and refining their chronological framework. This has now been undertaken on the basis of the bones of those who lived at Ban Chiang and of the animals they interred with the dead (Higham et al. 2011a, b). The results harmonize with the chronologies

Ban Chiang: Agriculture and Domestication, Fig. 2 Bronze mortuary offerings like these bangles were very rare at Ban Chiang

Ban Chiang: Agriculture and Domestication, Fig. 3 One of the few Iron Age painted pots recovered during the 1975 excavation at Ban Chian

obtained at other sites in Southeast Asia. The initial settlement of the site by Neolithic rice farmers took place in the 16th century BCE and the transition to the Bronze Age occurred in the late 11th century BCE (Fig. 1). As with other sites, iron forging began in the 5th century BCE.

With the expansion of fieldwork throughout mainland Southeast Asia in the last two decades, it is now possible to place Ban Chiang in its proper cultural perspective. It was one of many sites which was initially settled by rice farmers whose ultimate origin was the valley of the Yangtze River. This thrust south took place in the first few centuries of the second millennium and saw the incomers adapting and integrating with the indigenous hunter-gatherers. The new Neolithic communities maintained exchange contacts with the rapidly developing states of the Yangtze, which brought jades and bronzes into Lingnan and northern Vietnam, in exchange for cowries, turtle shell, and probably other desirable items such as kingfisher feathers. This exchange network probably involved the movement of specialist bronze casters south, for by the eleventh century, copper-based axes, chisels, bells, awls, bangles, socketed spears, and anklets formed the base repertoire of the Southeast Asian Bronze Age (Fig. 2). At some highly strategic sites, such as Ban Non Wat, this stimulated the rapid growth of aggrandizer groups interred with great wealth in princely graves. But at more remote locations such as Ban Chiang, the Bronze Age graves were poor. Iron was probably introduced into Southeast Asia through the development of a major maritime trade artery linking the region with both India and China. Again, some Iron Age sites, such as Prohear in Cambodia, were exceptionally wealthy in terms of exotic bronze drums and golden ornaments. Ban Chiang, however, being remote from the main trade links, was still poor save for its remarkable red on buff painted pottery vessels (Fig. 3).

Cross-References

▶ Agriculture: Definition and Overview
▶ Rice: Origins and Development

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Ban Non Wat, Archaeology of

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Introduction

Ban Non Wat is one of the many moated prehistoric sites that concentrate in the basin of the Mun River in Northeast Thailand (Higham & Kijngam 2009, 2011, 2012a & b; Higham 2011a & b; Higham et al. 2011). It is a key site for understanding the later prehistory of Southeast Asia for three principal reasons. A large area has been excavated over ten seasons. It has revealed a long and continuous sequence of occupation, and it has been dated on the basis of 76 radiocarbon determinations that have been subjected to Bayesian analysis.

Definition

This site is unique in Southeast Asia for the clarity and length of its prehistoric cultural sequence and the size of the analyzed material. There are 12 phases that begin with hunter-gatherers, followed by 2 Neolithic, 6 Bronze Age, and 3 stages of Iron Age occupation, each associated with human burials.

Key Issues

There are two key issues that dominate the interpretation and wider relevance of Ban Non Wat. The first is the application of AMS radiocarbon dating and Bayesian statistics to provide a valid chronological framework, and the second is to illuminate social change over 2,000 years of continuous occupation that led ultimately to the formation of early states.

Current Debates

This site has contributed new and relevant information that tests alternative models on prehistoric cultural developments in Southeast Asia: the relationships between intrusive Neolithic rice farmers, the timing of the initial Bronze Age, the impact of copper-base metallurgy on social organization, and the social changes that took place with the adoption of iron technology.

The area excavated concentrates in the middle of this circular site, which has a maximum diameter of 320 m, with ten smaller excavation squares distributed in a linear fashion between the moats. The moats and banks that ring Ban Non Wat have also been excavated and dated.

One of the problems that has hampered our interpretation of Southeast Asian prehistory has been the small areas excavated relative to the size of individual sites. By opening a large area, we have identified spatial patterns of activity on an unprecedented scale.

The sequence begins with occupation by hunter-gatherers, one radiocarbon determination on a shell midden falling in the sixteenth millennium BCE. However, the first of 12 fully documented cultural phases began in the early second millennium BCE, when the site was employed as a cemetery for a series of flexed burials that in all probability represent hunters and gatherers. These would have found a richly endowed habitat, offering plentiful resources including fish, shellfish, and a wide variety of animals that included at least four species of deer, pigs, and wild cattle.

This phase partially overlaps the initial settlement by rice farmers, whose ultimate origin lies in the Yangtze Valley. They are represented at Ban Non Wat by their occupation middens and a cemetery, the radiocarbon determinations showing that they arrived in the seventeenth century BCE. The dead were interred with elaborate mortuary rituals. A man and a woman were found in a seated position within large, lidded pottery vessels notable for their elaborate incised, impressed, and painted designs. Two individuals were buried with cowrie shell ornaments, indicating long-distance exchange with coastal groups. Other offerings included pig bones, shellfish, and bivalve shells thought to have had ritual significance. Infants were interred in lidded pots identical in form to those used for adults but naturally smaller.

This first Neolithic phase was followed by a second, dated between about 1250 and 1050 BCE. There was a decline in the quality of the now virtually undecorated pottery vessels placed with the dead and generally a poverty of other mortuary offerings. However, this was prelude to a dramatic change in the mid-eleventh century BCE, when the initial Bronze Age phase at the site saw the dead interred in deep graves, within wooden coffins associated not only with copper-base socketed axes but also up to

Ban Non Wat, Archaeology of, Fig. 1 Bronze Age burials

15 finely fashioned pottery vessels and a rich array of shell jewelry. Bronze Age 1 occupation gave way in the tenth century to arguably the most significant of all phases of occupation, for Bronze Age 2 witnessed a veritable starburst of social display in what can legitimately be described as princely burials (Fig. 1). This degree of wealth, unprecedented in the Bronze Age of Southeast Asia, saw men, women, and infants interred in very large graves, associated with up to 80 superbly painted mortuary vessels in many forms. Again, copper-base axes were placed with the dead, including some infants, as well as awls, chisels, anklets, and bells. There was a profusion of exotic marine shell jewelry including beads, earrings, and bangles, as well as marble bangles and earrings. The dead were also interred with fish and pig remains that strongly suggest that mortuary feasting took place at the time of burial.

Such feasting is a means whereby social aggrandizers can leverage their status through public demonstrations of hospitality and wealth. For at least eight generations, according to the radiocarbon chronology, this wealthy lineage retained its high status, while contemporary graves elsewhere on the site, and in a nearby settlement, were markedly poorer.

Part way through the third phase of the Bronze Age, in the ninth century BCE, this degree of wealth sharply declined. Although some individuals were still buried with multiple exotic ornaments, the majority were markedly poorer, with only a handful of pottery vessels and a few shell ornaments being associated. Now the dead were buried in cemeteries laid out in row, with many graves disposed head to toe in columns. One grave stands out. It was the burial of a young man accompanied by 29 clay molds for casting bronze socketed axes and bangles. The latter were cast in a manner not hitherto documented in Southeast Asia. A series of molds were set in place like books on a shelf, and the molten metal was then cast into them simultaneously. This is a form of mass production, but curiously, no bangles were found in any of the contemporary graves.

The sixth and final Bronze Age phase is dated from the seventh to the early fifth centuries BCE and saw some modifications to the ceramic forms while retaining the basic repertoire for decoration. Again, the dead were interred with modest offerings when compared with the initial phases of the Bronze Age. Now, however, many were accompanied by spindle whorls and lumps of clay. The former were used to manufacture the filaments prior to weaving, and the latter may be used as a dye or a mordant. It seems that the community in question was beginning to specialize in fabric production.

This continued seamlessly into the early Iron Age. Four Iron Age phases have been identified in the upper Mun Valley, and at Ban Non Wat, we can trace a seamless transition from the late Bronze Age to the earliest Iron Age as the cemetery expanded over time in an easterly direction. Thus, we can identify the point in this sequence where the first iron artifacts were placed with the dead and date it to the second half of the fifth century BCE. This is the first time that this has been done in Southeast Asia. It is most significant that very rare beads and other ornaments of agate, carnelian, and glass were also found with the first people buried with iron. These forms of ornamentation are known to have been stimulated by exchange contact across the Bay of Bengal into India, and their conjunction at Ban Non Wat suggests that they came together, as a package, into the interior of Southeast Asia.

The first items to be forged from iron include large socketed spears, hoes, points, and bangles. There are also kits of small tools, such as knives and awls. The early Iron Age also saw a notable increase in the number of bronzes found, these taking the form of anklets, rings, and bangles on occasion cast using the lost wax method. Lead and tin items were also found, albeit rarely. During this earliest of the four Iron Age phases, many pots were placed with the dead, and these often contained complete fish skeletons. Pigs, cattle, and water buffalo limbs were also found in human graves, suggesting that feasting was a feature of this period.

A vital feature of Ban Non Wat, and many other Mun Valley Iron Age settlements, is that they were surrounded by multiple banks and moats. These are considerable engineering works that have for long been enigmatic. However, we excavated long trenches across them at several sites and identified not only the profile of the moats but the date of the encircling banks. It seems that the moats had a flat base, the banks being formed by heaping up the accumulated surface soil. The relevant radiocarbon determinations indicate construction in the third and fourth phases of the Iron Age, dating from about CE 200 to 600. The moats were fed by the rivers that then flowed past each settlement and could have been controlled to maintain a constant supply of water. Their actual purpose is not known, but they were probably multifunctional. Defense is one probability; we know that conflict was by now prevalent. The food offerings in Iron Age graves also remind us that wherever there is water in this region, there are also fish. There is also the possibility that the moats were an expression of the social standing of those who conceived them, for the later Iron Age was a period when immensely rich individuals were interred at the site of Noen U-Loke, only 1.8 km from Ban Non Wat.

The terminal Iron Age in the upper Mun Valley overlaps the period known in Southeast Asia as Chenla, when the first inscriptions were composed. From these, we can read of chiefs, known as *pon*, who exercised authority over water reservoirs and whose communities included weavers, rice farmers, and herdsmen. It was from this social matrix that the civilization of Angkor was generated. Thus, at Ban Non Wat, we can trace the entire course of prehistory from hunter-gatherers through the Neolithic, Bronze, and Iron Age to the origins of civilization.

Future Directions

The next stage in archaeological research in the Mun Valley of Northeast Thailand is to excavate further moated sites to provide comparative information on the course of prehistoric social change. This needs to identify further evidence for the presence of hunter-gatherers and their interactions with early rice farmers. The presence of a rich Bronze Age elite at Ban Non Wat will come into sharper focus if similar groups can be found at other sites in the region. An elite can only be properly defined if contemporary poor lineages can be identified. These Iron Age sites are so large that their internal structure needs to be investigated. Thus, excavations at Non Ban Jak, a moated mound near Ban Non Wat, have revealed a residential quarter for the first time, with a lane separating rooms belonging to two different houses.

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► Dating Techniques in Archaeological Science
► South and Southeast Asia: Historical Archaeology

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Ban Non Wat: Agriculture and Domestication

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Basic Site Overview

Ban Non Wat is a large prehistoric site located in the upper Mun Valley of Northeast Thailand surrounded by a double set of moats and banks. Like the concentration of similar sites in this region, it sits upon a major route linking Central Thailand with the Khorat Plateau and beyond to the Mekong River and has immediate access to a vital resource, salt. Excavations began in 2003 and have continued uninterrupted to the present. An unprecedentedly large area has been uncovered, and few sites if any in Southeast Asia are as well documented.

Evidence of Early Agriculture

The cultural sequence is divided into 12 phases. These began with occupation by hunter-gatherers, who interred the dead in a tightly flexed position. A probable shell midden has provided a radiocarbon determination in the

16th millennium BCE, but the burials belong to the second millennium BCE. This was followed by two phases of Neolithic burials, six Bronze Age, and three Iron Age phases, all represented by human burials. This sequence has been dated on the basis of 75 determinations, some taken from in situ charcoal from hearths and others from the freshwater shellfish regularly placed as mortuary offerings with the dead. The Bayesian analysis of these dates shows that the initial Neolithic settlement began in the mid seventeenth century BCE. The transition from the late Neolithic to the Bronze Age took place in the late eleventh century BCE, while the Iron Age began in the second half of the fifth century BCE (Higham & Higham 2009).

For the first time in Southeast Asia, it has therefore been possible to assess the nature and pace of cultural change over a period of over two millennia in the context of a secure chronological framework. The initial settlement by Neolithic farmers saw that the inhabitants share the cemetery with those who chose to inter the dead in a flexed position. Such interaction between intrusive rice farmers and indigenous hunter-gatherers has become increasingly recognized in other Southeast Asian sites. Evidence for agriculture comes from the remains of rice in middens and a burial, while the dog, pig, and cattle bones come from domestic stock. The Neolithic inhabitants interred their dead either in an extended and supine position or within lidded mortuary vessels. The latter involved both adults and infants (Fig. 1). Pottery vessels were elaborately decorated with incised, impressed, and painted designs of considerable sophistication that are paralleled in other Neolithic sites from Central Thailand to Vietnam and north into China. Other grave goods include exotic cowrie shells, shell beads, bivalve shells, and pig bones (Higham & Kijngam 2011). The middens contain a wide variety of bones from hunted animals, fish, and shellfish. It was clearly an environment that provided an abundance of food.

The transition into the Bronze Age is documented on the basis of seven graves that contain adults, infants, and children

Ban Non Wat: Agriculture and Domestication, Fig. 1 Some of the mortuary vessels placed with the dead at Ban Non Wat were decorated with fine-painted designs (Reconstructed illustrations by Dr. Warrachai Wiriyaromp)

(Higham 2011a; Higham & Kijngam 2012). All reveal a sharp increase in the elaboration of mortuary rituals and the quantity of offerings placed with the deceased. Thus, where a couple of pots might be found with late Neolithic individuals, with Bronze Age 1, this rose to as many as 17. Copper socketed axes were a regular finding in these burials, as were shell bead and pig bones. This initial Bronze Age phase lasted perhaps no more than two generations before Bronze Age 2, when mortuary wealth rose to such a degree of wealth that we can describe the burials as princely (Fig. 2). Again, copper-based axes were regularly encountered, even with infants, as well as chisels, awls, and bells. The dead wore unparalleled quantities of exotic shell and marble ornaments, particularly bangles, beads, and earrings. Over 80 fine ceramic vessels were found, in many and varied forms, some bearing sophisticated painted designs (Fig. 3). A singular feature of these burials is that some men and women were partially exhumed and then the bones were replaced in a carefully placed heap within the grave. This might have been undertaken so that distinguished ancestors were incorporated within social rituals. There is little doubt that during this phase, Ban Non Wat harbored an elite social

Ban Non Wat: Agriculture and Domestication, Fig. 2 Burial 28 dates to the early Neolithic at Ban Non Wat and contained a man in a seated position within a large, lidded ceramic vessel decorated with incised and impressed patterns and painted designs

group that had secured preferential, perhaps restricted, access to exotic valuables that included copper, shell, and marble. The phase lasted from about 1000–850 BCE.

The ensuing phase saw a continuation of very wealthy graves, incorporating tens of thousands of shell beads, multiple shell bangles, and several bronzes. However, with phase 3B, the mortuary wealth fell sharply although the basic protocols associated with interring the dead continued: the same orientation, placement of pottery vessels, and creation of rows of graves. This relative poverty continued into Bronze Age 4, when graves covered the excavated area and were placed not only in rows but also head to toe. Bronzes were now very rare indeed, although one burial contained a bronze founder, a man accompanied by multiple molds for casting bangles and two bivalve molds for axes. The final Bronze Age witnessed new forms of ceramic vessel, several containing complete fish skeletons as food offerings, as well as spindle whorls and clay that may well have been used to dye cloth.

Iron Age burials formed a seamless continuation from the late Bronze Age with virtually identical pottery vessels but also the first iron in the form of spears, knives, tool kits, and bangles.

Ban Non Wat: Agriculture and Domestication, Fig. 3 Burial 197 was one of the richest graves of the early Bronze Age at Ban Non Wat. The man was interred with several copper implements, richly decorated pots, and exotic shell bangles

Three spears had iron blades and cast on bronze hilts. The first glass, carnelian, and agate ornaments were also found (Higham 2011b).

The excavation of a series of squares lineally across the site has shown how the settlement area progressively expanded over time. During the Iron Age, the floor of an area that had been used to impound domestic cattle and water buffalo was identified on the western edge of the site, and complex water control features on the eastern edge were in place as, towards the end of the Iron Age, the moats and banks round the site were constructed. In late Iron Age burials, there was a proliferation of glass ornaments in graves, along with more carnelian, agate, gold, and bronzes that reflect social change heralding the imminent development in the region of early states from the fifth and sixth centuries CE.

Cross-References

► Agriculture: Definition and Overview
► Rice: Origins and Development

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Bananas: Origins and Development

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Basic Species Information

A Multipurpose Crop

Bananas (*Musa spp*.) are a key domesticate of subsistence farmers across the wet tropics and subtropics. Although they are one of the most important commercial crops in the world, about 85 % of banana production is for local food consumption.

The wild banana plant, which does not produce edible fruit, is still used for many other purposes within the primary center of banana diversity or natural range. Among remote societies of South and Southeast Asia, these uses include leaves for roof thatching, flower bracts as legume, leaf sheaths for fibers, and several parts of the plant for medicinal purposes (Kennedy 2009). These practices are likely to have a very long history and would have been crucial to the generation of cultivated banana varieties (cultivars).

Recent genetic, archaeological, and linguistic findings have substantiated this assumption (Perrier et al. 2011). These multidisciplinary studies have enabled the first reconstruction of the entire history of banana domestication and dispersal, from wild species to the current vast array of edible banana varieties.

The Key Role of Human Intervention

Banana plants are among the largest herbs in the world, and some specimens can reach 10 m height. As herbs, they propagate by means of seeds and side-shoots, called suckers. The cultivars are mostly sterile, with seedless fruits and very limited pollen production. Artificial propagation is vegetative (clonal) whereby suckers are collected and replanted. As a consequence, the presence of banana plants beyond the primary diversity center can only be due to human intervention, usually cultivation.

The planted suckers need about 1 year for fruiting and bunch harvest. Repeated vegetative propagation yields many cultivars with similar genetic composition. Thus, the plants are genetic markers of the people that introduced them originally to a region.

Botanical Background: Groups and Subgroups

The monocotyledon Musaceae family includes the Asian and African genus *Ensete*, the genetically proximal Asian *Musella* genus, and the East Asian genus *Musa*, which is divided into sections with 22 (Eumusa, Rhodochlamys) and 20 chromosomes (Australimusa, Callimusa). Almost all the cultivars belong to the Eumusa section and are diploid or triploid hybrids from *Musa acuminata* (A-genome) alone or from hybridization with *Musa balbisiana* (B-genome) (De Langhe & de Maret 1999). Wild AA grow naturally within the humid-warm tropics part of the diversity center – from India to New Guinea – while wild BB are mostly confined to the drier periphery to the north, from NE India, over monsoonal Southeast Asia, to the Philippines.

Current cultivars are classified into groups according to the respective genome origins: edAA (for edible AA compared to the wild AA), AAA, AB, AAB, and ABB. In this classification, A and B indicate the genomes of the parental wild species. The existence of edBB and of BBB has still not been firmly established.

A cultivar group of minor significance, including Fe'i bananas, is confined to the Pacific region and is derived from Australimusa species (Kennedy 2008). It is not discussed further in this entry.

Only a modest minority of the about 600 cultivars have been strictly reproduced clonally. Many cultivars are the product of somatic mutations, slight genetic and/or epigenetic changes causing modest differentiation in features such as size, plant color, fruit form, and bunch structure. Within each group, the resulting sets of cultivars are called subgroups. They are quite distinct from each other. It is estimated that some subgroups, such as the AAB Plantains in Africa or the AAB Plantains in the Pacific, may contain up to 100 cultivars, all of them probably being mutants from one or a few original clones. Since somatic mutation is a relatively rare process, these considerable subgroups would suggest vegetative propagation over many centuries or millennia since the time of introduction to the respective regions.

Timing and Tracking Domestication

Stepwise Domestication of the Banana

Genetic research has shown that edAA were the original cultivars, from which all the triploid varieties and a few AB cultivars derived by various crossings. The evolution from wild to edible AA involved seed suppression and progressive parthenocarpy development. It is assumed, but not yet firmly demonstrated, that the latter evolution has been caused by century-long cloning. The development of partial to complete sterility, however, calls for the classical explanation that these edAA are in fact hybrids between wildAA parents of significantly different genetic composition, as is the common case with interspecific hybrids. Indeed, the species *M. acuminata* displays a quite pronounced morphological variation all over the *Musa* primary diversity center, with the variants confined to restricted areas. They have therefore been called "subspecies," and at least eight wild AA ssp. are recognized. Research with mtDNA and cpDNA markers has eventually demonstrated that edAA are inter-subspecific hybrids in various combinations, which explains the diversity in current AA cultivars (Perrier et al. 2011).

The pattern of banana domestication implies that plants from region-specific wildAA subspecies were moved between regions by human populations, for the natural hybridizations to become possible. Archaeological and linguistic investigation has revealed that such movements would have happened in the area of New Guinea and Eastern Indonesia even before the arrival of Austronesian-speaking peoples, perhaps around 4,000–3,500 years ago (Donohue & Denham 2009).

Triploidy Formation

Partially sterile AA cultivars can produce viable diploid gametes. If these are fertilized by haploid pollen, triploid bananas can be formed. Human interaction would have brought different cultivars into contact with other edAA as well as with wild AA subspecies and even the BB species. The addition of A or B genomes to these AA cultivars produced the large range in AAA, AAB, and ABB subgroups.

Because triploid bananas are more vigorous and robust than diploid ones, they largely dominate in all regions where the crop has been introduced. The ABB are typical for the drier tropics, while AAA, AAB, and the few AB thrive best in the humid tropics.

The current distribution of traditionally grown cultivars is rather complex, with more or less characteristic sets in different regions of the tropics. For example, the AAB African Plantains are the only subgroup found in the lowlands of West and Central Africa, while an altitude-preferring AAA subgroup is typical for East Africa. The two subgroups probably have different histories, with different people responsible for their introductions at different times. On the other hand, the AAB Pacific Plantains are the only Eumusa traditionally grown in the Pacific islands to Hawa ii, which strongly indicates that their distribution is linked to the colonization of the Pacific by Austronesian-speaking ancestors.

The Need for Multidisciplinary Research

Banana plants do not contain wood, and the lack of seeds and pollen in the cultivars leaves phytoliths and starch grains as the most common vestiges of their existence in the past, which explains the difficulty in tracking their archaeological visibility (see Denham et al. 2009). The center of diversity poses the additional problem of distinguishing the phytoliths of wild bananas from those of cultivars, except for the metric distinction between edAA and AAA (Vrydaghs et al. 2009).

Circumstantial archaeobotanic evidence of domestication has only been found thus far. It has been demonstrated that *Musa* phytoliths found during the excavations in Kuk (New Guinea), dating to 7,000–6,400 cal BP, belonged to plants that were managed by humans (Denham et al. 2003). On the other hand, phytoliths found in West Africa in pits radiocarbon-dated to c. 2,500 cal BP do not belong to wild *Musa*, since they are beyond the natural range of *Musa* spp.; they, therefore, indicate introduction of the AAB Plantain under cultivation by that time (Mbida et al. 2001).

The above-explained example of AAB African and Pacific Plantains and altitude-preferring AAA shows how the complex geographical distribution pattern of subgroup presence can be a helpful historical marker of different human populations (see Perrier et al. 2011). Within this historical framework, linguistic research proves to be remarkably productive. Traditional generic names for crops are highly conservative within a language family, and analysis of their reflexes can provide the tracks for the presence of the corresponding people. A striking example is the evolution of the generic term *qaRutay, still used among the Aeta people in the Philippines, but of which an elucidated sequence of reflexes over Indonesia and Asia seems to mirror the movement of cultivated bananas from Eastern Indonesia to India (Donohue & Denham 2009). It is tempting to suppose that analogous sequences of subgroup generic names and their reflexes could shed light on many details of this human intervention.

Cross-References

- ▶ Agricultural Practices: A Case Study from Papua New Guinea
- ▶ Agriculture: Definition and Overview
- ▶ Archaeobotany of Early Agriculture: Microbotanical Analysis

▶ Domestication Syndrome in Plants
▶ Domestication: Definition and Overview
▶ Genetics of Early Plant Domestication: DNA and aDNA
▶ Kuk Swamp: Agriculture and Domestication
▶ Nkang: Early Evidence for Banana Cultivation on the African Continent
▶ Plant Domestication and Cultivation in Archaeology
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Banpocun, Archaeology of

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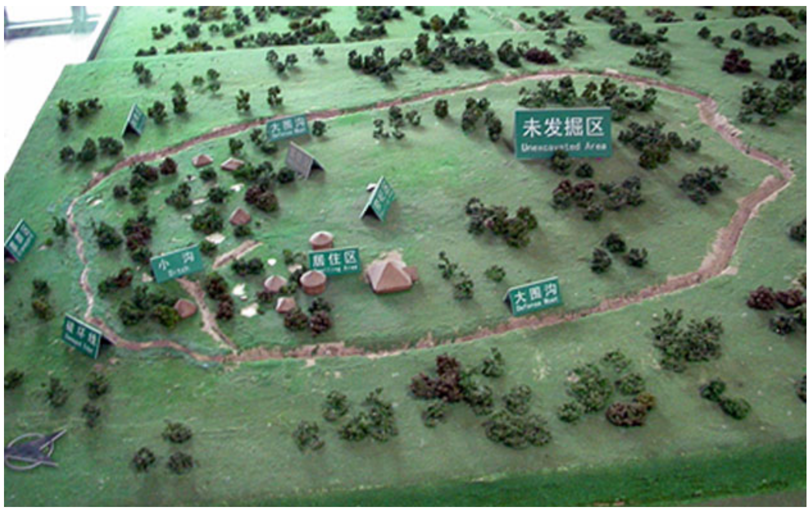
Introduction

Banpocun (Pan-p'o-ts'un) or Banpo is a site of the Neolithic Yangshao culture, located near Banpo village on the eastern bank of the Chan River, east of Xi'an, Shaanxi province, China. The entire site is estimated to be c. 5 ha in size, of which an area of 1 ha was uncovered during five seasons of excavation carried out from 1954 to 1957, led by Shi Xingbang of the Institute of Archaeology at the Chinese Academy of Sciences (Fig. 1). Archaeological deposits were divided into two phases. The early phase contained very rich material remains and was named the Banpo variant (*leixing*), dating to c. 4800–4300 BCE. Fewer ruminants were found from the late phase, named the Xiwangcun variant or Late Banpo variant, generally dating to c. 3500–3000 BCE (Institute of Archaeology, Chinese Academy of Sciences 1963). The entire excavated area of the Banpo site has been preserved as China's first on-site museum, the Xi'an Banpo Museum, which was first constructed in 1958 and rebuilt in 2006. Banpo has been further excavated in recent years, but a new excavation report has not yet been published.

Definition

Banpo is the first Yangshao culture site excavated on a large scale, providing rich data for understanding the economy, culture, and social organization of a Neolithic settlement. It is the type site of the Banpo phase, and many contemporary sites sharing similar settlement layout and material assemblages later have been found over a large region in the middle Yellow River valley.

Banpocun, Archaeology of, Fig. 1 Excavation of the Banpo site



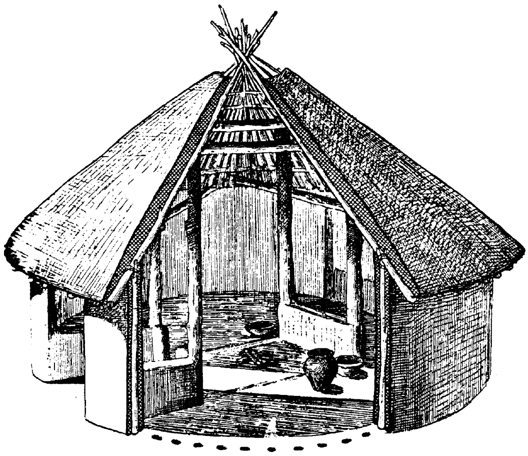
Banpocun, Archaeology of, Fig. 2 Model of the Banpo settlement

Key Issues/Current Debates/Future Directions/Examples

Settlement Layout

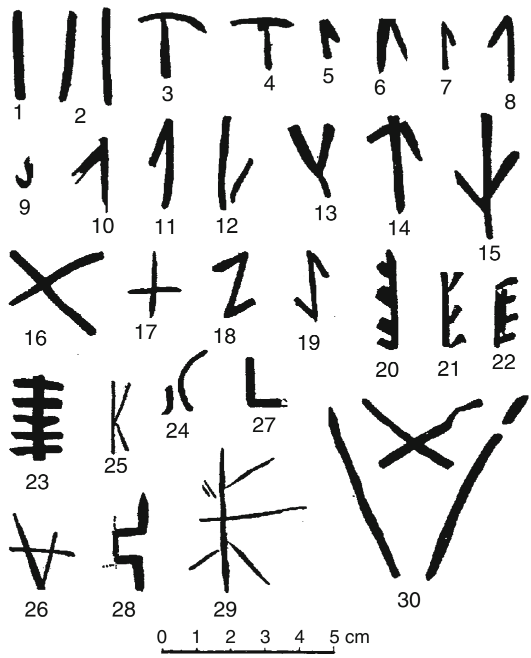
The residential area of the Banpo settlement is located in the center of the site, about 3 ha in area, including 46 buildings, more than 200 ash pits (mostly used as storage before abandonment), 2 livestock pens, and nearly 70 children's burial urns. Dwellings appear to have been divided into two clusters, separated by a shallow ditch, 1.5 m deep and 2 m wide. Each dwelling cluster consisted of one large building, up to 160 m^2 in size, surrounded by a number of medium and small structures, measuring 30–40 m^2 and 12–20 m^2 in size, respectively. The residential area was fortified by a moat, 5–6 m deep and 6–8 m wide. To the north of the ditch was a cemetery, and to the east were pottery kilns (Fig. 2).

The dwellings of the Banpo phase were either semisubterranean or at ground level. Each house had a hearth at the center and a doorway opening to outside. All the structures were built with wattle-and-daub walls and foundations, and the upper walls and roofs were supported by wooden posts. These houses were mostly



Banpocun, Archaeology of, Fig. 3 Reconstruction of a Banpo house

Banpocun, Archaeology of, Fig. 4 Painted pottery vessel from Banpo



Banpocun, Archaeology of, Fig. 5 Banpo pottery marks

circular structures, but a few were square or rectangular in shape (Fig. 3).

A population level of 5–600 for the entire village has been estimated by the excavator mainly on the basis of the extent of the settlement and the sizes and layout of the houses. The actual population size, however, is difficult to assess, because a large part of the settlement has not been excavated.

Material Remains

Ceramics (more than 500,000 potsherds) are the most numerous material remains excavated, accounting for 80 % of the artifactual assemblage at Banpo. Pottery was probably made on site, suggested by the presence of six kilns. Nearly 1,000 vessels have been restored and are classified into four categories, including serving receptacles, water containers, cooking utensils, and storage vessels. Ceramics are mainly reddish or orange in color, some painted with human, animal, plant, or geometric designs (Fig. 4).

Twenty-two incised symbols have been found on the black band near the rim of pottery *bo* bowls (Fig. 5). They occurred singly, perhaps identifying the makers of the pottery or possibly the owners. Such pottery marks have been found at several Yangshao culture sites, and some of these forms appear to resemble certain numerals in the oracle-bone inscriptions of the Shang dynasty dating to the late second millennium BCE. It is possible that the Yangshao pottery signs were one of the sources of the Shang writing, but these pottery marks have not normally been regarded by archaeologists as indicating the contemporary existence of a writing system.

More than 5,000 tools were excavated from the site, variously made of stone, bone, deer antler, and pottery. The tool types include axe, adze, spade, knife, grinding stones (slab and hand stone), arrowhead, spearhead, harpoon, net-sinker, and fishhook. They have been classified into three categories, based on their presumed functions, as agricultural, hunting-fishing, and craft-manufacturing implements.

Agriculture appears to have played an important role in the subsistence economy. Carbonized remains of foxtail millet (*Setaria italic*) were found at the site in significant quantities; cabbage seeds (*Brassica* sp.), hazel nuts, chestnuts, hackberry seeds, and pine nuts were also present. Other types of plants may also have been used by the Banpo people; but due to the absence of flotation method at the time of excavation, floral remains were not systematically uncovered.

Matting, basketry, and weaving were part of the craft production, evidenced by impressions of baskets, mats, and textiles on the bottoms of pottery vessels. A large number of spindle whorls, a type of weaving tool, have also been found at the site. It is unclear exactly what materials were used for making textiles at Banpo, but traditionally hemp and kudzu were among the indigenous plants used for weaving in China, as mentioned in ancient texts, such as *The Book of Odes*.

Many animal bones have been found at the site, identifiable as mammals, birds, and fish. Pig (*Sus domestica* L.) and dog (*Canis familiaris* L.) were clearly domesticated. Bones from many species of wild animals were present, including two types of deer (*Pseudaxis hortulorum* Sw. and *Hydropotes inermis* Sw.), sheep (*Ovis* sp.), bovine (Bovidae indet.), horse (*Equus* sp.), fox (*Vulpes* sp.), rabbit (*Lepus* sp.), gazella (*Gazella* sp.), chicken (*Gallus* sp.), and carp (Cyprinidae indet.). Pig bones were the most numerous in the faunal assemblage, followed by Chinese river deer (*Hydropotes inermis* Sw.). Hunting and fishing were important subsistence activities as evidenced by a great variety of wild animal remains and numerous arrowheads, harpoons, net-sinkers, and fishhooks.

Burials

A total of 174 adult burials and 73 children's urn burials have been excavated. Adult burials were found in pit graves, mostly located in the cemetery. Among 118 nondisturbed burials, 71 contained grave goods. Except for two cases in which two males and four females, respectively, were interred, each burial usually contained one skeleton in an extended position with the head pointing to the west or northwest. Grave goods consist mostly of pottery, ranging between one and 17 items, with an average of 5–6 pieces in each burial.

Children's urn burials have been found mainly near houses. They were associated with no funerary items, except one case which contained a small pot. It is noteworthy, however, that a burial belonging to a child of about 3–4 years old was furnished with an oblong wooden coffin and contained six ceramic vessels, three stone pellets, an earring, and a set of 76 bone beads girdled around the waist. This burial, dating to the late Banpo phase, was unique in terms of its rich furnishing, suggesting that social stratification may have emerged during the late phase of the settlement's occupation.

Social Organization

Banpo society was evidently egalitarian in nature during its early phase. There is no indication of social hierarchy present in the burial or residential remains. This site, however, has been routinely described by archaeologists in China as a typical Neolithic matriarchal or matrilineal settlement (see the Xi'an Banpo Museum website: http://www.bpmuseum.com/en/), as opposed to the patriarchal or patrilineal society that presumably developed in the late Neolithic period. The concept of matriarchal society, primarily based on the nineteenth–century evolutionary theory proposed by Henry Lewis Morgan (1877, *Ancient Society*) and Friedrich Engels (1884, *The Origin of the Family, Private Property and the State*), was systematically introduced to China by Guo Moruo (1930) in the 1930s. Banpo was the first archaeological case in which Chinese scholars attempted to employ such a theoretical framework to interpret Neolithic social organization, in support of Marxist doctrine.

The Banpo excavator argued that matrilineal rules of descent are reflected in the two collective burials at the site, one each exclusively of females or males, and that this pattern contrasts with the single-male or single-female burial pattern characteristic of the monogamous family in patrilineal society. The rich child burial was interpreted as belonging to a girl, indicating that females enjoyed a high social status then. The settlement pattern was also described as arranged in a way suitable for the pairing marriage, believed to have been practiced in a matrilineal society (Institute of Archaeology, Chinese Academy of Sciences 1963: 226-33). The statement that the Yangshao culture was a matriarchal society soon became a standard phrase adopted in many archaeological publications, although evidentiary support is lacking in the archaeological record of some cases (Yan 1989). The reported evidence for matriarchal practice at Banpo is clearly less than convincing. For example, the rich child burial said to be of a girl is problematic, as the sex of a skeleton 3–4 years old cannot be determined. Although some criticisms were made, demonstrating faults in both theory (Pearson 1988; Tong 1998: 262-72) and applications (Wang 1983, 1987), the classical evolutionary model was commonly accepted among Chinese archaeologists then and has continued to be influential, but to a lesser extent, today (e.g., Institute of Archaeology, Chinese Academy of Social Sciences 2010: 204, 413, 652-3).

Cross-References

► China: Museums
► Chinese Field Methods

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Barley: Origins and Development

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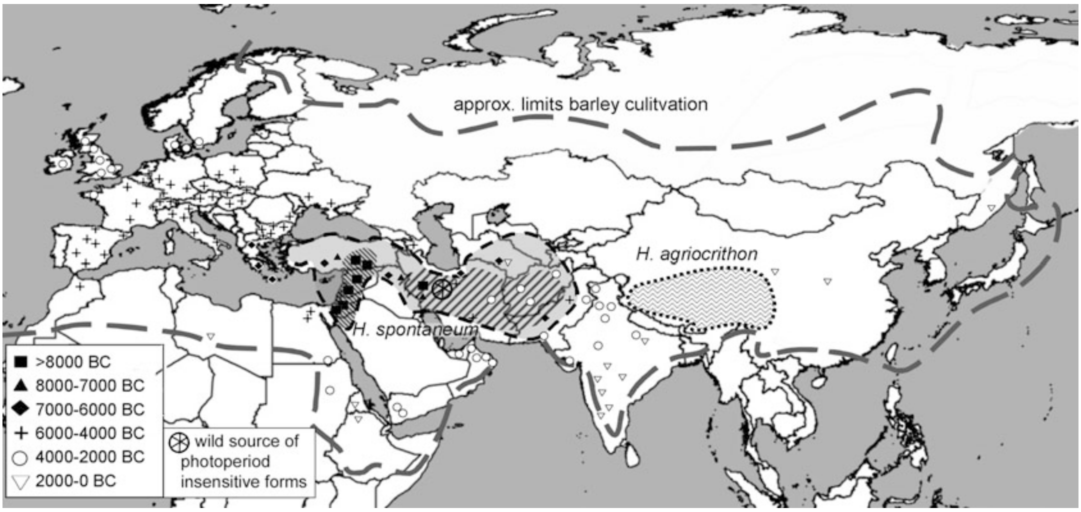
Basic Species Information

Barley (*Hordeum vulgare* L.) Poaceae derives from the Old English *baere* related in origin to the Latin *farina* or flour (Ayto 1990) and is known variously as *da mai* (China), *orge* (French), *gerste* (German), *orzo* (Italian), and *cebada* (Spanish) (van Wyk 2005). Barley is a major crop in global agriculture. Modern statistics (e.g., from faostat.fao.org) indicate that barley production globally follows only wheat, rice, and maize. Barley can be turned into breads and porridges, as well as beers and whiskies.

Barley was one of the founder crops of early agriculture in Southwest Asia and parts of the earliest farming systems that spread across Neolithic Europe, North Africa, and the Indus Valley. Its wild progenitor is *Hordeum spontaneum* K. Koch, which occurs widely in the eastern Mediterranean eastwards to Central Asia in the open woodland steppe through to the taller grass steppe zone (Hillman 2000; Harris 2010). Wild populations further west, such as in the Maghreb region of North Africa as well as some of those on its eastern margins, may or may not be aboriginally wild but could be feral populations. Barley is a generally more tolerant cereal than



Barley: Origins and Development, Fig. 1 Map showing the approximate maximum limits of traditional barley cultivation (*thick dashed line*) in relation to its wild range (*gray zone*). The map differentiates likely eastern and western subzones within the wild range that had separate domestications, as well as the locations for the development of original photoperiod-insensitive barley in Iran. The *symbols* show representative archaeobotanical finds that chart the earliest spread of barley

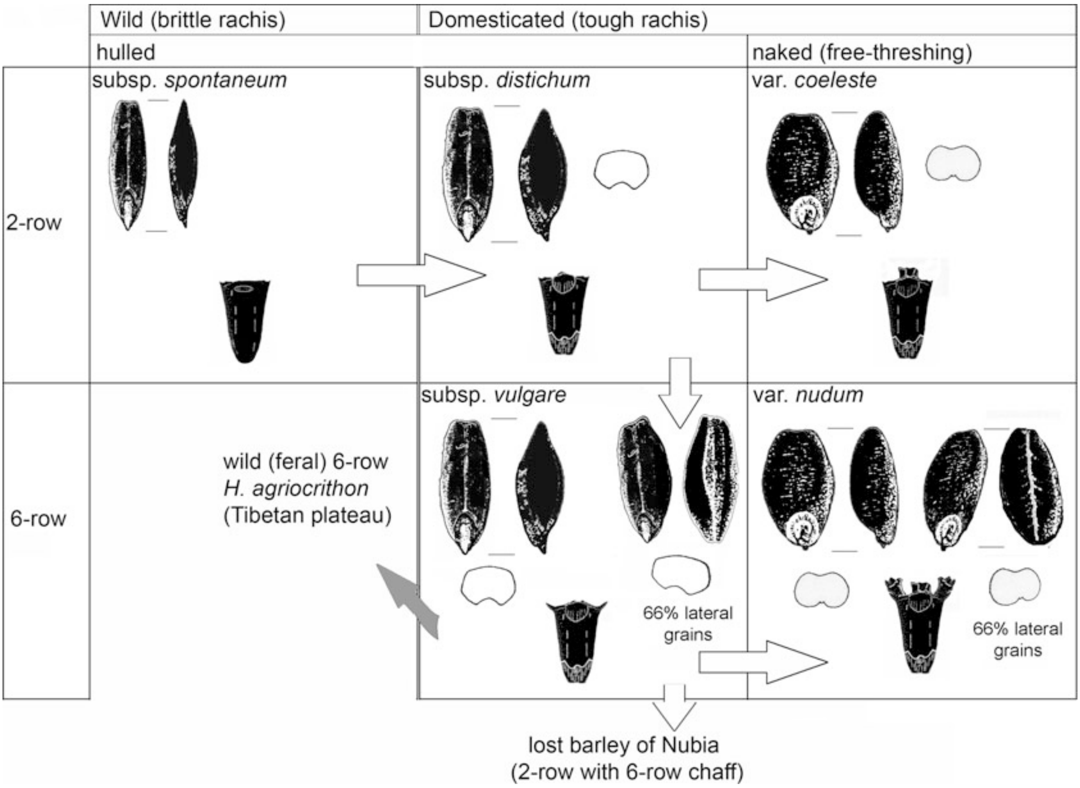
wheat, with which it is often found. Barley can be grown on more saline soils and with lower rainfall. It can also tolerate colder conditions than wheat. Thus, barley has reached to higher altitudes and higher latitudes than wheat (see Fig. 1).

Major Domestication Traits

Genetics and archaeology combine to imply that barley was domesticated more than once across the greater Near East, with three origins a likely minimum (Fuller et al. 2012). All are located across Southwestern to Central Asia (Fig. 1). Such evidence includes two genetic variants that make non-brittle domestic-type ears, and several other gene frequencies have geographic structure suggesting differences between east and west (Morrell & Clegg 2007). Genetic differentiation suggests a western Levantine domestication area and an eastern domestication, perhaps in the greater Iranian plateau region. While most wild and cultivated barleys are grown over the winter and flower in the spring, controlled by day length, other varieties have lost the linkage of day length to flowering and are well suited to spring/summer cultivation at higher latitudes or altitudes. These photoperiod-insensitive (summer) barleys derive from domestication of a separate wild population in the mountains of Iran (Jones et al. 2008).

Timing and Tracking Domestication

Archaeobotanical evidence tracks both the evolution of domesticated barley, at least with regard to its western Levantine origin. Sites in several parts of the Levant have reported evidence for pre-domestication cultivation, most often involving apparent arable weed flora associated with morphologically wild barley remains (Fuller et al. 2012). Such evidence goes back to the PPNA period (9700–8800 BCE). Subsequently there is evidence for gradual morphological change including the steady increase in the percentage of non-shattering barley rachis remains and in average grain size (width and thickness) of grain samples over time. Both lines of evidence point towards



Barley: Origins and Development, Fig. 2 Diagram of the main types of barley and evolutionary pathways between them. These are illustrated by potential archaeobotanical differences in grain and rachis morphology

change between the Late PPNA (c. 9000 BCE) and the Late PPNB 7000–6000 BCE and indicate gradual domestication over a ~3,000-year period.

Archaeobotanical evidence for barley is widespread, allowing the spread of this crop to be tracked (Fig. 1). It was an essential part of the founder crop package that dispersed from the "Fertile Crescent" westwards to Neolithic Europe, starting about 7000 BCE and reaching the British Isles just after 4000 BCE. Similarly, it spread rapidly eastwards to the Indus Valley and Turkmenistan, where it is present by 6000 BCE. The dispersal into Egypt and up the Nile is later (c. 4000 BCE), while the spread of barley in monsoonal India or to southern Arabia took place after 3000 BCE. The first barley in southern India or China appears to date more recently than 2000 BCE.

Barley has evolved into a number of distinct varieties, illustrated diagrammatically in Fig. 2. Whether barley has 2 or 6 rows of grains on the ear and has free-threshing (naked) grains or hulled ones should be separable in archaeobotanical remains (see Fig. 2). Wild barley normally has two rows of grains, and grains have tightly fitting hulls; this is a two-row, hulled, and shattering wild type. The first change with domestication is the loss of spike shattering, which can be tracked archaeologically with the recovery of tough rachis remains. Two changes that occurred after were the increase to six-row and the development of free-threshing (or naked) barley. While naked barley appears to have evolved once, originally in early two-rowed forms, 6-row barley has evolved 3 times, including local independent parallel mutations in eastern Asia and the western Mediterranean (Komatusda et al. 2007).

Thus there are three main variant genes that create six-row barley (*Hordeum vulgare* var. *hexastichium*), a condition that only exists among domesticated races, and these also show east/west patterning (Tanno & Takeda 2004). In ancient Nubia there was a unique, now lost, barley that has six-row architecture and chaff and only produces two grains. Palmer et al. (2009) demonstrate that this has 6-row genetics and may represent a local reversion as adaptation to the extreme aridity in Nubia. Recent work on genetic variation in wild barley (*Hordeum spontaneum*), which unlike wheat has a large eastern range extension into Pakistan, Afghanistan, and Central Asia, shows systematic variation in allele frequency. Morrell and Clegg (2007) have demonstrated that allele frequencies in cultivated landraces are best explained by two origins from differentiated wild barley populations, one of which was in the Levant, while the other is suggested to lie somewhere from Zagros mountains eastwards towards Central Asia.

Hordeum agriocrithon, a wild six-row barley of the Tibetan Plateau, is likely to be a feral derivative of domesticated 6-row barley or a hybridization from a 6-row crop into two-rowed *H. spontaneum*, rather than truly wild (Tanno & Takeda 2004). All naked barleys, including the naked 6-row commonly grown in the Tibetan Plateau, share the same nude genetic mutation (Pourkheirandish & Komatsuda 2007). This suggests that they derive this trait from the early naked barleys that had appeared by the Late Pre-Pottery Neolithic of Southwest Asia.

Cross-References

- ► Agriculture: Definition and Overview
- ► Archaeobotany of Early Agriculture: Macrobotany
- ► Chickpea: Origins and Development
- ► Domestication Syndrome in Plants
- ► Domestication: Definition and Overview
- ► Genetics of Early Plant Domestication: DNA and aDNA
- ► Lentil: Origins and Development
- ► Pigeon Pea: Origins and Development
- ► Plant Domestication and Cultivation in Archaeology
- ► Plant Processing Technologies in Archaeology
- ► Wheats: Origins and Development

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Barrow Area Sites: Nuvuk, Utqiaġvik, and Birnirk

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Introduction

The Barrow area is home to several important archaeological sites (Fig. 1). Among these are the sites which fall under the general heading of Utqiaġvik, including Utqiaġvik proper, Ukkuqsi, and Kugok; Nuvuk; and Birnirk (type site of the Birnirk culture), Alaska.

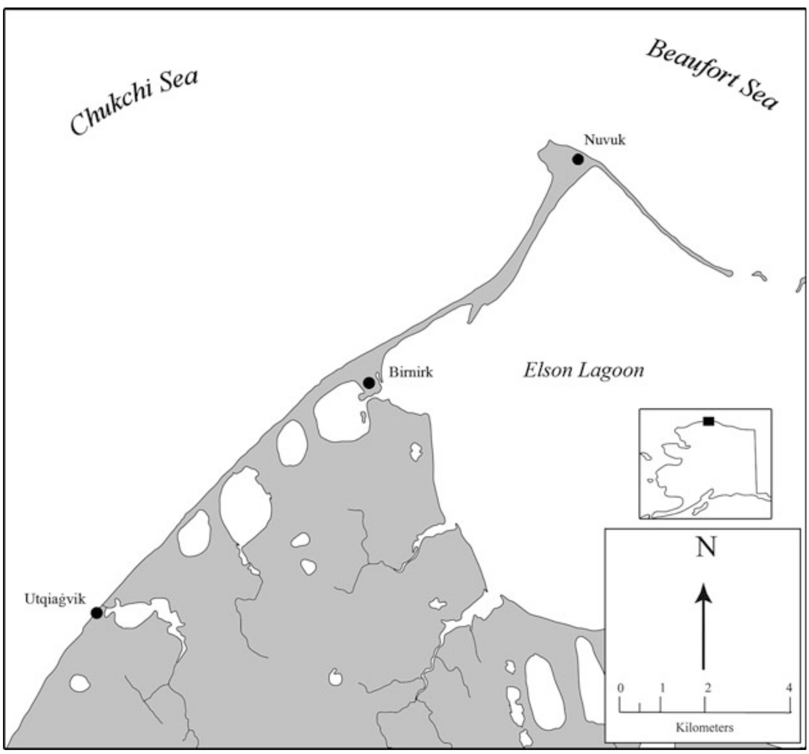
The earliest "archaeology" in the Barrow area was done by nonprofessionals, often by purchasing artifacts from residents who excavated for pay. Notable among them were Murdoch (1892), Stefánsson (1914), Wissler (1916), Ford (1959), and Van Valin (1941), a Barrow school teacher.

James A. Ford excavated at Nuvuk in 1932, Utqiaġvik in 1932, and Birnirk in 1936. Ford's report (1959) on his excavations on the Chukchi coast defined harpoon head typology for this region and provided extensive and well-illustrated descriptions of artifacts from Birnirk through contact period sites.

Definition

Utqiaġvik

Utqiaġvik (Iñupiaq for a place to hunt snowy owls) is the traditional Inupiaq name for the community of Barrow. The name Utqiaġvik (or Utkiavik) also refers to the archaeological component of the community as a whole, which also includes two areas which are sometimes referred to separately, Ukkuqsi, and Kugok. The precontact settlement was on the Chukchi Sea coast, concentrated on high ground on either side of Kugok Ravine. It consisted of at least 60 mounds, which had



Barrow Area Sites: Nuvuk, Utqiaġvik, and Birnirk, Fig. 1 Map of Barrow area sites been built up in part by superposition of sod-covered semisubterranean houses.

Utqiaġvik has a very limited number of radiocarbon dates, given the amount of excavation that has taken place at the site. However, it has long been recognized as having been occupied from Late Western Thule times until the present day, and the majority of the material excavated from the site corresponds to this understanding. However, Birnirk burials were recovered from the Kugok area of the site as early as 1932 (Ford 1959), and more recently a Western Thule burial was recovered from a pit dug through the floor of a Birnirk house at Ukkuqsi (Zimmerman et al. 2000). Lithics, which have been identified as Arctic Small Tool Tradition (ASTt) have also been recovered from Utqiaġvik, indicating that the area was being used at least as early as 4000–5000 BP.

Utqiaġvik was originally mapped by Ford in 1932, with more extensive mapping by Stanford in 1968 (who began the mound numbering system) and the Utkiavik Archaeological Project (UAP). A number of the mounds have been hidden or destroyed by modern construction of roads. All portions of the site except Kugok are threatened by coastal erosion and sea level rise.

Utqiaġvik

In 1981 through 1983, major excavations were carried out at the Utqiaġvik site in Barrow (Hall and Fullerton 1990). These excavations concentrated primarily on houses, although some work was done on activity areas outside the structures. The vast majority of the material excavated was late precontact and post-contact. The excavations of Mound 34, which included a prehistoric *qargi* (ceremonial center), were published in a monograph (Sheehan 1997).

In 1986, a number of blocks of tundra from the Utqiaġvik site slumped onto the beach in Barrow. In 1990, a salvage excavation of the single remaining slump block was carried out. Radiocarbon dates averaged 1281–1395 calCE (Mason 1991).

A number of human remains have been recovered from Utqiaġvik. Ford recovered the frozen and partly desiccated bodies of two women from the floor of a house which some Barrow residents had begun excavating in imitation of Ford's work (Ford 1959). The Utqiaġvik Archaeology Project recovered a number of individuals in a similar state of preservation from a collapsed house in Mound 44 at Utqiaġvik (Newell 1984). These were catastrophic, not deliberate, burials.

Kugok

Kugok is the name of the ravine that bisects the settlement of Utqiaġvik. It contains a stream that was a summertime freshwater source for the residents. The name is generally applied to a group of mounds at the head of the ravine, which contained Birnirk burials. Van Valin may have recovered some Birnirk burials in this area. Ford reported the recovery of 15 individuals (Ford 1959: 25-30). Four additional individuals were recovered by the Utqiaġvik Archaeological Project (UAP) in 1981.

Ukkuqsi

Ukkuqsi is the name given to the subarea of Utkiavik located around the mouth of Kugok ravine, particularly a large mound on the south side of the ravine. In 1994, the frozen body of a young girl was exposed by erosion (Zimmerman et al. 2000). The autopsy indicated that she most likely died of starvation and had experienced disabling health issues in life. Artifacts recovered during excavation ranged in age from post-contact glass beads found at and near the surface to two harpoon heads and a Birnirk throwing board from the floor of a house through which the meat pit in which the little girl had been buried had been cut.

Nuvuk

Nuvuk is located at the tip of the Point Barrow spit (Fig. 2). At contact, the settlement was larger than Utqiaġvik; the last residents moved away in the late 1940s. Until recently, Nuvuk had been considered a late precontact through post-contact site and therefore of little archaeological interest. Recent work by a large community archaeology project (Jensen 2009a, b, 2012) has revealed the largest known cemetery in North Alaska, with graves dating from early Thule

Barrow Area Sites: Nuvuk, Utqiaġvik, and Birnirk, Fig. 2 Excavating at Nuvuk. Burial excavations foreground and test pit excavation in rear. Beaufort Sea in background. View northeast

(possibly late Birnirk) through late Western Thule. Radiocarbon dates on the graves range from 614–770 calCE up to 1469–1648 calCE. That work also revealed a precontact/contact period work area located on lower ground at a distance from the graveyard and the winter village, with radiocarbon dates ranging from 1472–1649 calCE up to 1663–1953 calCE, and an artifact inventory including metal tools and imported wood, indicating some use after time of contact. There was also an earlier occupation at Nuvuk that contained the first evidence for Ipiutak north of Point Hope, including portions of two structures and faunal remains. Radiocarbon dates place it between 330 and 390 calCE. Nuvuk is currently the best dated of the Barrow area sites. All of the sites except Kugok are threatened by coastal erosion and sea level rise.

Wilbert Carter (1966) described Nuvuk in 1953 as made up of 19 "locations" with indications of houses. Some had multiple houses or rooms, giving a total of 46 houses or meat caches. His work resulted in the recovery of a number of artifacts, which he interpreted as recent (i.e., pre- and post-contact Inupiat), although illustrations in some of his reports suggest that early material was present.

When the Nuvuk Archaeological Project (NAP) began excavation (Jensen 2012), the village had eroded, but graves were noted in the erosion face. Initial salvage excavations of these graves revealed what proved to be the precontact cemetery. An adjacent Christian graveyard has markers dating from the early 1900s. During the period immediately preceding contact Barrow area residents had shifted to surface "burials." There is an extensive modern history of collection of human remains from the surface in the Nuvuk vicinity, which presumably removed many of these individuals from the Nuvuk mortuary precinct.

The human remains excavated from Nuvuk by the NAP were carefully documented by physical anthropologists prior to their reburial. Samples were retained for ancient DNA (aDNA) extraction, stable isotope analysis and radiocarbon dating. These studies are underway at the time of writing.

Barrow Area Sites: Nuvuk, Utqiaġvik, and Birnirk, Fig. 3 Some of Birnirk mounds from the air. Note Elson Lagoon waters encroaching. View north

Birnirk

Birnirk (Piġniq in Inupiaq) is located at the base of the Point Barrow spit, between Elson Lagoon and the Chukchi Sea (Fig. 3). It is made up of a group of 16 mounds near the shore of the lagoon, separated from the Chukchi Sea by a series of gravel beach ridges. Birnirk is the type site of the Birnirk culture and is currently designated a US National Historic Landmark. Some parts of the site are threatened by sea level rise.

James Ford's work indicated that the major occupation at Birnirk was relatively early, predating what was then known of occupation at Utqiaġvik. However, some of Carter's later work, as well as explorers' accounts suggest that the site was occupied to some extent past the time of contact. The few radiocarbon dates from the site are all early, ranging from 684–878 calCE to 992–1156 calCE. However, these dates were on harpoon heads chosen to date the transition between Birnirk and Thule, rather than materials chosen to clarify the duration of occupation (Morrison 2001). Ford produced very detailed (1 foot contour) maps of Birnirk. These maps were published together with his description of his 1930s work (Ford 1959). This remains the best published information on the site.

Stefánsson reportedly recovered one individual from Birnirk, but no further documentation is available. Ford (1959) recovered a number of individuals here, as did Carter, although it is not clear if they were the result of deliberate burials. The stratigraphy of the mounds at Birnirk is extremely complicated. It is unclear if the human remains were recovered from within houses, as in the cases at Utqiaġvik, or were deliberately buried in grave structures, as seems to have been the case at Nuvuk and Kugok.

Key Issues/Current Debates/Future Directions/Examples

A key research issue is clarifying the occupational history of these sites. Only Nuvuk has a reasonable suite of radiocarbon dates (Jensen 2009a, b). Both Birnirk and Utkiavik could benefit from a program of systematic dating of well-chosen existing specimens. However, modern excavation standards are quite different than when Birnirk was last excavated, so some controlled excavation would help. There is a large well-excavated collection from Utqiaġvik. However, the existence of multiple Birnirk burials at Kugok, coupled with the Birnirk finds from the house floor at Ukkuqsi, suggests that there was at least a small Birnirk occupation at Utqiaġvik, which apparently was not encountered by earlier excavators. Resolving this issue will make it feasible to address other questions.

One question of interest concerns changes in the material culture found at the sites, and whether they relate solely to in situ cultural development or whether a population replacement from elsewhere was involved. The aDNA studies from Nuvuk, coupled with modern DNA studies of the North Slope, should help to resolve this question. Improved chronological control should better identify the timing of changes in material culture, as well as apparent changes in social and cultural organization. This will permit these changes to be situated in an environmental context, in order to investigate the human ecodynamics.

A related question is what role the Barrow area played in the development of the Thule culture and whether it was the source for the Thule migration. Various conflicting theories exist, an extreme one of which includes a multi-century abandonment of the Barrow area. Although neither the stratigraphy at the sites nor the known radiocarbon chronology appears consistent with this scenario, better understanding of individual site chronologies will clarify the situation.

The broad outlines of paleoeconomy in the Barrow area are understood from prior excavations. However, none of the sites has had a rigorous zooarchaeological study carried out. Midden deposits still exist at Birnirk and Utqiaġvik where productive studies could be carried out.

All of these sites are threatened by coastal erosion and sea level rise. The warming of permafrost and concurrent deepening of the active layer is also a major threat to the generally excellent preservation which currently exists at these sites.

Cross-References

- ▶ Biomolecular Archaeology: Definition
- ▶ Bone Chemistry and Ancient Diet
- ▶ Cape Krusenstern Societies
- ▶ Community Archaeology
- ▶ Cultural Heritage and Communities
- ▶ Cultural Heritage Management and Native Americans
- ▶ Cultural Heritage Outreach
- ▶ DNA and Skeletal Analysis in Bioarchaeology and Human Osteology
- ▶ Ethics and Human Remains
- ▶ Frozen Conditions: Preservation and Excavation
- ▶ Human Migration: Bioarchaeological Approaches
- ▶ Hunter-Gatherer Settlement and Mobility
- ▶ Hunter-Gatherer Subsistence Variation and Intensification
- ▶ Hunter-Gatherers, Archaeology of
- ▶ Indigenous Collaboration in Archaeology Education
- ▶ Island Nation Sites and Rising Sea Levels
- ▶ Local Communities and Archaeology: A Caribbean Perspective
- ▶ Native American Graves Protection and Repatriation Act (NAGPRA), USA
- ▶ Permafrost Digging
- ▶ Zooarchaeology

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Basilica in Classical Archaeology

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Introduction and Definition

The Latin term basilica is a transliteration of the Greek Βασιλική (“belonging to the king”, “royal”) and generally refers to a wide and sumptuous covered hypostyle hall, mainly associated with a forum square (Gros 2001: 260-89, with bibliography). This definition is ably demonstrated by an important inscription from the Roman theater of Iguvium (modern Gubbio) (*CIL* XI.5920a-b = *ILS* 5531: “Cnaeus Satrius, son of Cnaeus, a colonial commissioner, provided the *basilicae* with paneled ceilings”) (“*C*]*n*(*aeus*) *Satrius Cn*(*aei*) *f*(*ilius*) *Rufus*, *IIIIvir iur*(*e*) *dic*(*undo*) / *basilicas sublaqueavit*...”). The term can also be employed to designate rooms with the same spatial and architectonic characteristics belonging to other public, and even private, complexes (Gros 2003, 2004). As a matter of fact, as the *basilicae forenses*, the two *basilicae* of Gubbio’s theater, built flanking the scenic sector during the early Augustan period, constituted large and luxurious halls provided with columns, roofing, and pavement, designed for the reception, passage, and shelter of citizens in a manner similar to the more common *basilicae* of forum spaces. The basilica, therefore, was a monumental, multivalent space that, in the case of a *basilica forensis*, added the basic functions of hospitality and accommodation to the judicial, administrative, and commercial activities specifically linked to the forum and which originally had been conducted outdoors.

Key Issues/Current Debates/Future Directions/Examples

The typology, elaborated in Rome from the end of the third century BCE onward, was most likely inspired by similar structures of the Hellenistic eastern Mediterranean (e.g., Wilson 2005). The basilica gradually replaces *atria* with *tabernae* that would normally border forum squares of the middle Republican period. These buildings were modeled along the lines of the traditional Italo-Roman atrium house and were mostly private property that could be rented for public activities, such as auctions, or religious activities, such as the *Tubilustrium* (Varro *LL* 6.14). The *atrium Regium* of the Forum Romanum, located between the *forum Piscarium* and the *Comitium* in the area of the Basilica Aemilia, is considered, also thanks to the onomastic correspondence (*aule basilike* = *atrium Regium*), the "ancestor of the Roman basilicas" (Gros 2001: 260-4). The construction of Basilica Porcia in 184 BCE, the first to be designated, as many *atria* previously, with the gentilician name (*nomen gentilicium*) of the founder (*De viris illustribus*, 47), has been realized at the site of "*atria duo* [. . .] *et quattuortabernas*"; and to be more precise at the site of *atrium Maenium* and *atrium Titium*, purchased by Cato the Elder with public funds in the area of the *Lautumiae* (Liv. 39.44.7). An analogous development takes place in Republican colonies as demonstrated by the forum of Cosa, which is bordered on three sides by *atria publica* that anticipate the construction of the basilica (c. 120 BCE) (Brown et al. 1993: 207-45).

The influx of Hellenistic traditions soon rendered the buildings of the republican tradition both inadequate and outdated, an inadequacy that led to the genesis and elaboration of the prototypical basilica. This transformation is evident in the monumental center of Rome in the space of only a few decades, with the identification, attested in Plautus (*Curculio* 1-472; *Captivi* 813-815), of the *atrium Regium* as a basilica. The construction of the Basilica Porcia (184 BCE) and the Basilica Aemilia (179 BCE during the censorship of M. Fulvius Nobilior) soon followed, as did the Basilica Sempronia (169 BCE). All of these building projects conferred both effectiveness and regularity to the Forum Romanum. The complex archaeological research into the first urban *basilicae* seems to demonstrate the gradual architectural development of this typology, which quickly acquires monumentality thanks to the installation of internal arcades erected to delimit wider naves and through the longitudinal axis of the building with respect to the square (Coarelli 1985: 135-66). This collocation may be noted in the several cities of Republican Italy, including Cosa, Alba Fucens, Ardea, and Aquileia, although it must be noted that one of the best known *basilicae* of the late second century BCE, that of Pompeii, opens up on to the city's forum along one of its short sides (Ohr 1991).

The basilica of Pompeii is of great interest for many reasons: it preserves in the substantially intact interior one of the recurrent elements of forum *basilicae*, namely, the *tribunal* (David 1983), which was a high podium (sometimes with columns) where magistrates used to sit during judicial proceedings. The example at Pompeii, furthermore, anticipates with some of its architectonic and planning details the model of basilica that Vitruvius would postulate in the late first century BCE (Gros 1984) when he planned the colony of Fanum Fortunae, an example that remains unknown to archaeology (*Arch*. 5.1.6-10). The isolation of the internal space by means of continuous walls at the expense of the more common arcades and the use of a so-called "colossal" order for the internal colonnade are principal factors of the analogy drawn between Fanum Fortunae and Pompeii. The basilica of Pompeii, however, respects the Vitruvian prescriptions in the organization of the central space and for the presence of the *tribunal* as well. The position of the building is different compared to the forum square and, accordingly, the *tribunal* inside the basilica that in the Vitruvian model is located in relation with an *aedes Augusti* in a quadrangular exedra that opens at the end of the minor, central axis. The pattern of the exedra with judicial, administrative, and/or religious functions will be replicated with success in many *basilicae* starting in the early Imperial period, as demonstrated by the cases of Rusellae, Lucus Feroniae, Iuvanum, Saepinum, Herdonia, and Gnathia as discussed by P. Gros (Gros 2001: 270).

Rooms with apsidal or even more simple quadrangular *exedrae*, very common annexes inside the basilica starting from the early Imperial period, were used as *tribunalia* or as traditional curia (Balty 1991), but, as shown by the Vitruvian basilica with its *aedes Augusti*, they could include inside statues of dynasts ideally destined to protect and guarantee the correct execution of administrative and judiciary activities (cf. also the statuary groups of the *basilicae* of Velleia, Otricoli, and Bologna).

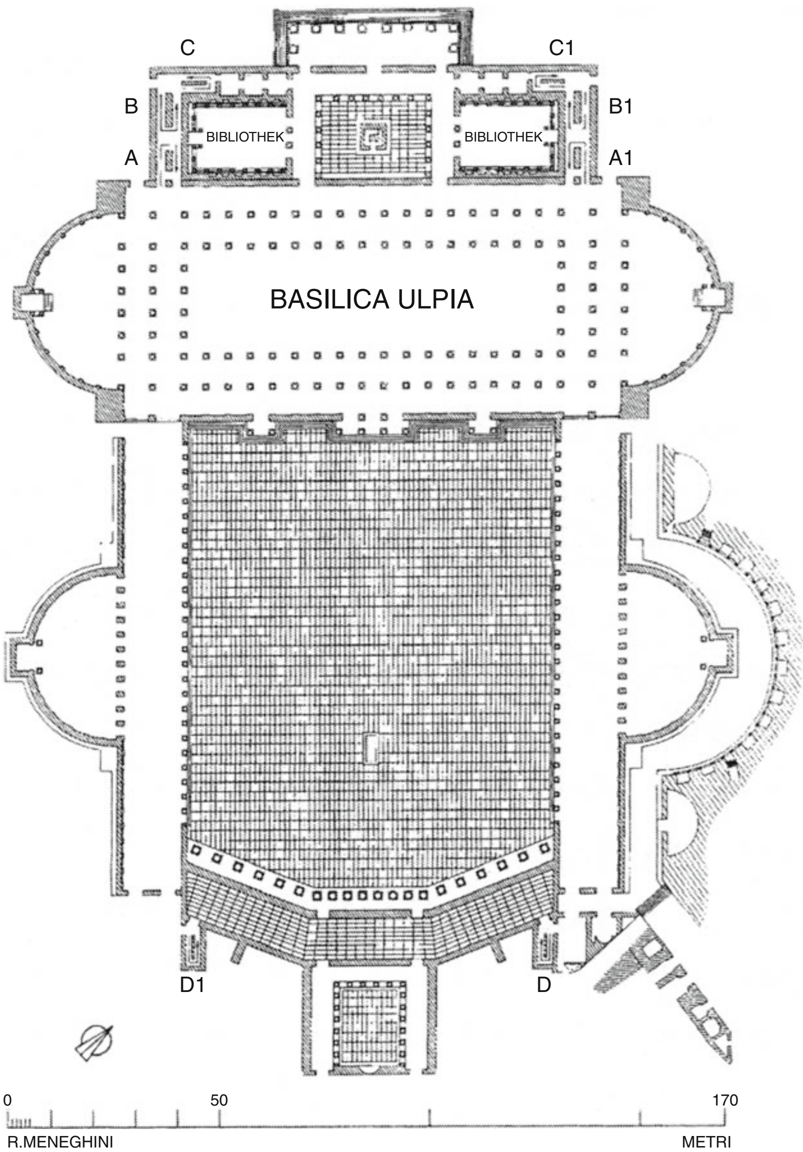
"The basilica is provided with an apse defined as a *tribunal*, a curia, and a sanctuary of Augustus at the same time, it is probably the monument which architecture expresses more effectively compared to others the new hierarchy of functions imposed by the political structure at the beginning of the Imperial period. No other composition allows us to appreciate better the sense of the evolution of power that took place between the end of the Republic and the beginning of the Empire; the consensus organization that implied an institutional and urban relationship between the sacred and the political at the beginning is now overcome by a subordination of the judiciary to the sacred, where the sacred assumes the forms of the Imperial cult [. . .] This takeover of judiciary (*tribunal*) and administrative (curia) functions under the aegis of power is typical of the monarchical drift of a system in which the local autonomies traditionally recognized by the citizen status have the right to exist only in a restricted and symbolically controlled framework . . .." (Gros 2001: 296-7).

In the meantime, from the final decades of the first century BCE, the *basilicae* that bordered the Forum Romanum were also linked with more or less radical projects dedicated to the Imperial family and their glorification. The Basilica Aemilia, the only one among the more ancient Roman *basilicae* to survive in any measure, which for centuries had celebrated the name of the famous Republican *gens*, had a two level arcade dedicated to Caius and Lucius Caesar added on its facade facing the square in front of the *tabernae novae* (14-2 BCE) (Coarelli 1985: 173-89). This construction replaced arcades that were already present from the previous chronological phases (Coarelli 1985: 201-9). An even more decisive action took place on the southern side of the Forum Romanum that had been partially occupied by the Basilica Sempronia since 169 BCE. It was now removed and replaced by Basilica Iulia, started by Julius Caesar and completed by Augustus; it was thereupon destroyed by fire almost immediately and was therefore rebuilt and rededicated to the emperor's adopted children (12 CE).

The planimetric organization of these two, exceptional urban *basilicae*, numbered among the most beautiful buildings ever built in Rome, was similar and, in clearly emphatic forms, also repeated the common pattern of the basilica type: a wide central room with a major height (*spatium medium*), surrounded by one or more aisles on which could stand galleries or an ambulatory and anticipated by a facade or *porticus* opening toward the forum's square. As building types became progressively more monumental during the Imperial period, an even more radical application of this tendency may be observed in the Basilica Ulpia of the Forum of Trajan (106–113 CE), which was, at the time, the largest basilica ever built with 8,500 m^2 of covered space and five naves (Fig. 1). The main novelty of the Basilica Ulpia is represented by the presence of two apses at the nave's sides, and this pattern will have great fortune into the realization or renovation of some important peripheral *basilicae*, mostly in Africa (e.g., Aquileia, Augusta Raurica, Leptis Magna, Bulla Regia, Sabratha, Volubilis) (Gros 2001: 282-7).

If, as observed, in Rome and in the urban centers of the western Mediterranean, a strict relationship existed between the basilica and the *porticus* (Nünnerich-Asmus 1994), this relationship is not well attested in the eastern provinces of the Roman empire. As a matter of fact, considering, for example, the plans of the *basilicae* of Ephesus and Smyrna, it is difficult to formally distinguish them from the numerous, long *stoai* that usually bordered the civic *agorai*. On the other hand, the three *basilicae* of the *agora* of Corinth, a *colonia libertinorum* that became capital of the Roman province of Achaea under Augustus, are linked to the Western rules.

A "normal" pattern that, applied also to the *basilicae* of other provincial capitals such as Tarragona and Carthage, will have a long life in the West, partially transformed under the influence of the architecture of public baths – *basilicae thermarum* are also well known – and by the need for dynastic propaganda implemented with more and more daring and emphatic forms. In Rome the Basilica of Maxentius (or Basilica Nova) was completed by Constantine I. The great nave, covered by three cross vaults, does not adopt the usual side aisles with columns, but rather employs a system of three large rooms per



Basilica in Classical Archaeology, Fig. 1 The Basilica Ulpia in the Forum of Trajan (From Gros & Torelli 2007: 227, Fig. 121, with kind permission)

side interconnected and covered by mighty barrel vaults, according to construction indications that resemble closely the colossal rooms of the Imperial baths. The long central room, whose rhythm was quite different from the side rooms, was focused at its western side on an apse that hosted a colossal acrolithic statue of the emperor as Zeus enthroned (the fragments of which are now housed in the Palazzo dei Conservatori of the Capitoline Museums in Rome). This statue, god on earth with his gaze cast *instinctu divinitatis* toward the sky, together with analogous *simulacra* and apses, must have contributed to select the basilica as the ideal building type to celebrate the Christian god as well.

Cross-References

▶ Agora in the Greek World
▶ Architecture, Roman
▶ Baths and Bathing, Roman

▶ Forum
▶ Imperial Cult, Roman
▶ Romanization
▶ Stoa
▶ Topography of Rome

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Bass III, William M.

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Basic Biographical Information

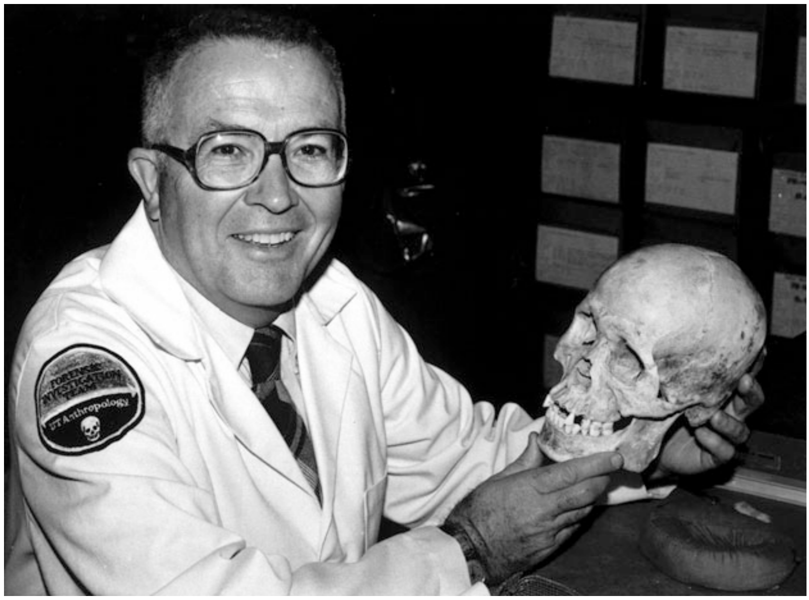
Education and Professorships

Dr. William "Bill" Bass (Fig. 1) was born in 1928 and raised in Virginia, receiving a B.A. in Psychology from the University of Virginia and his MS in Anthropology from the University of Kentucky. He had already earned two university teaching positions in departments of anthropology a year and a half prior to completion of his doctorate from the University of Pennsylvania in 1961. These appointments were Instructorships at the Universities of Nebraska and Kansas. Bass's graduate mentors, Drs. Charles Snow and Wilton Krogman, heavily influenced him throughout his career. With the Ph.D., he earned Assistant, Associate, and full Professorships during his tenure at Kansas from 1961 to 1971. He came to the University of Tennessee in 1971 to head the Department of Anthropology and develop a graduate program, remaining chairperson until 1992. Bass became Professor Emeritus in 1998, after 6 years as Professor and Director of the Forensic Anthropology Center.

Major Accomplishments

Bioarchaeology

Dr. Bass guided his student excavation crews during the summers of 1956 through 1959 pioneering the formulation of prehistoric Plains mortuary site archaeology. As the physical anthropologist for the Smithsonian Institution's River Basin Survey, Bass and his students excavated numerous cemetery sites, chiefly in South Dakota at Sully, a protohistoric Extended Coalescent site, Mobridge; a protohistoric Postcontact Coalescent, Le Beau phase site; and



Bass III, William M., Fig. 1 Dr. William M. Bass, III, in the Human Osteology Laboratory at the University of Tennessee, Knoxville, c. 1978

Leavenworth, a historic Arikara site, uncovering hundreds of burials that produced thousands of human skeletons in exquisite states of bone and dental preservation. From 1961 until 1970, Bass was field director for the National Science Foundation and National Geographic Society that serially funded field excavations of prehistoric skeletal remains from the Northern and Central Plains region, particularly, South Dakota.

Half a century of graduate students from Kansas and Tennessee and numerous researchers studied these pristine skeletal collections creating data sets and quantitative and qualitative methods and techniques to answer questions about the Plains people's prehistoric lifeways, from demography to pathology and warfare. Those students, Douglas Ubelaker, Walter Birkby, Richard Jantz, Pat Willey, and Ted Rathbun, to name a few, all continued studying becoming professors of human skeletal biology in both bioarchaeological and forensic contexts. In 1994, Douglas Owsley and Richard Jantz dedicated to Bass an exciting volume, *Skeletal Biology in the Great Plains*, culminating much of these results.

Dr. Bass's interest in bioarchaeology continued at the University of Tennessee where in the late 1970s he and Professor Walter Klippel directed, with US National Park Service funding, the excavation of a large Mississippian cemetery at the Averbuch site in central Tennessee. Similar to the Plains skeletal series, the Averbuch remains of nearly 1,000 skeletons have provided a research base for numerous theses, dissertations, and research articles. A book that Bass initiated during his tenure at Kansas, *Human Osteology, A Laboratory and Field Manual*, now in its 5th edition (Bass 2005), has served as a cornerstone text in the teaching of human osteology at both undergraduate and graduate levels.

Forensic Anthropology

Dr. Bass's initial exposure to forensic anthropology was with Dr. Charles Snow making a positive identification from a burned body, and Drs. Bass and Krogman are the only anthropologists who have examined the remains of the Lindbergh baby. The victim was the 20-month-old son of famed trans-Atlantic aviator Charles A. Lindbergh and his author wife, Anne Morrow Lindbergh. The child was kidnapped from the family home in 1932, and skeletal remains were discovered several months later.

These mentors sparked an interest that Bass formally developed into a graduate curriculum at the Universities of Kansas and Tennessee. While he performed human identification services in Kansas, a near, full-time shift of interest to forensic anthropology occurred when he became Head of Anthropology at the University of Tennessee. During this transition, Bass realized that academic departments of physical anthropology were producing new professors more rapidly than university positions could support. He also noticed an ever-increasing reliance among the pathologists, medical examiners, and coroners he was consulting with, for a resource with expertise in forensic osteology.

During his first year in Tennessee, Dr. Bass was exposed to several cases where the remains were neither skeletal nor fresh. This contrasted to his work in Kansas where most remains were skeletal. In 1977, the examination of Confederate Civil War Colonel William Shy, a casualty from the 1864 Battle of Nashville (Bass 1997), made a profound impression on Bass; science had no idea how long it took for soft tissues to decompose. Bass turned his research energy to studying soft tissue decomposition, the process of skeletonization, and requested an outdoor laboratory to document the process. By 1980, he began in earnest witnessing decomposition events first-hand with bodies donated from medical examiners. Time since death estimation became a steadfast research focus of a fledgling crop of Bass's graduate students dedicated to understanding this process.

The dual reputation of an engaging and theatrical teaching presence and a burgeoning avant-garde research program deciphering the stages in human decomposition combined to the granting of the prestigious award of National Professor of the Year in 1985 by The Council for Advancement and Support of Education. Subsequent to that recognition, Bass created the Forensic Anthropology Center, an endowed research program in the Department of Anthropology focusing on research in all realms of forensic anthropology, including archaeology and other diverse components of victim decomposition and scene dynamics.

As Dr. Bass's expertise and reputation in understanding decomposition strengthened because of his outdoor laboratory observations at the research "facility," he was summoned to examine more cases and venture estimations of time since death for medicolegal testimony. This prompted more cases, more research, and more students. Virtually everything we now understand about the entomological foundations of decomposition originated from studies initiated at Bass's facility by him and his students. Besides a comprehensive understanding of how temperature guides gross decomposition events, soft tissue histology from organ biopsy has been examined during the decomposition process along with soil and odor biochemistry and situational scenarios with burial, body position, clothing, coverings, fabric variety, trace evidence, cadaver dog exposure, and water submersion. In 1994, a symposium in honor of Dr. Bass was presented by his students at the American Academy of Forensic Sciences meeting, and the following year those papers were published in a special volume (see References).

Cross-References

- ▶ Bioarchaeology: Definition
- ▶ Ethics and Human Remains
- ▶ Forensic Anthropology: Definition
- ▶ Human Remains in Museums
- ▶ Human Skeletal Remains: Identification of Individuals
- ▶ North American Plains: Geography and Culture
- ▶ Skeletal Biology: Definition
- ▶ Taphonomy in Bioarchaeology and Human Osteology
- ▶ Time Since Death in Bioarchaeology and Human Osteology

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Bass, George Fletcher

Cemal Pulak
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Basic Biographical Information

George F. Bass was born in Columbia, South Carolina, on 9 December 1932. He graduated from The Johns Hopkins University in 1955 with an M.A. in Near Eastern archaeology and attended the American School of Classical Studies at Athens, Greece, between 1955 and 1957. During that time he participated in preclassical excavations at Lerna in Greece and Gordion in Turkey. After serving in the US Army as a lieutenant in South Korea (1957–1959), he began doctoral studies in classical archaeology at the University of Pennsylvania.

In 1960, at the request of his department chairman, Rodney Young, Bass learned to dive prior to excavating a Bronze Age shipwreck of around 1200 BCE reported by journalist Peter Throckmorton off Cape Gelidonya, Turkey. That summer, with Throckmorton, Bass directed the excavation of the wreck, the first ancient wreck excavated in its entirety on the seabed and the first excavated and published by a diving archaeologist. With this excavation, Bass set the example for future underwater archaeological research by demonstrating that shipwrecks could be recorded and excavated to the same rigorous archaeological standards applied to terrestrial sites. Based on the ship's cargo of scrap bronze, and copper and tin ingots, Bass concluded that the ship was Canaanite in origin and that the role of Bronze Age Near Eastern seafarers had gone mostly unnoticed because their trade goods consisted primarily of raw materials, which left no trace in the archaeological record, because on arrival they were soon manufactured into artifacts characteristic of the importing cultures – a view now widely accepted, but radical for its time.

While excavating a seventh-century CE Byzantine wreck (1961–1964) and a fourth-century CE Late Roman wreck (1967–1969) at Yassıada, Turkey, Bass implemented new techniques and tools, including an underwater telephone booth, a submersible decompression chamber without surface support, and a method of mapping shipwrecks by stereophotogrammetry. In 1964, he launched the two-person *Asherah*, the first commercially built research submersible in the United States.

In 1964, Bass received his doctorate from the University of Pennsylvania and joined its faculty. In 1967, Bass's team was the first to locate an ancient shipwreck, with side-scan sonar, a second or first century BCE Hellenistic wreck near Yalıkavak, Turkey. He assisted the excavations of a Bronze Age city on Santorini, Greece, in 1968; spent a sabbatical year at the University of Cambridge (1969–1970); and in 1971 excavated a preclassical site in southern Italy, his last terrestrial excavation.

In 1973, Bass resigned from the University of Pennsylvania to form an institution devoted to the exploration and study of underwater cultural heritage, the American Institute of Nautical Archaeology (AINA). AINA's first field project was a Turkish-coastal survey that located a dozen ancient shipwrecks. In 1976, Bass affiliated AINA with Texas A&M University, which started a graduate program in nautical archaeology, a new branch of archaeology that has achieved academic recognition largely through his and his colleagues' work. A Distinguished Professor Emeritus at Texas A&M since 2000, Bass directed the Nautical Archaeology Program (NAP) until 1993. AINA – renamed the Institute of Nautical Archaeology (INA) in 1979 – became world-renowned by conducting underwater research on four continents.

In 2000, INA added a research and conservation center in Bodrum, Turkey.

In the 1970s, Bass initiated the excavations of two shipwrecks of the American War of Independence: the American privateer *Defence* in Penobscot Bay, Maine, and the British "Cornwallis Cave Wreck" in the York River, Virginia, before turning the excavations over to other scholars. He was no less active in the Caribbean, initiating surveys and excavations in Jamaica and the Turks and the Caicos Islands, all of which he turned over to colleagues and students.

Between 1977 and 1979, Bass excavated an eleventh-century CE shipwreck at Serçe Limanı, Turkey, which was then the earliest known wooden hull built according to modern construction methods. In 1979, INA purchased the 65-ft, steel-hulled *Virazon*, which Bass had taken to Turkey on loan from the US Navy in 1964, and outfitted it with a recompression chamber and equipment for underwater surveys and excavations.

In 1984, Bass began the deepest large-scale excavation ever conducted under water, of a Bronze Age ship lost around 1300 BCE at Uluburun, Turkey. Its cargo of raw materials and personal possessions provided further evidence for Bass' theory of Bronze Age Near Eastern traders that he had proposed in his book on the Cape Gelidonya wreck. In 1985, Bass turned over the Uluburun excavation to another of his students.

Bass codirected with former students the excavations of the fifth-century BCE Tektaş Burnu wreck (1999–2001) and the sixth-century BCE Pabuç Burnu wreck (2002–2003) in Turkey. During that time, INA acquired a two-person submersible of revolutionary design, *Carolyn*, and built a 45-ft catamaran to support it in its successful surveys.

Major Accomplishments

Bass has been widely recognized for his significant achievements and contributions to the field of nautical archaeology. He has been awarded the Archaeological Institute of America's Gold Medal for Distinguished Archaeological Achievement (1986), the Explorers Club's Lowell Thomas Award (1986), the National Geographic Society's La Gorce Gold Medal (1979) and its Centennial Award (1988), the J.C. Harrington Medal from The Society for Historical Archaeology (1999), and the Historical Diving Society's Pioneer Award (2006). In 2002, President George W. Bush presented Bass with the National Medal of Science. The Archaeological Institute of America established a lecture series in his honor and presented him with the Bandelier Award for Service to Archaeology (2011); he was elected a fellow of the American Academy of Arts and Sciences in 2012. Bass received honorary doctorates from Boğaziçi University in Istanbul (1987) and the University of Liverpool (1998).

Bass has written, coauthored, and edited eleven books; published more than 200 scholarly and popular articles; and lectured around the world. His books include *Archaeology Under Water* (1966), *A History of Seafaring Based on Underwater Archaeology* (1973), *Archaeology Beneath the Sea* (1975), *Yassı Ada I: A Seventh-Century Byzantine Shipwreck* (1982), *Ships and Shipwrecks of the Americas* (1988), *Beneath the Seven Seas: Adventures with the Institute of Nautical Archaeology* (2005), *Serçe Limanı* I*: An Eleventh-Century Shipwreck* (2004), *Serçe Limanı* II*: The Glass of an Eleventh-Century Shipwreck* (2009), and *Archaeologist Beneath the Sea* (2012).

Cross-References

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▶ Hellenistic and Roman Anatolia, Archaeology of
▶ Hellenistic and Roman Egypt, Archaeology of
▶ Throckmorton, Peter

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- 2005. *Beneath the Seven Seas: adventures with the Institute of Nautical Archaeology*. London: Thames & Hudson.
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Bates, William Brian (Badger)

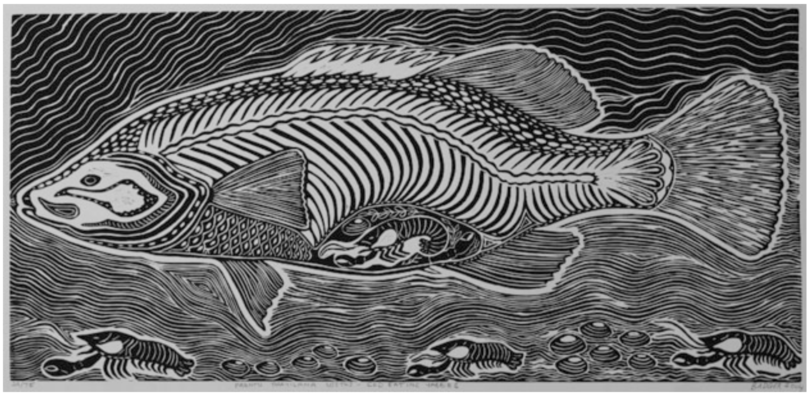
Christopher Wilson
Yunggorendi First Nations Centre, Flinders University, Adelaide, SA, Australia

Basic Biographical Information

William Brian (aka "Badger") Bates was born in 1947 at Wilcannia, New South Wales (NSW). His mother Emily Clark (c. 1925) was the youngest daughter of Annie Moysey, a Kurnu Paakantyi matriarch from the Louth area. His stepfather Gilbert Bates was from Yancannia in the Mutawintji area, and his biological father was Mick "Stinger" Hornell, a nonindigenous man from White Cliffs, NSW. Bates is an Elder of the Paakantyi group from the Paaka or Darling River between Wentworth and Bourke. His closest association is with the Kurnu Paakantyi country between Wilcannia and Bourke including the Darling and Warrego River junction, the lower Paroo River, and Mutawintji. He was raised by his extended family, and his main cultural educator was grandmother Granny Moysey, with whom he traveled his country, learning language, history, and culture. At the age of eight, his grandmother began to teach him how to carve emu eggs and make wooden artifacts which later became part of his artistic repertoire.

He worked as an Aboriginal Sites Officer with the National Parks and Wildlife Services, Broken Hill, NSW, for 22 years (1983–2005) until the age of 59, when he retired to focus on art and his role as a cultural heritage advisor full time. Badger worked with many Australian archaeologists including Peter Clark and Allen Thorne (Mungo National Park); Dan Witter, Jeanette Hope, Harvey Johnson, and Sarah Martin (National Parks Regional Archaeologists); Colin Pardoe (Lake Victoria Project); Ben Gunn (Mutawintji rock art projects); as well as Simon Holdaway and Trish Fanning on the Western NSW Archaeological Project. Badger's cultural knowledge was vital for understanding Australian archaeology particularly the process for cooking in heat-retainer ovens and eating marrow from kangaroo tail cooked in ashes for which archaeologists began to realize why kangaroo bones were broken into small pieces in some sites. Badger has attended and spoken at many national and international conferences, including ICOMOS and Indigenous Land Conferences where he presented papers in Mutawintji. He continues to campaign for more substantial involvement of Aboriginal people in the management of National Parks and Reserves throughout Western NSW.

Bates is regarded as both a traditional and contemporary indigenous artist who is well known nationally for his carving and linoprint (Fig. 1). Bates works in a variety of media including wood, stone, lino, metal, and found objects and produces themes that include anthropological, archaeological, and political references associated with his cultural attachment to the Darling, lower Paroo, and lower Warrego Rivers. His artwork is an extension of indigenous oral traditions, and his work shares important knowledge about ceremonial and mythological places, traditional life ways, stories about the ancestral spirits, as well as contemporary issues such as the degradation of the Darling River and Stolen Generations issues (see Fig. 2). As an arts educator, Bates has held several roles while teaching linocut, sculpture, and carving including TAFE lecturer at Wilcannia; outback field trip mentor for the College of Fine Arts, University of New South Wales; artist's residency at Wilcannia Arts



Bates, William Brian (Badger), Fig. 1 Parntu Thayilana Wiithi – cod-eating yabbies, Linocut print 2004

Bates, William Brian (Badger), Fig. 2 Stone Sculpture – Stolen Generations Memorial, Mt Annan, Sydney, 2007

Community in 2006 and 2007; and mentor for the River Red Gum art project, NSW, in 2011.

Bates has been heavily involved in activism, education, archaeology, and cultural heritage management in Australia. He successfully campaigned on behalf of indigenous land rights and the protection of significant sites against unacceptable management, spoilage by mining, agricultural practices, and urban expansion. This included the Mutawintji National Park hand back.

Major Accomplishments

Contributions to Archaeology

During his extensive period working as an Aboriginal Sites Officer for the National Parks and Wildlife Services, NSW, for 22 years (1983–2005), Badger was heavily involved in indigenous cultural heritage management and archaeology within this region. This included ongoing protection and management of many cultural and archaeological sites in Western NSW (i.e., burials and middens at Lake Victoria and Menindee Lakes; rock art sites at Mutawintji, Sturts Meadows, and Peery; and, stone quarries, open sites, and stone arrangements at Tibooburra), and he campaigned against unacceptable management practices and lack of indigenous involvement at Mutawintji National Park between 1983 and 1998 (Fig. 2). Badger was also instrumental in the controversial return of "Mungo Girl" from ANU, after the Paakantyi, Ngiyampaa, and Muthi Muthi elders sent him to Canberra to support their case in 1992 (Fig. 3). Furthermore, he was a cultural educator, providing education and training to archaeologists and other community members about the cultural and spiritual dimensions of archaeological materials and country (see Fig. 3).

Bates, William Brian (Badger), Fig. 3 Badger at a canoe scar cut out by his grandmother Granny Moysey c. 1922, Wilcannia

Selected Art Exhibitions

2010 Museum of Contemporary Art, Sydney, "*In The Balance: Art for a Changing World*." Badger exhibited three linocut prints as part of a group exhibition.

2009 "Tin Huts, Grilled Fish, and Johnny Cakes," solo exhibition of linocut prints, wooden, metal, and found object sculptures. Mildura Regional Gallery.

2009 and touring till 2012 Objects Gallery and Australian Museum exhibition "Menagerie, Animal Sculptures by Aboriginal and Torres Strait Islander Artists." Badger contributed 3 sculptures.

2008 "Life on the Darling" exhibition of Badger's linocut prints and sculptures, together with paintings of other Wilcannia artists Phillip Bates, Murray Butcher, and Willy Hunter, Australian Museum, Sydney.

2007 "*Bubbles on the Surface II*" at Monash University Gippsland Campus, solo exhibition featuring Badger's recent linocut prints and wooden sculptures.

2005 Solo exhibition of 20 linocut prints, Hazelhurst Regional Gallery and Arts Centre, Gymea, Sydney.

2004 "Wilcannia Mission School Kid," inaugural solo exhibition for the opening of the relocated Broken Hill Regional Art Gallery, Sully's Building, featuring linocut prints, wood, and steel sculptures.

2009 "Marella : The Hidden Mission." Badger contributed 3 linocut prints.

2009 Wilcannia Artists in Residence and Community Artists. Exhibition of the eight artists and community participants of the 3-year program. Broken Hill Regional Gallery.

2008 "Bubbles on the Surface III" Exhibition, Switchback Gallery, Monash Gippsland, featuring work of Badger Bates and Treanha Hamm, with Daphne Wallace and Chrissie Joy Marshall. Badger contributed 23 works, including linocut and photopolymer prints and embossings, wooden sculptures, and metal sculptures.

2006 New England Regional Art Museum (NERAM) exhibition *"Bubbles on the Surface I"* with Daphne Wallace, focusing on indigenous artists interpreting their association with water, in this case the Narran River and Narran Lake and the Darling River.

2005 "First People: First State," an exhibition of NSW Indigenous Art, NSW Parliament House, Sydney, with other NSW indigenous artists

Prizes and Awards

- Finalist in the NSW Indigenous Art Prize in 2012, Telstra Art Award
- Finalist in the Inaugural NSW Indigenous Art Prize in 2005
- Murdi Paaki Regional Council Citizen of the Year 2003
- Murdi Paaki Regional Council Community Service Award 1997 in for Outstanding Services to Heritage and Culture
- NSW National Parks Aboriginal Heritage Achievement Award 1993

Cross-References

- ▶ Australia: Cultural Heritage Management Education
- ▶ Australia: Indigenous Cultural Property Return
- ▶ Cultural Heritage and Communities
- ▶ Cultural Heritage Management: Building Bridges
- ▶ Ethnoarchaeology
- ▶ Holographic Epistemology: Native Common Sense
- ▶ Indigenous Archaeologies
- ▶ Indigenous Archaeologies: Australian Perspective
- ▶ Indigenous Knowledge and Traditional Knowledge
- ▶ Indigenous Peoples, Working with and for
- ▶ Intangible Cultural Heritage

Further Reading

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Baths and Bathing, Greek

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Introduction

Across time and in every culture, bathing is a primal necessity, and the bathing techniques and practices of a culture are revealing for its social concepts, values, and ideas. Thus, the analysis of bathing culture in Greek societies from the Archaic through Hellenistic periods (c. sixth to first century BCE) gives intriguing insights into changing attitudes towards key issues such as cleanliness, purity, leisure, collective pleasure, and enjoyment.

The evidence of Greek bathing culture includes three different sources:

1. Bathing images that are mainly represented on vases from sixth to fifth century BCE Athens and also on some South Italian vases of the fourth century BCE. These images show either nude young women or nude young men washing their entire body at high pedestal basins (*louteria*). Genders are strictly separated in these scenes, but bathing is still performed predominantly collectively, in groups of 2–5 persons. This corpus of bathing images is unique in the ancient Mediterranean world, and in its highly standardized imagery also has no parallel in any later cultures. While many aspects of these images are debated, it is obvious that they served primarily to display perfectly beautiful, well-groomed nude bodies in an intriguing variety of poses and did not faithfully depict contemporary bathing practices and facilities. Even as largely fictional representations, the bathing images were clearly shaped by and in turn reinforced and reflected contemporary social concepts of beauty, body, and gender (Kreilinger 2007; Stähli 2013).
2. Literary, epigraphic, and papyrological texts from different regions of the Mediterranean.

Some date to the fifth to first centuries BCE and others come from the Roman Imperial period, but cite earlier authors or clearly refer to earlier periods. While the texts are scanty overall and heterogeneous in date, genre, and provenance and offer no detailed description of a visit to Greek baths, they can be exploited for important information about the reputation, use, and management of baths, as well as related topics such as concepts of cleanliness.

3. Archaeological remains of over 200 bathing facilities from the fifth century BCE onwards that are located across the entire Mediterranean. These remains are by far the most important and conclusive evidence for an assessment of Greek bathing culture and will be the main focus in the following.

Definition

Greek societies washed and bathed regularly for ritual-cultic purification, personal hygiene, and relaxation and recreation. While purifying ablutions and simple cleansing required only cold water and could be performed in natural bodies of water or at simple basins, thorough cleansing and particularly relaxing bathing practices entailed the development of purpose-built bathing facilities, including a sophisticated technology to heat water and spaces. How Greek bathing facilities can be clearly distinguished from that of other ancient Mediterranean cultures (e.g., Etruscan, Punic, Roman) is debated; identification is mainly based on date (above all fifth to first century BCE), context (e.g., Greek city, Greek sanctuary, Greek *gymnasion*), and bathing program (see below).

"Greek" bathing facilities were mainly found in three different contexts:

1. Houses and royal palaces, which provided mostly single rooms for individual bathing and rarely more extended bath suites for collective bathing. Bathing forms employed mainly hot water and occasionally hot air to induce sweating. Comprehensive statistics cannot be provided for this vast category, because standards varied widely between different cities. Thus, while in Olynthos (northern Greece, 432–348 BCE) about 27 % of the known 86 houses had their own bathing room, in Delos (Cycladic island, 167/166–69 BCE) this standard was only provided in about 14 % of the known 89 houses. In general it is obvious that a private purpose-built room for bathing was always a luxury and never became standard in the Greek world (Trümper 2010).
2. Sports facilities (*gymnasia*/*palaistrai*) that provided single rooms for collective bathing and sometimes more extended bathing facilities. The default bathing form consisted of simple basins for washing with cold water; these were occasionally complemented by pools for collective cold plunge baths. By contrast, hot bathing was only rarely and tentatively introduced and exclusively in the form of sweat baths. Bathing facilities were most likely a standard of sports facilities, because athletes had to clean themselves after training. However, of the 22 Greek *gymnasia* that are partially or fully excavated, only 13 so far have yielded evidence of bathing facilities (Delorme 1960; von den Hoff 2009; Trümper 2013a).
3. Independent publicly accessible baths ("public" baths, *balaneia*) which offered a broad variety from single to multiple collective bathing facilities, always including bathing forms with hot water and, much more rarely, hot air for sweating. By contrast, cold water was used for washing hands and feet and only exceptionally for immersion baths. While the "public" baths were mostly freestanding buildings, they could also be incorporated in larger building complexes, albeit always as self-contained, independently accessible units. Most of them were built in urban or suburban contexts, with the exception of four examples in extraurban sanctuaries, among them most prominently the sanctuary of Zeus in Olympia. Currently, 70 "public" baths are known from the entire Mediterranean, 39 of which were discovered in the southeastern Mediterranean (Libya, Cyprus, and mostly Egypt),

22 in the northeastern Mediterranean (Turkey, and mostly Greece), and nine in the western Mediterranean (mostly Sicily and South Italy) (Trümper 2006, 2009; Lucore & Trümper 2013).

The "public" baths, built exclusively for the purpose of bathing, offer the best evidence for reconstructing the development and crucial changes of bathing standards. House owners strove to emulate the standards and innovations of "public" bathing culture, whereas bathing facilities in *gymnasia* developed largely independently, obviously for sociocultural reasons. According to literary sources, hot baths had a somewhat dubious reputation, at least in fifth and fourth century BCE Athens, because they would destroy the morals and bodies of bathers, most notably young men, who were supposed to devote their day to exercising in the *gymnasion* instead of to idle chatter in the *balaneion* (especially Aristophanes*, Nubes 1046, 1053-1054;* see also Plutarch*, Demetrius 24.2-3;* Athenaeus*, Deipnosophistae 1.18c;* Trümper 2013b).

Historical Background

Literary sources from the second century CE refer to the existence of *balaneia* ("public" baths) in Sybaris (Greek colony in South Italy) at the end of the sixth century BCE (Athenaeus, *Deipnosophistae* 12.518 c). This may be an anachronism, however, because Sybaris was notorious for its wealth and luxurious lifestyle, of which public hot baths obviously constituted an indispensable part for an author of the Roman Imperial period. The earliest archaeological remains date only to the fifth century BCE. The earliest *balaneion* so far was discovered in Athens outside the city wall near the Dipylon Gate. It has been dated to the period when the city and particularly its fortifications were rebuilt after the Persian wars (after 480/479 BCE). Slightly later, around 400 BCE, the most famous sanctuary of the Greek world, that of Zeus in Olympia, was provided with its first *balaneion* for the convenience of the visitors (see below). At the end of the fifth century BCE, private bathrooms are testified to in some houses, such as the houses of Olynthos, which were, on average, large and well appointed (Trümper 2010).

When cities and sanctuaries were gradually monumentalized and provided with standard building programs from the fourth century BCE onwards, the number of bathing facilities increased. Thus, ten of the 70 *balaneia* were constructed in the fourth century BCE, in Greece, Asia Minor (Turkey), and a Greek colony in France (Marseille). At the same time, *gymnasia* appeared as monumental edifices with simple cold water bathing facilities (Delorme 1960; von den Hoff 2009; Trümper 2013a).

The revolution of Greek bathing culture occurred in the Hellenistic period (end of fourth century to 31 BCE), however, both in terms of quantity and quality. Thus, most of the known *gymnasia* and particularly 59 of the 70 known *balaneia* were built in this period, in settlements all over the Mediterranean. Furthermore, innovative concepts and standards of bathing were introduced in all different urban-architectural contexts (see below). This agrees well with general sociocultural trends of the Hellenistic period, notably a significant increase in the dissemination and refinement of urban culture; a new focus on individual well-being, pleasure, and luxury; and major advances in the fields of science, technology, as well as architecture and urban planning. While most of the Hellenistic societies were affected by these same trends, distinct bathing practices developed in different regions of the Mediterranean. Three different regions can be discerned: the western, northeastern, and southeastern Mediterranean (Trümper 2006, 2009). Regional diversity was most likely due to different traditions, behaviors, and norms in societies that were now often multiethnic and multicultural. For example, Greek settlers that were invited by the new Greek rulers (Ptolemies, 306–31 BCE) to settle in recently conquered Egypt brought their own bathing practices, and Greek *balaneia* appeared all over Egypt from the third century BCE onwards. According to written sources, indigenous people also frequented these

Greek baths and may have had significant impact on the development of an idiosyncratic Graeco-Egyptian bathing culture (see below).

Despite the significant changes in bathing culture from the fifth through first century BCE, the important feature of patronage did not alter during this period. Written sources confirm that *balaneia* were predominantly, if not exclusively, privately owned and managed as profitable business investments (e.g., IG 2^3 84, 418/417 BCE; IG 2^2 2495, 335/334 BCE; ID 98, B, 33–34, 377/376–374/373 BCE; Isaeus, *Dikaiogenes* 22–24; Isaeus, *Philoktemon* 33; for references in Ptolemaic papyri, see Préaux 1947: 44). They did not figure among the standard building tasks of cities, such as political-administrative buildings, theaters, and *gymnasia*, nor were they popular targets for generous donors before the first century BCE. Exceptions were probably the few baths in sanctuaries that were under the responsibility and supervision of the respective administrations (see especially the *diagramma* of Andania, IG 5,1 1390, lines 106–111, 91/90 BCE or first century CE). Thus, the "public" aspect of most *balaneia* refers to their accessibility – publicly accessible for entrance fees – and not to their patronage, ownership, or management. By contrast, *gymnasia*, including their bathing facilities, were commonly financed by the cities and were the preferred objectives of private benefactors from the second century BCE onwards.

Key Issues/Current Debates

Greek bathing culture was first studied comprehensively and masterfully by the French scholar René Ginouvès (1962). Although the archaeological evidence has almost doubled since 1962 and research questions have changed significantly, Greek bathing culture did not receive much attention, particularly in comparison to the more popular Roman equivalent. Instead, it has long been underestimated in its significance, both for the ancient Greek world and in modern scholarship, notably cultural and sociohistorical studies.

This changed only recently, with the reexamination and excavation of numerous Greek baths (e.g., Caulonia, Locri Epizefiri, Morgantina, and Velia in Italy; Hephaistia, Olympia, Pella, and Thessaloniki in Greece; Buto/Tell el-Fara'in, Euhemeria/Quasr el-Banat, Karnak, Kom el-Khamsin, Krokodilopolis/Medinet el-Fayoum, Schedia, Taposiris Magna/Abusir, and Theadelphia/Kharabet Ihrit in Egypt) and with the first international conference dedicated to this topic, which took place in Rome in 2010 (Lucore & Trümper 2013).

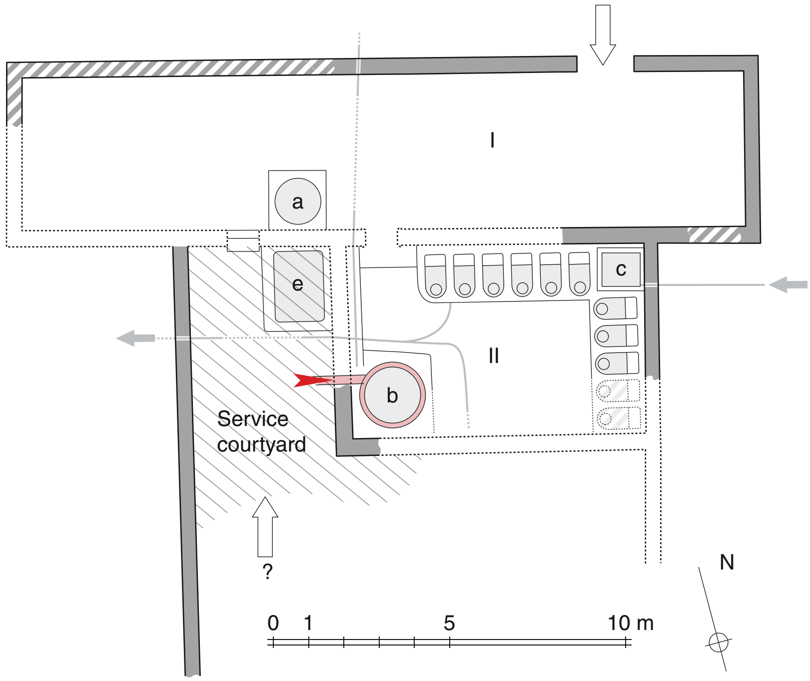
Greek baths are now explored as important evidence of sociocultural concepts, practices, and traditions. A key concern is to carefully reconstruct all bathing practices and standards, their social significance, and the technologies and resources they required. Major emphasis is placed on chronological development and regional differences and the political, social, and cultural factors that may have affected and inspired changes and diversity. This reassessment of Greek bathing culture is based on new excavations that employ modern methods and technologies, a critical reevaluation of old excavations, and extensive cross-cultural studies, notably comparisons with societies whose bathing culture is well known and thus may give crucial insights into the sociocultural complexity and intricate connotations of bathing.

Balaneia ("Public" Baths)

Balaneia in the Northeastern Mediterranean

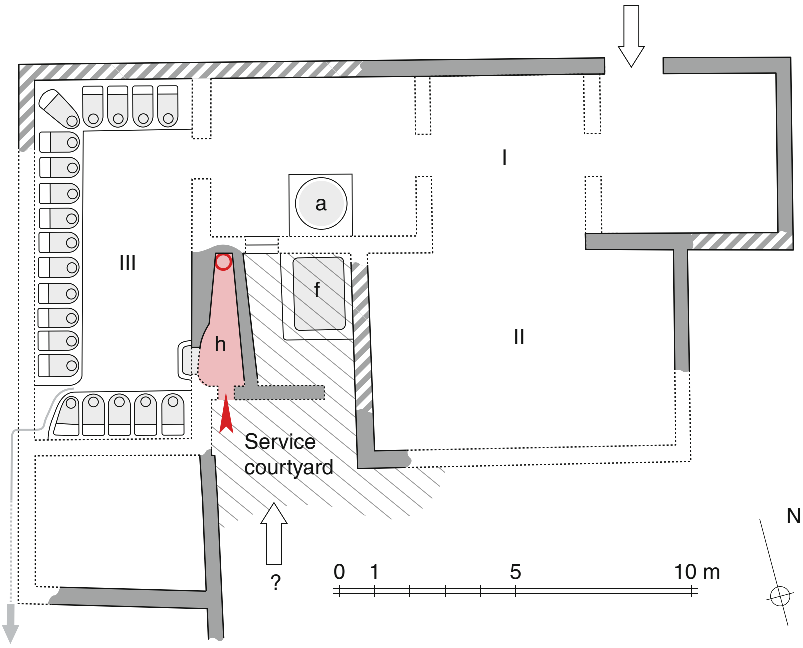
The development of Greek bathing culture can be demonstrated exemplarily in the sanctuary of Zeus in Olympia, which was provided, from about 400 BCE onwards, with a sequence of *balaneia* that were constantly refurbished and modernized. The first *balaneion* ("Older Sitzbath"), built around 400 BCE, included only one bathing form, notably 11 small hip-bathtubs (or sitz bathtubs) for simple cleansing shower baths (Fig. 1). Warm water was poured over the sitting bather with vessels, either by the bather or by an attendant; the used water was then collected in a hemispherical cavity at the bottom of the bathtub and had to be bailed out by hand. While hip-bathtubs were arranged in Olympia along the walls of a rectangular room (II), in other baths round bathing rooms (*tholoi*) predominated.

Baths and Bathing, Greek, Fig. 1 Olympia, "Older Sitzbath": plan of the second phase, late fourth century BCE; © Thibaud Fournet (After Kunze & Schleif 1944: pl. 13)



Although the bathing process was performed individually, the lack of walls or screens between bathtubs assured that bathing in a *balaneion* was overall a collective experience. Better preserved baths show that niches were inserted in the walls above bathtubs for storing clothes, bathing utensils, and occasionally oil lamps. Furthermore, bathing rooms were, in general, decorated with waterproof pavements, stucco, and furniture. The Olympian bathroom, probably from the beginning and certainly after a remodeling in the late fourth century BCE, had a cauldron for heating water, which was operated and supplied from an adjacent service courtyard (with water reservoir e). While the function of the large entrance hall (I, with well a) that was taken over from a previous building cannot be safely identified, it may have been used for activities related to bathing (strolling, waiting, light exercise, drinking water supply).

This first bath was replaced by another ("Younger Sitzbath") around 300 BCE (Fig. 2), which provided essentially the same bathing standard as its predecessor, albeit with increased capacity (room III with 20 hip-bathtubs), multifunctional lounges (I, II), and improved service installations. The latter were now located outside the bathing room, but adjacent to it (furnace with boiler in h, water reservoir f) so that hot water was conveniently available through an opening between furnace and bathing room. These key elements – a room with hip-bathtubs and, well separated from this, service facilities for storing and heating water – constituted the standard of all *balaneia* from the fourth century BCE onwards. These baths were simple and mostly functional in design and decoration. Most challenging was the roofing of round rooms, whose interior diameter could be about 11 m (c. 40 hip-bathtubs). In this case, a central support was required, evidence of which in the form of bases was found in several baths (e.g., in Athens: Dipylon Bath, Baths outside the Piraeus and Diochares Gates). Some fourth century BCE baths in Greece, however, had lavish decoration with polychrome figured pebble mosaics in bathrooms or entrance rooms suggesting that this building type had gained in prestige and importance (e.g., Ambrakia; Athens, Bath outside Diochares Gate; Corinth, Centaur Bath; Piraeus, Serangeion Bath). Another innovation of fourth century BCE baths was the duplication

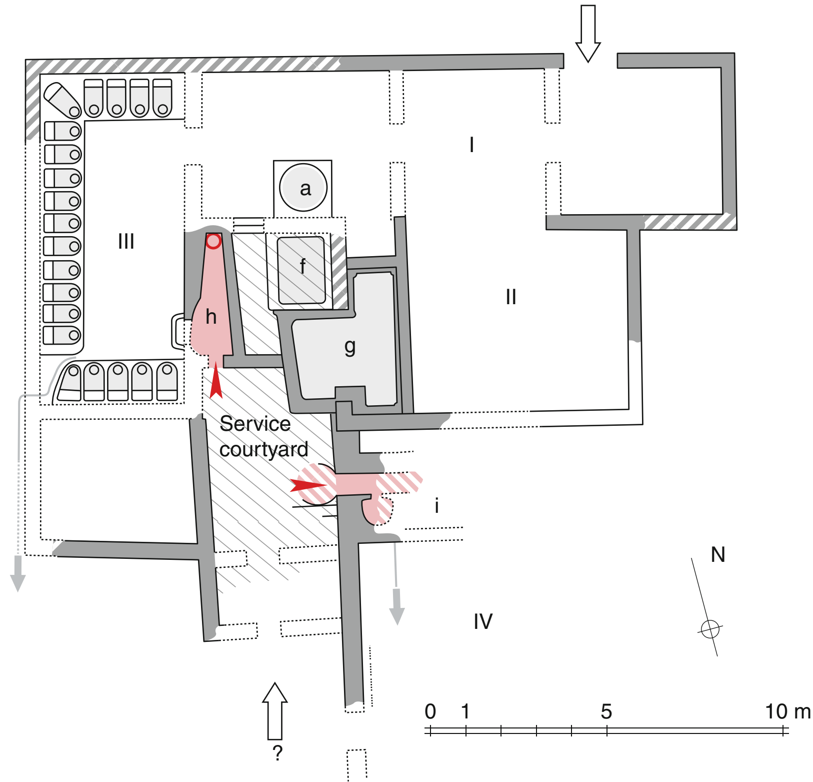


Baths and Bathing, Greek, Fig. 2 Olympia, "Younger Sitzbath": plan, c. 300 BCE; © Thibaud Fournet (After Kunze & Schleif 1944: pl. 16)

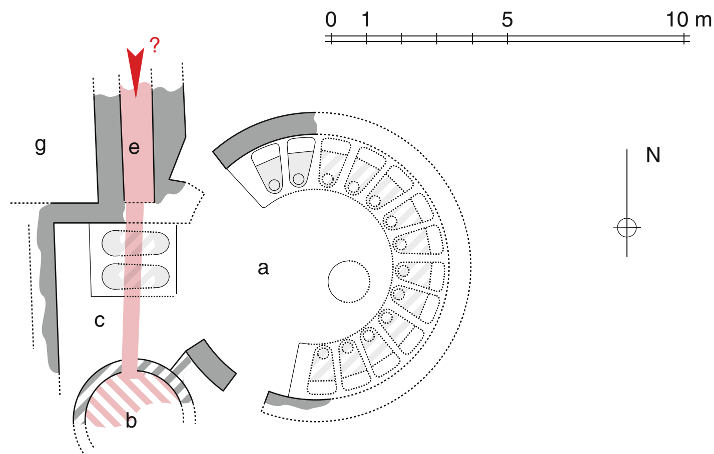
of bathing rooms with hip-bathtubs (mostly two *tholoi*; e.g., Ambrakia; possibly Piraeus, Serangeion Bath), which were most likely designed for use by the different sexes. Written sources testify that women frequented *balaneia* and that gender separation was a major concern. Some papyri from third century BCE Egypt mention a women's *tholos* and possibly also a men's *tholos*, suggesting that baths with double *tholoi* reserved one round bathing room for each of the sexes (Ginouvès 1962: 222–3; Meyer 1992; Trümper 2012). By contrast, if *balaneia* with single bathing rooms were used by both sexes, gender separation could only have been achieved through different bathing hours.

The simple functional *balaneion*, introduced in the fifth century BCE at the latest and consolidated and partially refined in the fourth century BCE, was continuously used through the first century BCE and in some regions even beyond that date. At the same time, a significant change in bathing standards occurred in the Hellenistic period, from the third century BCE onwards, with the introduction of new relaxing bathing forms. Cross-cultural studies on bathing clearly show that two criteria are considered as standard for relaxing bathing: heat and time. This means that a certain amount of time has to be spent in a comfortably warm or even hot environment that consists commonly of water, dry heat, or steam. All relaxing bathing forms also have a physically cleansing component, through the use of water or sweating. Relaxing bathing forms are thus not a real antipode to merely cleansing ones, but include and thereby substitute for them. In Greek bathing culture, the new relaxing bathing forms entailed and required advanced technology, increased monetary expense, and, above all, a collective societal endorsement of leisure, pleasure, and indulgence. They would most likely have enticed people to extend their visits to the baths and would have increased the importance of bathing as a social event.

To return to Olympia, shortly before its abandonment in the first quarter of the second century BCE, the "Younger Sitzbath" was provided with such a new relaxing bathing form, whose nature cannot be safely determined, but which was heated with hot air that circulated in a subterranean channel (hypocaust system) (Fig. 3: IV, i, supplied by new water reservoir g). The successor of this bath ("Late Hellenistic Bath"), built in the second half of the second century BCE, incorporated fully developed modern standards (Fig. 4): a – still predominant – *tholos* with 13



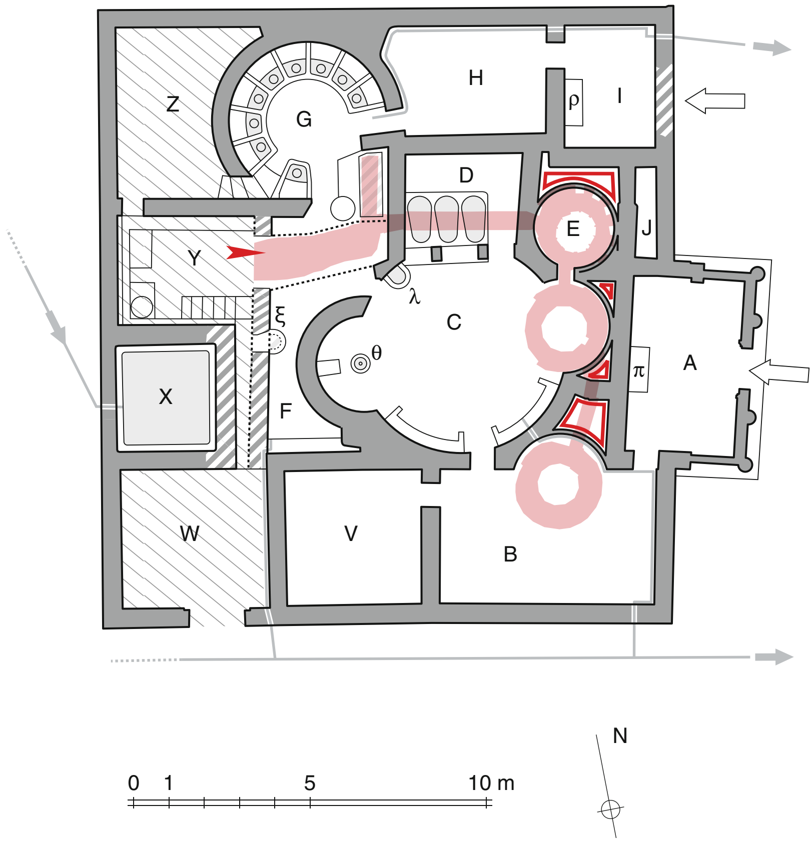
Baths and Bathing, Greek, Fig. 3 Olympia, "Younger Sitzbath": plan, c. early second century BCE; © Thibaud Fournet (After Kunze & Schleif 1944: pls. 16-17)



Baths and Bathing, Greek, Fig. 4 Olympia, "Late Hellenistic Bath": plan, second half of second century BCE; © Thibaud Fournet (After Sinn et al. 2003: 619, Figs. 4-5)

hip-bathtubs (a), two large bathtubs for individual relaxing immersion baths in hot water (c), and a small round room for collective sweat bathing in hot air (b). The two new bathing forms were heated by a sophisticated hypocaust system (e) that also provided hot water for the hip-bathtubs.

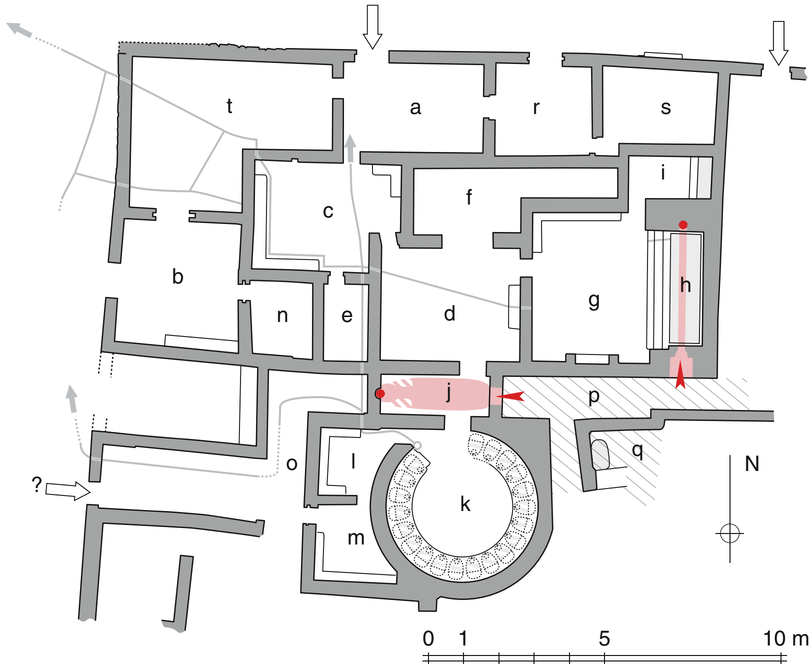
Several other baths in Greece offered a similarly complex bathing program, among them the fully excavated example in the sanctuary of Asklepios in Gortys (Peloponnesus) (Ginouvès 1959) (Fig. 5). Although this bath was, probably in the second century BCE, inserted into a preexisting building with a



Baths and Bathing, Greek, Fig. 5 Gortys, Bath in the Sanctuary of Asklepios: plan, c. second century BCE; © Thibaud Fournet (After Ginouvès1959: 165, Fig. 187)

different function, its design represents key elements of the new standard: a clear separation of bathing (A–F, V) and service (W–Z) sections; a lavish colonnaded entrance (*propylon* A); a *tholos* (G) with nine hip-bathtubs; a room (D) with three individual immersion bathtubs; a small round collective sweat bath for about four bathers (E); several multifunctional lounges and a distributive room with benches and various cold water basins (B, C with basins θ and λ, H); a fully developed hypocaust system with a ring-shaped channel for heating water, the relaxing bathing forms and parts of two lounges (B, C); and finally double entrances to the bathing section (A and I, both with statue bases π and ρ; third service entrance to room W) for differentiated use. The archaeological evidence even suggests that bathers could not pass over the hypocaust system (Y) from the distributive room C to the *tholos* G; thus, the two bathing sections were probably entirely independent, just using a common heating system (Y). The nature of this differentiated use cannot be safely determined, but the different circulation patterns may have provided the option to choose between a quick cheaper merely cleansing bath (G–I) versus an extended costlier stay in the relaxing section (A–F, V).

While this bath is located in an urban or suburban sanctuary of the healing god Asklepios, it did not necessarily serve as a specific medical-therapeutic facility. Water was not supplied by a particular mineral spring, and the bathing program has parallels in urban-secular baths. Despite major progress of medicine in the Hellenistic period, neither medical texts nor the archaeological remains of other Asklepios sanctuaries reveal a particular concern with the development of specific therapeutic bathing practices (Flemming 2013). Similarly, general ritual purifying bathing did not require sophisticated *balaneia* with hot bathing forms, but consisted mainly of washing



Baths and Bathing, Greek, Fig. 6 Megara Hyblaea, Bath in the Agora: plan, c. mid-third century BCE; © Thibaud Fournet (After Vallet et al. 1983: 51, Fig. 37)

parts of the body (hands, head, and feet) at simple basins with cold water. Therefore, *balaneia* in sanctuaries most likely granted visitors the same cleansing and relaxing bathing experience and convenience as their equivalents in urban-secular contexts (Trümper 2013b).

In the northeastern Mediterranean, the complex refined bath type and its simpler equivalent were used well into the first centuries BCE and CE and then gradually replaced by new bathing standards, notably Roman baths. The sanctuary in Olympia was again among the first sites in Greece to be provided with a fashionable Roman-type bath around 40 BCE ("Greek Hypocaust Bath"). This bath no longer included a cleansing section with hip-bathtubs, but only a large pool for collective relaxing immersion baths in hot water (see below). This pool, as well as the entire bathing room, was now heated by a modern hypocaust system with brick pillars.

Balaneia in the Western Mediterranean

New bathing standards were also introduced in other regions of the Mediterranean in the Hellenistic period, albeit with noticeable differences. The most sophisticated and advanced bathing culture was developed in the western Mediterranean, notably Sicily and South Italy. Most of the nine known baths in this region were built in the mid-third century BCE and abandoned around 200 BCE and included two distinct sections, spatially and conceptually clearly separated. For example, the well-preserved *balaneion* in the Agora of Megara Hyblaea (Sicily) (Fig. 6) had a cleansing section with traditional *tholos* (k, c. 20 hip-bathtubs), two multifunctional rooms with benches (l, m), an entrance from the adjacent street (o?), and a large bottle-shaped furnace for heating water (j). By contrast, the much larger and better appointed relaxing section had its own entrance on the Agora (a), a series of multifunctional rooms with (c, d) or without (e, f) benches, and a large bathing room (g) with a bench and a collective immersion pool (h). The latter was heated by its own hypocaust channel to keep the water warm. This large collective heated immersion pool differs significantly from the individual immersion bathtubs in northeastern baths; not only was its construction, operation, and maintenance far more costly, but it promoted above all a truly collective bathing experience, requiring bathers to use the same water and to face potential physical contact.

Both the cleansing and the relaxing sections in the *balaneion* of Megara Hyblaea were served by the same conveniently located service facilities (service courtyard p, well room q). While the central distributive room of the relaxing section (d) also had an access to the bottle-shaped furnace (j), probably for drawing warm water for various basins (in rooms d and g), room j was most likely completely filled by installations for heating water and thus could not be crossed in order to proceed from the relaxing to the cleansing section, and vice versa (cf. the similar situation in the bath of Gortys, see above). Hierarchy was clearly established by size, accessibility, and decoration, both within each section and between the sections. Thus, while all bathing rooms were provided with waterproof mortar pavements, only some of these pavements were decorated with small stone or marble pieces: room g with the immersion pool received the most intricate decoration pattern, followed by room d and *tholos* k, then room f, then room c, and finally, at the bottom of the decoration scale, rooms e, i, l, and m which had simple mortar pavements without any decoration.

It is obvious that the heating systems of these western Greek baths were more advanced than those of their northeastern equivalents, but the precise reconstruction and functioning of the furnaces and hypocaust systems is currently still much debated (Lucore 2013). The large bottle-shaped furnaces may have held large water basins or a series of juxtaposed (metal) cauldrons, heated by hot air from below; the immersion pools may have been supplied by their own hot water boiler or by innovative intricate devices such as a “tortoise” (*testudo*). The latter, so far only known from Roman baths and authors, consisted of a semicylindrical metal container that was situated over the fire in the furnace, on a slightly lower level than the bottom of the immersion pool. This container was closed at one end and open at the other, towards the immersion pool so that water could circulate constantly between the pool and the hot tortoise and thus be kept warm.

Other groundbreaking technologies were used in and maybe even developed for western Greek baths, most notably vaulting techniques. In the North Baths at Morgantina, the *tholoi* with hip-bathtubs and two rectangular bathing rooms were covered with a dome (diameter 5.75 m) and barrel vaults (spans of 5.00 and 5.00 m), respectively (Lucore 2009, 2013). These vaults were made of interlocking hollow terracotta tubes that were covered with a rough mortar on both sides and on the interior with additional painted plaster. Apart from the stunning aesthetic effect that these innovative vaults must have had on viewers, domed and vaulted roofs also had practical advantages: heat would have spread more evenly and condensation would not have dripped from the ceiling, but run along the curved walls. In the long run, the advance of vaulting techniques that was closely connected to the development of both Greek and, above all, Roman baths would allow the spanning of ever larger, impressive spaces.

Why the patrons and builders of western Greek baths pressed so much ahead in the development of the designs and related technologies of baths in comparison to their peers in the eastern Mediterranean, cannot be safely determined. Western Greek cities prospered in the third century BCE and were centers of inventions in the arts and sciences. This favorable, stimulating cultural and historical climate may well have had an impact on the promotion of the local bathing culture (Lucore 2009).

The western Greek baths shared significant characteristics with early Roman baths, which developed in the early second century BCE at the latest and are currently known from some 17 cities in Italy, France, and Spain. These early Roman baths commonly included only one or two multifunctional entrance rooms or lounges for activities related to bathing (*apodyterium*, *tepidarium*) and a single bathing room with a collective heated immersion pool (*caldarium*) (Tsiolis 2013). Thus, the crucial difference between western Greek and early Roman baths is that the latter entirely abandoned the separate cleansing section with hip-bathtubs.

Currently, the evidence of western Greek baths and early Roman baths is strangely distributed: no city has yielded clear evidence of both a Greek bath and an early Roman bath (second or early first century BCE), with the possible exception of Pompeii. Indeed, the famous Stabian Bath in Pompeii has often been identified as a Greek bath that was transformed into a Roman bath in the second century BCE, but the complex history of this building is much debated and requires critical reassessment. Another recently excavated example, the bath of Fregellae (Latin colony southeast of Rome, 328–125 BCE), provided evidence of two phases (Tsiolis 2013). The bath of the second phase, dated to the early second century BCE, was clearly Roman, but the predecessor from the late third century BCE cannot be fully reconstructed. While it certainly contained a relaxing section with a heated collective immersion pool, the existence of a separate cleansing section cannot be fully excluded – the more so because remains of a bottle-shaped furnace, a characteristic feature of the cleansing section in western Greek baths, have recently been uncovered.

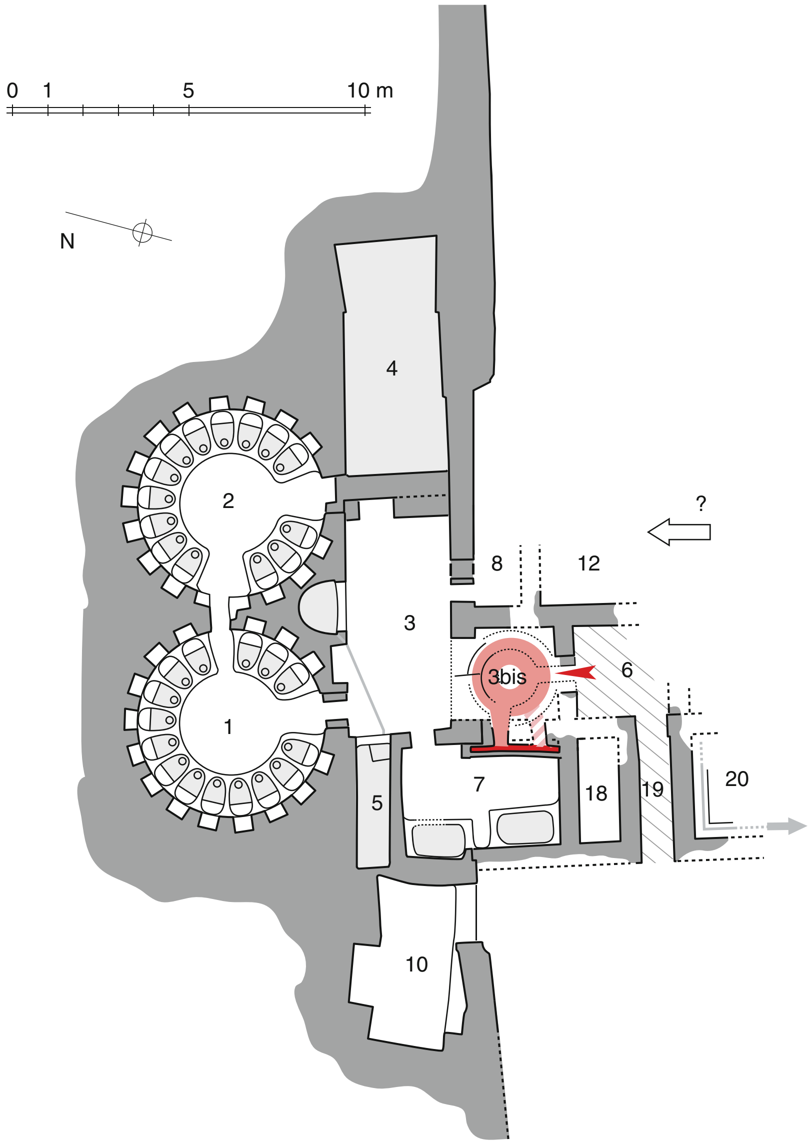
Therefore, the intriguing relationship between Greek and Roman baths cannot yet be fully assessed and reconstructed. It seems only obvious that the western Mediterranean was the "think tank" of bathing culture in the decades around 200 BCE and very much influenced its development in future centuries. Greek baths may have anticipated their Roman equivalents for a short period in the crucial advancement of bathing culture, notably in the development of both collective leisure bathing as a sociocultural concept and the appropriate technological requirements. Alternatively, these innovative features could have been developed simultaneously in different settings, with two different results, notably the rather short-lived western Greek cleansing and relaxing bath type and the more successful early Roman relaxing bath type, which was maintained and refined in the following centuries.

Balaneia in the Southeastern Mediterranean

In contrast to the bathing culture in the northeastern and western Mediterranean, that of the southeastern Mediterranean was more conservative and austere. In southeastern *balaneia*, hip-bathtubs were, from the second century and probably already third century BCE onwards, only complemented by individual immersion bathtubs that were not heated by a hypocaust system, but simply filled with hot water. Arranged mostly in separate rooms in groups of 2–6, the immersion bathtubs were always far outnumbered by the hip-bathtubs, suggesting that cleansing bathing always prevailed (Fig. 7: 1–2, 7). While in about half of all *balaneia*, rooms with hip-bathtubs were duplicated, this almost never occurred for rooms with immersion bathtubs. Thus, relaxing bathing was clearly reserved for a few privileged bathers and possibly even for one of the sexes, notably the male. The *tholos* or *tholoi* commonly constituted the center and focus of the *balaneia* and were surrounded by extended corridor systems and secondary (bathing or service) rooms. Idiosyncratic to southeastern baths, these corridors certainly facilitated circulation but may also have served for strolling and as a substitute for multifunctional lounges that were mostly missing in these baths.

Recent research on the Hellenistic bath of Taposiris Magna (northern coast of Egypt, west of Alexandria; Fig. 7) has shown that heating systems of southeastern baths could be far more complex and sophisticated than hitherto assumed (Fournet & Redon 2009, 2013). This bath was partially cut into the rock (rooms 1–5, 10, northern part of room 7) and is therefore exceptionally well preserved. Its heating system (3bis), however, refined in a second phase around 100 BCE, was built in front of the rock-cut parts, close to the *tholoi* with hip-bathtubs (1, 2). While the circular furnace served primarily to heat water for the bathtubs, it also heated adjacent spaces through openings (3) and a heating wall (7). The latter is similar to the wall heating systems of Roman baths, where hot air circulated in "hollow walls." Made of large tiles, the heating wall in Taposiris Magna heated the small relaxation section of the bath (7).

Some southeastern *balaneia* were modernized under Roman rule (after 30 BCE) by transforming *tholoi* into sweat baths or constructing collective cold or hot water pools, but the Greek bathing concept was still



Baths and Bathing, Greek, Fig. 7 Taposiris Magna/Abusir, Bath: plan of the second phase, c. 100 BCE; © Thibaud Fournet & Bérangère Redon (Fournet & Redon 2013: 245, Fig. 6)

astonishingly long-lasting. Thus, Greek baths, with a clear focus on simple cleansing hip-bath-tubs, were still used and even constructed in the second century CE, and Roman bathing customs were overall only reluctantly introduced and accepted. This may be one of the reasons why Egypt has yielded more evidence of Greek baths than any other region in the Mediterranean and why the Egyptian baths show significantly more traces of constant repairs and remodeling than their equivalents in other regions. Remarkable also is the distribution of baths which clearly reflects the enormous popularity of public bathing in this country. Thus, even small settlements (e. g., Euhemeria/Quasr el-Banat, Theadelphia/Kharabet Ihrit) were provided with two large public baths, and large cities with an even denser network of such establishments (e.g., in both Buto/Tell el-Fara'in and Krokodilopolis/Medinet el-Fayoum four public baths were found so far).

Sports Facilities *(Gymnasia/Palaistrai)*

While bathing facilities of sports facilities remained largely simple and ascetic for the above-mentioned sociocultural reasons, even they were affected by the dramatic evolution of bathing culture in the Hellenistic period, albeit to a different degree than the *balaneia*. The default athletic bathing form, notably simple bathing rooms with basins for cold water ablutions (*loutron*/*loutra*), was continuously built and used from the fourth through the first century BCE. Epigraphic sources show that these *loutra* enjoyed a certain popularity and prestige because generous donors paid for their construction and refurbishment from the second century BCE onwards. For example, according to inscriptions, the bathing facilities of the *gymnasion* in Pergamon (Asia Minor/Turkey, capital of the Attalid kingdom), built in the first half of the second century BCE at the expense of King Eumenes II, were improved several times by well-known local citizens, notably in the late second century BCE and again in the mid-first century BCE. Although the building is fully excavated, these improvements cannot be safely identified in the archaeological record, however, and they seem not to have changed the general bathing standard (Trümper 2013a).

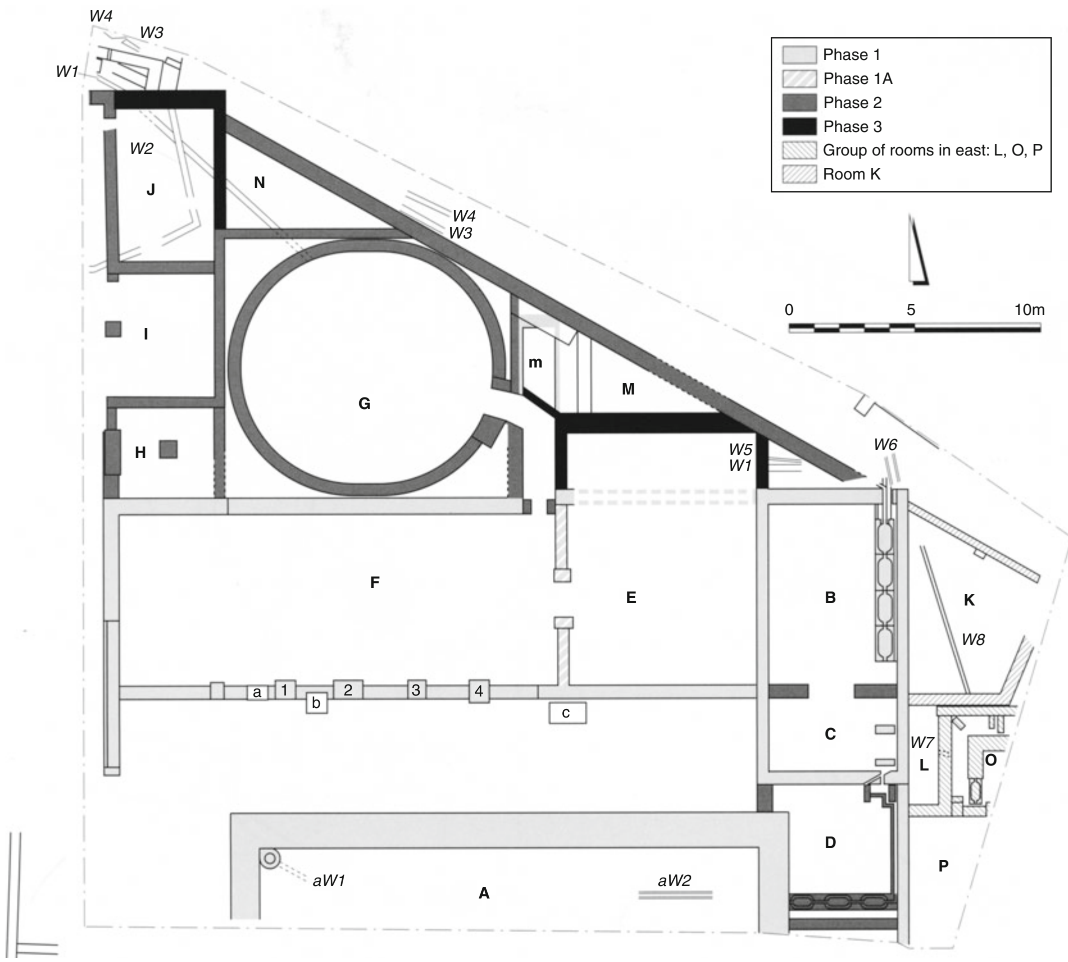
In some other *gymnasia*, however, the austere *loutra* were either supplemented or even substituted by extravagant facilities for collective sweat bathing in hot air in the second century BCE. These consisted either of rectangular rooms with barrel vaults (Delos, "Sea Palaestra," and "Gymnasium") or of large round rooms (diameters of 5.90–10.20 m: Assos in Asia Minor/Turkey, Eretria and Thera in Greece, Solunto and possibly Akrai in Sicily) (Trümper 2008: 250–75, 2013a). For example, the *gymnasion* of Eretria (Euboea/Greece, Fig. 8) was built at the end of the fourth century BCE with a simple *loutron* (B) and remodeled in the second half of the second century BCE to include a large round sweat bath (G). These round rooms are well known and were much debated for a long time, and only recent research has ascertained that both the challenging roofing (with conic or domed roofs) and the heating (most likely with hot stones or braziers) could be realistically accomplished.

While these various sweat baths must already have revolutionized the experience and concept of athletic bathing, the most significant change occurred only from the late first century BCE onwards when independent sophisticated Roman baths were built in or next to Greek *gymnasia* and hot water was used for the first time in the Greek athletic context. For example, the *gymnasion* of Pergamon was provided with a Roman bath ("West Bath") in the first century CE and a second larger equivalent ("East Bath") in the second century CE (Trümper 2013a). Consequently, in Asia Minor (Turkey) the formerly two distinct concepts – Roman bath and Greek *gymnasion* – were merged into a new building type in the first and second centuries CE, the so-called Bath-Gymnasia. This granted the survival of the Greek *gymnasion* by simultaneously accommodating a dramatically changed concept and perception of bathing.

Future Directions

Since research on Greek baths and bathing culture has only been revived in the last 10–15 years, many of the issues addressed here still require more in-depth analysis. Most important is the full publication of recent and ongoing excavations of both Greek *balaneia* in the different regions of the Mediterranean and early Roman baths in the western Mediterranean. This will provide crucial new insights into important aspects such as the often neglected and little known history of baths (date of construction, remodeling phases, and abandonment); heating and vaulting technologies; water management, particularly water supply, which is so far poorly understood, especially with regard to quantity and consistency or seasonal variances as well as distribution within the baths; circulation patterns and user differentiation; and the urban context of baths that is often insufficiently known.

Based on such comprehensive fundamental research, broader synthetic questions could be reassessed, most notably the possible sociohistorical reasons for obvious regional differences in bathing culture, including the complex interrelation and transition between Greek and Roman bathing customs.



Baths and Bathing, Greek, Fig. 8 Eretria, Gymnasion: phase plan; phase 1 end of fourth century BCE, phase 2 second half of second century BCE; Mango 2003: 56, Fig. 58

While the bathing images on vases have been much studied in recent years (Kreilinger 2007; Stähli 2013), a comprehensive assessment of all written sources related to bathing in the Greek world is still missing.

A reassessment of all different sources – images, texts, and archaeological remains – could finally result in a more differentiated comparative evaluation of the discourses on Greek bathing culture in the various media. Greek bathing culture could then finally receive the attention it deserves, both in interdisciplinary studies of the ancient Mediterranean world and in cross-cultural studies on bathing and related topics.

Cross-References

- ▶ Baths and Bathing, Roman
- ▶ Hellenistic and Roman Anatolia, Archaeology of
- ▶ Hellenistic and Roman Egypt, Archaeology of
- ▶ Sicily and Magna Graecia, Archaeology of

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Further Reading

This topic is currently not conveniently and easily accessible in recent English handbooks or textbooks. The standard handbook is still Ginouvès 1962 (in French), which is excellent, but partially outdated for the assessment of bathing images and the archaeological evidence of baths.

An overview of recent and current research is available in the proceedings of the recent conference on *Greek*

Baths and Bathing Culture. New Discoveries and Approaches (Lucore & Trümper 2013). The 14 English contributions include summaries of recent and ongoing fieldwork (Caulonia, Fregellae, Locri Epizefiri, Monte Iato, Morgantina, and Velia in Italy; Hephaistia/Lemnos and Thessaloniki in Greece; Euhemeria/Qasr el-Banat, Taposiris Magna/Abusir, and Theadelphia/Kharabet Ihrit in Egypt) as well as synthetic assessments of topics such as bathing images; bathing in Greek medicine; heating systems; vaulting systems, also in relation to contemporary science (Archimedes); urban context of Greek public baths; and the relationship between Greek and Roman baths. The second part of this book consists of a catalog of all currently known Greek *balaneia* (for each bath: short catalog text, bibliography, standardized plan).

Baths and Bathing, Roman

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Introduction

Public baths were arguably the primary social institution of the Roman world. A trip to the local public bath was both a practical and pleasurable ritual, fundamental to the routine of daily life – we have evidence of everyone from slaves to the emperor himself frequenting the public baths on occasion. Many baths also catered for experiences well beyond that of simply getting clean; bathers could spend several hours in the baths, socializing or attending to a multitude of other needs and desires.

The baths were at the forefront of Roman architectural, engineering, and design development. The forms expressed in the bath buildings, along with their materials and technologies, were among the most innovative, ambitious, and impressive of their day and have remained influential through to modern times. Public baths were a ubiquitous feature of most cities and towns, irrespective of size, as well as in many sanctuaries and military camps; they became a defining feature of Roman civilization throughout the Empire and beyond.

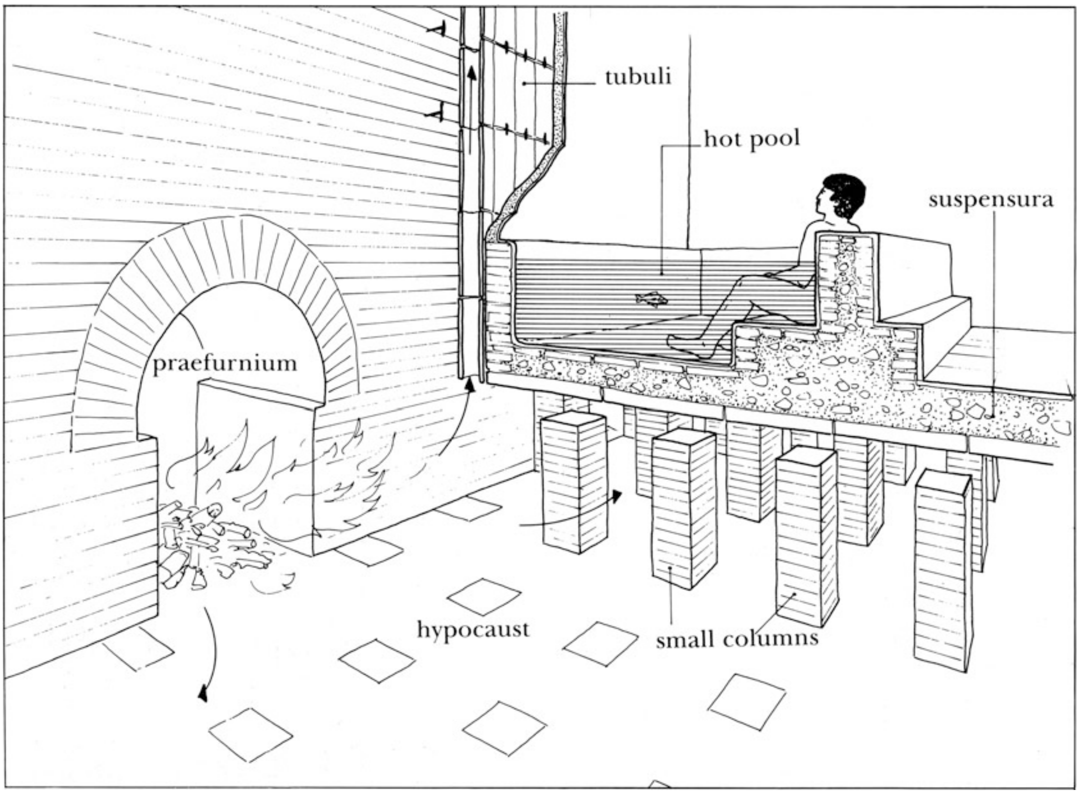
Sources and Reception

It is obvious from the sheer number of baths alone (see Types of Bathing Facilities) that the act of public bathing was extremely popular, and their centrality to daily life is confirmed by the fact that references to bathing are to be found everywhere, including in official inscriptions, on informal graffiti, in school books, on tombstones, and of course in the literary sources, where they are frequently mentioned by poets (most notably Martial), historians, philosophers, and the like.

The sources make frequent references to positive aspects of the baths, including their grandeur, beauty, atmosphere, and social and medical benefits. However, as to be expected with any popular institution, they were not universally praised and we do hear the occasional dissenting voice. Gripes with the baths ranged from annoyance at the drunken, lecherous, licentious, sycophantic, or arrogant behavior of some regular visitors, to instances of theft (a common issue at the baths, subject to strict laws, and, if the laws did not work, curse tablets [Fagan 1999: 36-38]), to the water being too dirty, cold, or hot (Nielsen 1990: 18; Fagan 1999: 181-186). There were also moral objections to the popularity of the baths, with several commentators raising concerns about the negative effects on society of the perceived indulgences and luxuries offered at the baths (Seneca Letters 86 is one such lament). These objections, though eloquent, would appear to be the viewpoint of a conservative minority, and even their objections were not serious enough, in most cases, to stop the critics themselves from frequenting the baths, further highlighting their importance as a social and cultural hub.

Definition

The Roman public bathhouse in its many contexts may be distinguished from earlier forms of



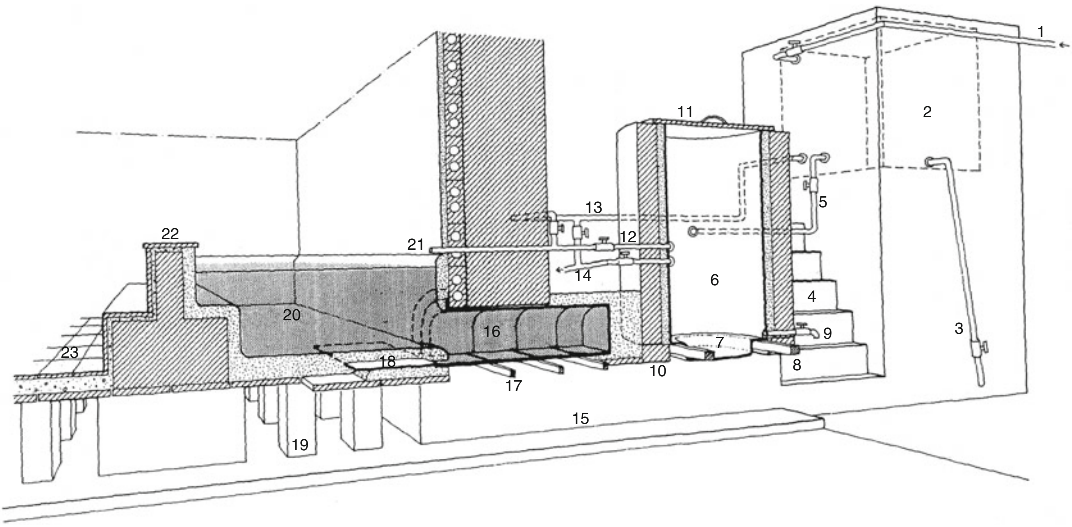
Baths and Bathing, Roman, Fig. 1 The heating system of a Roman bath (modelled on the *caldarium* of the Central Baths in Pompeii). Image: Jean-Pierre Adam (Adam 2011), with permission

public bathing (see the entry on ▶ Baths and Bathing, Greek, in this encyclopedia) and defined by the existence of three primary characteristics: (1) a complex heating system based around the hypocaust, (2) bathing rooms of differing temperatures, and (3) the presence of communal pools. While some of these elements could be present in the earlier "Greek-style" baths (with which the Roman baths had many aspects in common – see Historical Background), it is the combination of these elements that epitomizes the Roman style of public bathing regardless of context.

Heating

A Roman bath was heated by the hypocaust; an underfloor system of heating that was fully developed by the early second century BCE. Prior to this time, heating of rooms and water tended to be carried out with the use of braziers or on occasion by simpler forms of underfloor heating (see Historical Background and the entry on ▶ Baths and Bathing, Greek, in this encyclopedia). The hypocaust functioned by allowing hot air and gasses to flow through a space created beneath the floor of a room (Fig. 1). The most common way to create this space was to raise the floor via the use of multiple square or circular brick columns (*pilae*), typically standing between c. 0.70–1.40 m in height, and placed roughly 0.80 m apart from center to center. Resting on the *pilae* was the floor matrix, usually consisting of large square tiles (*bipedales*), upon which was laid a 0.30–0.40-m-thick brick and mortar packing into which the desired surface material was laid.

The heat was generated by a simple, slow-burning furnace (*praefurnium*), consisting of



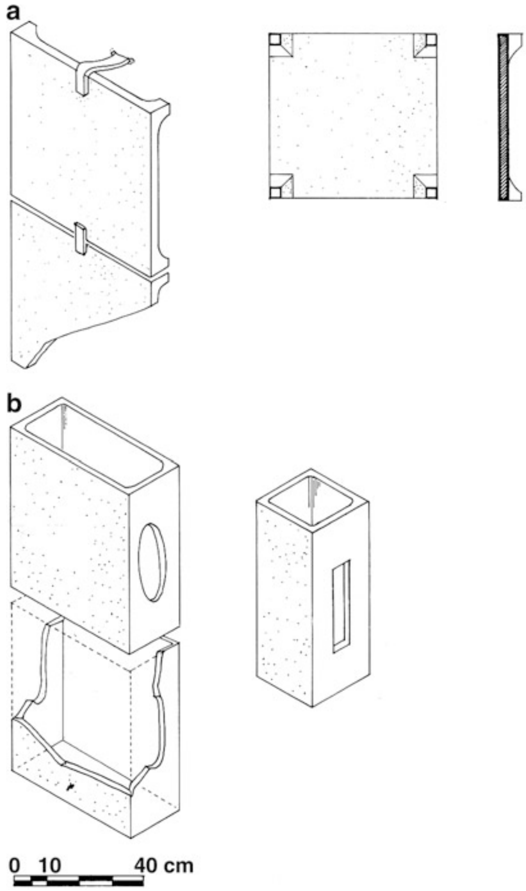
Baths and Bathing, Roman, Fig. 2 Reconstruction of the heating and water systems of a *caldarium*, including boiler and *testudo*. © Koninklijke Brill NV (after Manderscheid 2000: 496)

a fire placed in one or more openings in the external wall below the floor of the heated room (Fig. 1). Two spur walls (not pictured) were often built either side of this opening (and either side of the wall) to help draw the hot air and gasses through the system. The hot air and gasses eventually rose up through flues set into the wall and exited the system via vents set just below the eaves of the building (see also "tubulation" below). As to be expected, there were many design variations with the hypocaust system, not least with the *pilae*. One such variation – and a notable example of ancient recycling – is still to be seen in Athens, with the reuse of 17 Hellenistic period columnar grave monuments as *pilae*.

Service areas were invariably situated outside these heated rooms. Depending on the size or build of the bath, these areas could vary from simple semi-open spaces (usually with some form of screening to hide the work areas from the public) through to a complex network of underground passages (such as those at the Baths of Caracalla in Rome). It was from these services areas that the water supply for the baths was also controlled. The water to be used in the heated pools was piped into large metal boilers that were often sensibly positioned above the furnace (Fig. 2). Once heated by the boiler, the water could be mixed with cold water (as required) by the service attendants as it was being piped into the pools: a particularly well-preserved example of a water-supply system was found in a villa at Boscoreale, a settlement buried in 79 CE by the same eruption of Mt. Vesuvius that destroyed Pompeii and Herculaneum. Some baths also incorporated a semicylindrical metal container known as the *testudo* into their water-heating systems (Fig. 2). The closed end of this device was placed above the furnace in direct contact with the fire, while the open end was incorporated into the sidewall of the pool. This configuration allowed the pool water to circulate directly above the furnace, thereby maintaining a much warmer water temperature for the bathers.

From the first century BCE onwards, it became common to create hollow passages in the walls of the heated rooms (beyond the basic, but necessary flue system), in a technique known as tubulation. This provided several structural and functional benefits: it allowed for the improved circulation and extraction of hot air and gasses; it provided the walls with dry lining, thereby alleviating dampness in such a hot and humid environment; and it led to a more efficient use of fuel through the effects of radiant heat contributing to a higher room temperature while simultaneously allowing for a more uniform and safer temperature for the floors and the walls – an important concern for the patrons (Nielsen 1990: 17-8; Yegül & Couch 2003: 175; Schiebold 2006; Yegül 2010: 88-9). The radiant heat generated by tubulation also allowed for larger heated rooms to be built and for these rooms to be well lit, because large windows could now be placed in the walls of heated rooms without the loss of too much temperature. The interplay between the sun and the variously decorated surfaces of the baths, coupled with the potential for pleasant views, added to the spectacle of a visit to the baths. As Seneca colorfully informs us (*Letters* 86.8), well-lit baths were popular among patrons.

Tubulation appeared in several forms and subtypes, varying over time and region, but two forms, *tegulae mammatae* and *tubuli*, were by far the most commonly utilized throughout the Empire (Fig. 3). *Tegulae mammatae*, literally "tiles with nipples," consisted of specially constructed flat tiles with projecting studs on each corner that were attached to the wall with metal clamps. *Tubuli* were custom-made hollow box-shaped tiles, open at both ends and often on the sides. These could be stacked on top of, and next to, each other to create an interconnecting network. *Tubuli* are considered to have been the most effective method for heating, as the air and gasses circulated through *tubuli* with less turbulence than with other solutions (Adam 1994: 269). They also had the added benefit of not necessarily requiring the use of costly, and ultimately ephemeral, metal clamps to attach them to the wall, thus saving on both materials and effort while also extending the life of the building. The use of *tubuli* essentially superseded *tegulae mammatae* in many parts of the Empire from the end of the first century CE onwards. However, the continued use of *tegulae mammatae* would seem to be a trend throughout Greece and in parts of the Western Empire (Nielsen 1990: 15, 1999: 36; McCallum 2010). There are also many examples of more than one type being utilized within the same building, as was the case in the Great Bath at Corinth where three different systems have been observed



Baths and Bathing, Roman, Fig. 3 Detail of a diagram showing **a**) tegulae mammatae **b**) tubuli. © Fikret Yegül (after Yegül 2010: 88, fig. 38)

(Biers 2003: 310). Tubulation was also utilized in some bath ceilings, providing further insulation and structural benefits, including in the thermal baths at *Aquae Sulis* (Bath, England).

When taking into account that the floor, walls, ceilings, pools, and water boilers were all heated by the same furnace, in effect every element of a room could be heated from a single source of fire under the floor – an ingenious and very efficient system.

Variated Temperatures

Not only did the Romans heat certain rooms of the baths, but they also manipulated the temperatures of these rooms and their waters to provide a variated experience for the bather as they moved from room to room. Consequently, the three fundamental room types experienced when taking a Roman bath were the cold bathing room (*frigidarium*), the warm room (*tepidarium*), and the hot bathing room (*caldarium*). Many baths also included a dedicated sweat room, referred to variously as a *sudatorium* or *laconicum*. Depending on the establishment this could be based around a wet heat or a dry heat.

Communal Pools

The physical process of bathing in a Roman bathhouse took place primarily in communal, fully immersible pools, often large enough for several people to bath simultaneously. Typically two or more pools were present in both the *frigidarium* and the *caldarium*; the *tepidarium* often functioned as a heat lock between the cold and hot rooms, although pools are present on occasion. In addition to communal pools, many baths (especially down to the first century CE) also featured a pedestalled washbasin (*labrum* –). This piece of bathing furniture had a long history in public bathing, from at least the Greek Archaic period onwards. Also extremely popular in Roman baths (and some earlier Greek gymnasia) were large swimming pools (*natatio*); these could be indoor or outdoor, heated or unheated, depending on the climate and the establishment.

Auxiliary Rooms

Aside from the rooms devoted to the actual act of bathing, public baths, regardless of size, also regularly included a dedicated changing room (*apodyterium*) with niches for the bather's clothes and personal effects as well as oiling rooms, latrines, and, depending on time and place, a courtyard and/or a large all-purpose indoor room for light exercise or socializing. Some baths even featured facilities for massage and sunbathing, as well as shops, mills, offices, large garden areas, running tracks, fountains, and cult spaces (typically of the Imperial family or Mithraea), with the largest baths even including further educational and entertainment zones such as libraries, lecture halls, class rooms, and eclectic art galleries (for a discussion of the individual elements of the baths, see Nielsen 1990: Appendix). The patronage and display of sculptural art in the bathhouses presented the Imperial family, local administrators, athletic clubs, and other personages and institutions of note a wonderful opportunity to honor gods and mortals while increasing their own status and reputation. Public baths regularly provide us with impressive examples of Roman art, along with copies of Greek sculpture and even pilfered Greek originals.

The written sources inform us that the rooms of the baths were also home to more ephemeral services and entertainments (professional and otherwise): food and drink sellers, depilators, poets, jugglers, musicians, dancers, mimes, and even male and female prostitutes are all known to have added to the bathing experience. One of the liveliest descriptions of the atmosphere in a small bath is from Seneca, who in the mid-first century CE complains of the noise made by people enjoying themselves or making a living at the baths (*Letters* 56.1-2). With so much available space and so many facilities on hand, some of the largest baths even became regular places of assembly for events and political gatherings, thereby taking on some of the roles traditionally reserved for the forum.

Bathing Pattern

There appears to have been no universal set pattern to how one would experience the baths; they vary tremendously in layout and features (as to be expected over such an immense chronological and geographical expanse), suggesting that, in essence, the baths could be approached how the individual bathers themselves desired. Furthermore, very few surviving sources describe in any great depth and clarity what was to them an everyday process. Undoubtedly, force of habit and the inherent restrictions imposed by the layout of the individual bathhouse would have played a role, as would have contemporary medical advice. One way to approach the bathing process would be to pay the fee (if there happened to be one at that particular establishment), get changed in the *apodyterium*, oil up, then work up a sweat (via light exercise or a dedicated sweating room), before finally entering the bathing rooms proper (perhaps most often in the basic order of *tepidarium*, *caldarium*, *frigidarium*), where first the oil, sweat, and potential dirt could be scraped off with a *strigil* (– soap was not widely used in the Roman Empire) and then one could enjoy a dip in the various plunge pools or even a swimming pool. A hefty dose of socializing and the enjoyment of any of the other delights on offer would supplement this process. Eventually the bather would return to the *apodyterium* to get changed and exit the establishment.

Types of Bathing Facilities

The widespread popularity and long history of the baths meant that many types of bathing establishment existed throughout the Empire. The two most basic types were freestanding baths and bathing facilities attached to larger complexes. There was of course a lot of variation within these two basic types.

Freestanding Bathhouses

The most common type of public bathing establishment throughout the Empire was the freestanding bathhouse, dedicated primarily to the act of bathing and socializing for groups of people. They varied greatly in size and accessibility (see Key Issues). The ubiquitous, smaller freestanding establishments are commonly referred to as *balnea*, while the larger and more imposing baths tend to be referred to as *thermae*. The interchangeability of these terms, and indeed many of the terms related to the baths in ancient times, still causes problems today (see Nielsen 1990: 3, Appendix; DeLaine 1993: 352-4; Fagan 1999: 14-9 with further references).

Balnea were often privately owned and varied greatly in layout and size, with some very innovative and unique design variations – in part caused by the necessity of fitting into preexisting town plans and the lay of a particular plot of land. Thermae tended to be state- or city-run enterprises; they were often more symmetrical in design and layout but were nevertheless among the most innovatively designed and decorated buildings to be found in a city of the Empire. In Rome alone, during the fourth century CE, census documents record that an incredible 856 small baths and some 10 or 11 massive thermae were in use (the exact number varies for both categories – *Notitia Urbis Regionum* and *Curiosum Urbis Romae* Regionum; Fagan 1999: 41-2; Yegül 2010: 2-3). Agrippa constructed the first thermae in the city of Rome during the last quarter of the first century BCE, and then we know of increasingly more elaborate and monumental thermae constructed by leading citizens and emperors, including (but not limited to) Nero, Titus, Domitian, Trajan, Commodus, Septimius Severus, Caracalla, Decius, Diocletian (the largest of the Roman Imperial thermae), Maxentius, and Constantine. Many other major cities also featured at least one thermae, including, but by no means limited to, Constantinople, with at least 8 thermae and 153 small baths (*Notitia Urbis Constantinopolitanae*; Yegül 2010: 3, 183), Carthage, Ephesus, Antioch, Lepcis Magna, Paris, Trier and Athens, with at least 2 thermae and over 50 small baths of various types (McCallum 2010). Even Ostia, the port of Rome, has seen several thermae and over 20 smaller baths uncovered during excavations (Yegül 2010: 69).

Bathhouses Attached to Larger Complexes

Bathing facilities were also regularly constructed as an element of much larger complexes, including gymnasia, military forts, sanctuaries, thermomineral resorts, domestic dwellings, and even churches.

Gymnasia

In those parts of the Empire where the gymnasium was an important cultural institution, notably in Greece and the Hellenized East, the tradition continued of incorporating bathing facilities to assist with cleaning after exercise (a practical tradition considering their exercise regime combined dirt, sweat, and oil), the difference being that during the first centuries of the Empire, most were outfitted with the latest in Roman heating technologies (see the entry ▶ Baths and Bathing, Greek, in this encyclopedia).

Conversely, many standard freestanding Roman baths incorporated some elements of the gymnasium into their design, most notably with the appearance of a small courtyard for light exercise, but it is with the great bath-gymnasium complexes of Asia Minor that we see the truest fusion of the features and activities of the Roman bath and the Greek gymnasium. Some of the most notable examples of this phenomenon are preserved at Ephesus (Harbour Bath-Gymnasium, Vedius Bath-Gymnasium, East Bath-Gymnasium, Theatre Baths), Sardis (Imperial Bath-Gymnasium – Fig. 4), Perge (South Gate Baths), and Miletus (Bath-Gymnasium of Faustina).

Military Baths

Wherever Romans went, so went the baths. As a result, baths were a regular feature of military forts (*castrum*/*castra*) around the outskirts of the Empire. These baths can be divided into two categories: large legionary thermae, typically located inside the fortress, and smaller *castellum* baths, which lay outside of the fort (Nielsen 1990: 77). The baths were designed by the military architects that accompanied the army, and it was these same architects who were often responsible for designing and constructing the baths in the newly conquered, assimilated, or created settlements at the frontiers of the Empire. As a result, we see in places like Roman Britain that the settlement baths regularly share design similarities with the baths from nearby military forts.

The Roman military can thus be seen as an important contributor to the spread of baths throughout the provinces of the Empire, with the baths themselves playing a significant role in the complex process of sociopolitical and cultural interaction and domination known as Romanization.

Sanctuary and Thermo-Mineral Baths

Any place where large crowds of people would be gathering or staying for an extended period benefitted from having public baths, and this was certainly the situation at sanctuaries where devotees congregated for days or even weeks at a time, be it for festivals (athletic or otherwise) or for healing. Baths were an integral part of many healing sanctuaries, as the medical writers of the time regularly recommended water-based cures for the treatment of various ailments. No more is this relationship more apparent than with the huge thermo-mineral bath centers in places such as Baiae in the Bay of Naples (Italy) and Allianoi in modern Turkey (located some 20 km northwest of ancient Pergamon). Thermo-mineral resorts such as these were extremely popular healing and holiday destinations, with the town of Baiae in particular gaining a reputation as a debauched playground of the well-to-do. Baiae was a very long-lived resort, in use from at least the early Roman Republican period through to the seventeenth century CE. Allianoi made the news again recently, threatened ironically by the very thing that gave it life – water – with the construction of the Yortanli dam condemning this ancient health retreat to be lost once more to history in late 2010/early 2011.

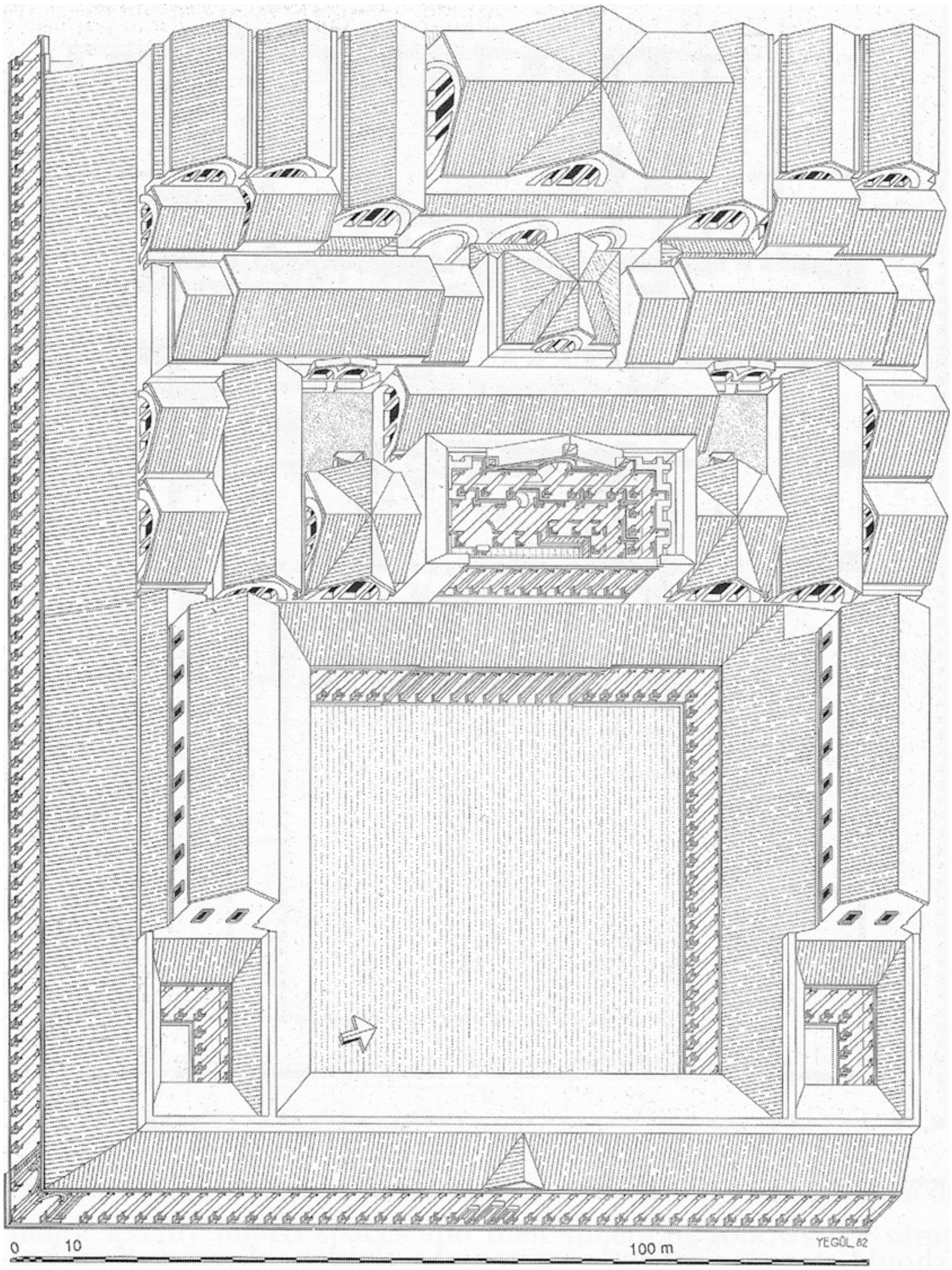
Houses, Villas, and Palaces

Bathing facilities were a common, but by no means universal, feature of domestic properties throughout the Empire. These ranged in size from small bathrooms with a simple tub through to luxurious miniature versions of public bathing establishments for use by several individuals simultaneously, be they family, friends, or business associates. Some of the best-preserved early examples are, not surprisingly, from the towns of Pompeii and Herculaneum; however, from the later Roman period, several huge and centrally located residences have been found in cities throughout the Empire, including Constantinople and Athens (Fig. 5). These buildings are sometimes referred to as palaces, with bathing facilities on par with their more public brethren.

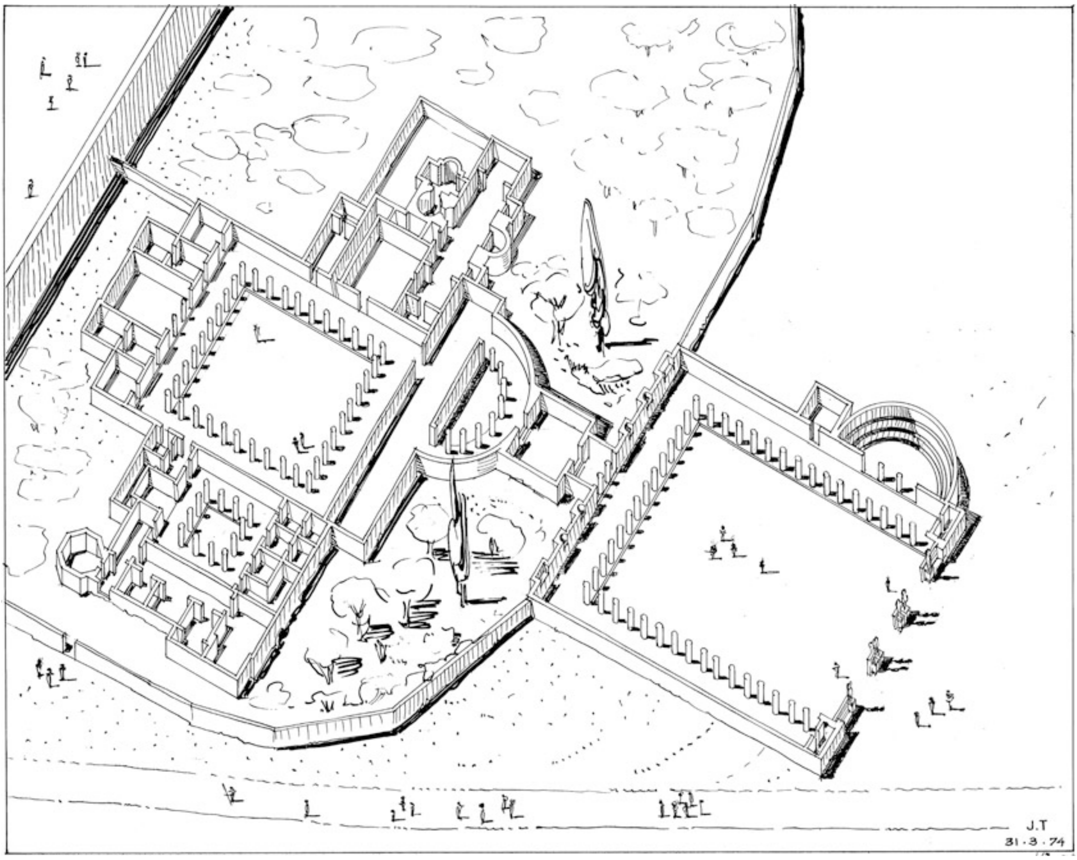
It is important to stress that not every property had elaborate bathing facilities; this is especially true of the multistory apartment complexes (*insulae*) where the greater urban population lived in Rome and other large cities. For these people the public baths were a vital utility.

Church/Baptistery Baths

The adoption of Christianity as the official religion of the Empire over the course of the fourth century CE did not halt the construction and use



Baths and Bathing, Roman, Fig. 4 Axonometric restoration of the Imperial Bath-Gymnasium complex at Sardis. © Fikret Yegül (after Yegül 2010: 164, fig. 74)



Baths and Bathing, Roman, Fig. 5 Cut-away perspective of the Palace of the Giants by J. Travlos. © American School of Classical Studies at Athens: Agora Excavations

of public baths. Indeed, it was not uncommon to build baths in connection with churches and monasteries or to utilize preexisting bathing establishments as baptisteries (see Historical Background).

Historical Background

Origins of the Roman Bath

The origins of Roman public bathing may be sought from several sources, although the degree of influence imparted by each source is debated and routinely subject to reassessment when new evidence is uncovered or published. A major influence is undoubtedly to be found in the long-standing public bathing and gymnastic habits of the classical and Hellenistic Greek world, especially from the Greek colonies in South Italy and Sicily (see the entry on ▶ Baths and Bathing, Greek, in this encyclopedia). There is also evidence to suggest that local bathing traditions of rural central Italy may have played their part in the development of Roman-style bathing and architecture, most notably through the use of bathing rooms with graduated temperatures in their farm houses (Varro *Ling*. 9.68; Fagan 2001: 417; Yegül 2010: 45-7). The influence of Etruscan and Punic public bathing habits on Roman bathing habits is currently less well understood.

The development of the hypocaust is a popular topic of debate. Based on the writings of Pliny the Elder (*Natural History* 9.168) and Valerius Maximus (11.1.1), the tradition has been to link the development of the hypocaust to the

Campanian oyster farmer and merchant Sergius Orata (flourished c. 90 BCE–80 BCE), but the archaeological evidence (and critical literary analysis) shows that this is incorrect. Examples of fully fledged hypocausts are known already from Central Italy at Fregellae (Latium) in the early second century BCE, from the late second century BCE in Pompeii (Stabian Baths), and from the second and first centuries BCE in Greece (Gortys, Olympia, and Athens) and Sicily (Megara Hyblaea) (DeLaine 1989; McCallum 2010; see the entry on ► Baths and Bathing, Greek in this encyclopedia), while more simple predecessors are known already in the Eastern Mediterranean from the sixth century BCE onwards (DeLaine 1989; Fagan 2001; Yegül 2010, 81-2, 84-6; see the entry on ► Baths and Bathing, Greek, in this encyclopedia). Wall heating (tubulation) on the other hand is considered to be of completely Roman/Italian origin (Yegül 2010: 86; although note the recent evidence from Taposiris Magna in Egypt and the hollow walls at Gortys mentioned in DeLaine 1989: 112).

The thermo-mineral resorts at Baiae and Himera in Sicily were in use from at least the early stages of the Republican period. It is therefore possible that aspects of the later public baths, such as the large communal pools, advanced heating systems, and not least the acceptance of public bathing as an enjoyable and socially acceptable event in Rome, may have some roots here (DeLaine 1989: 123; Fagan 2001; Yegül 2010: 49-50).

Whatever the exact origins of the Roman style of bathing, it is clear from the archaeology and their appearance in the literary sources that they were certainly a feature of Republican Roman life from at least the third century BCE onwards and that making a visit to a public bath became a commonplace daily event over the course of the second to first centuries BCE. As mentioned previously, the Roman bathing habit spread with the Empire. Those provinces with pre-existing public bathing cultures incorporated Roman bathing norms to differing degrees (notably in the Hellenized East and Egypt), but the adoption of Roman technologies and habits is seen everywhere to some extent.

Christianity

Over time, as to be expected, there are some changes to the public bathing habit, but the core experience remained fairly stable for an extraordinarily extended period. Even after Christianity was adopted as the official religion of the Empire during the fourth century CE we do not see an instant effect on the popularity of the baths, and there was certainly no universal ban on public bathing or even seriously sustained official opposition from the Church. Indeed, in some instances, the Church owned and operated public baths as a profitable business, and other times we see baths used for ablutions on religious holidays or attached to churches and monasteries for use as charity baths or for baptisms (Nielsen 1990: 147-8; Yegül 2010: 185, 202-3). Even bishops and monks were known to bathe in the baths and sometimes even with women (Nielsen 1990: 147).

There was some Christian opposition to the excessive wealth displayed at the baths and the phenomenon of mixed bathing (Nielsen 1990: 148 and see below) as well as to some of the more pleasurable and extracurricular aspects of a visit to the bath. We see this expressed clearly in the late sixth century CE by Pope Gregory the Great (540-604): “[Baths are] for the needs of the body. . .not for the titillation of the mind and sensuous pleasure” (Gregorius I Papa *Registrum Epistolarum* I, xiii, 3; Yegül 2010: 204). Additionally, some devotees did pursue the concept of *alousia* (abstinence from washing), but it was nothing like the phenomenon seen in Europe for some two centuries from the mid-sixteenth century CE. More serious was Christian opposition to exercise and nudity and indeed the whole cultural and educational institution of the gymnasium; this did lead to the dwindling of the gymnasium/exercise segment of the baths. The effects of this opposition were especially clear in the East, where the bath-gymnasium complexes had previously been so popular (Yegül 2010: 182, Chapter 11).

The Decline of the Roman Bathing Habit

While the Roman public bathing habit in some sense never ceased completely (it still lives on in altered form in the Turkish bathing habit), by the seventh century CE, and earlier in many places, it had undoubtedly ceased to be the widespread and integral social institution it once was. So what caused this to happen?

The downfall of many of the bathing establishments, especially the larger ones, can be linked to the civic and economic disorder and profound societal changes brought about by various "barbarian" incursions in Rome and throughout the Empire during the so-called Migration Period in the fifth through eighth centuries CE; the fate of the large baths was inextricably linked to the fate of the wider city. In a time of regular infrastructure damage, severe hardship, and depopulation, cities were simply unable to repair and maintain multiple city baths – they were too expensive to keep running, and, critically, they required a functional and plentiful water supply. The aqueducts, which could run for dozens of kilometers outside of the city, were especially prone to sullying or destruction by besieging armies, and priority was needed to be given to drinking water over the baths.

Baths continued to be built and maintained much later in the East than West, perhaps due to a more stable environment during these centuries of upheaval and change, but even these baths were in serious decline by the ninth century CE (Yegül 2010: 200). Undoubtedly, some of the thousands of smaller bathing establishments, with their much more modest water-supply needs, continued operating in some form or another, especially in the early Islamic East, where public bathing has continued through to the modern hammam still used in places like Turkey, Syria, Iran, and Tunisia today. We also know that many thermo-mineral health resorts remained in use over the next 1,000 years, most notably Baiae, which, as mentioned previously, continued in use until the seventeenth century. Despite the existence of these remnants of Roman bathing, it is clear that by the seventh century CE, the public baths had ceased to be a cornerstone of daily life.

Key Issues/Current Debates

While the Roman baths have received scholarly treatment at various times previously, interest in baths and the act of bathing in the Roman world has increased dramatically in the past 30 years, most notably through the 1980s and 1990s when there was a surge of literature and new approaches to balneological studies (including, but certainly not limited to, general works by Brödner 1983; Heinz 1983; Pasquinucci 1987; Nielsen 1990; Yegül 1992, 2010; Fagan 1999, 2001; DeLaine and Johnston [ed.] 1999; also several important articles by DeLaine that critically assess the state of the discipline, DeLaine 1988, 1992, 1993, 1999; and the comprehensive bibliographies compiled by Manderscheid in 1988 and 2004). This expanding scholarly corpus has incorporated the archaeological, literary, and epigraphic evidence over a vast chronological and geographical scale to provide us with a reasonably solid understanding of many aspects of the practical, physical, social, technological, and cultural aspects of bathing during the Roman period. Several of the current, and in some cases seemingly eternal, debates and key issues have been touched upon already (origins of the Roman style, developments over time, how they were perceived, their role as agents of Romanization, and the reasons behind the eventual decline of the Roman-style bathing habit); now three more are briefly addressed: "Who was bathing?" "How widespread was mixed bathing?" and "Why were the baths so popular?"

Who Was Bathing?

The question of who was bathing in the public baths is complicated in the sense that we are dealing with such disparate evidence over a huge expanse of geography and time. Further exacerbating this state of affairs is that the situation would have varied from bath to bath. Individual bathing establishments varied not only in size but also in degree of accessibility and exclusivity. While the largest baths catered for most, if not all, elements of the population with their immense size and cheap or free bathing (male/female, adult/child, rich/poor, and apparently even slave), the vast majority of baths were smaller facilities, inevitably catering to a more limited clientele based purely on their size alone. It is then perhaps best to envisage, and the sources suggests as much, that most public bathing establishments were similar to the night-clubs, cafes, or pubs of many modern cities. A particular bath attracted a certain clientele based on their facilities, decor, location, cleanliness, entry charge, and reputation (which could change very quickly). The choice of bath was apparently important enough among high society that one could enquire of a stranger which baths they used (Ammianus Marcellinus 28.4.10; Fagan 1999: 20). Furthermore, some bathing facilities explicitly served a specific gender, class, guild, or religious group, and of course those baths operating inside sanctuaries and military camps, or attached to buildings such as gymnasia and the like, would have all been accessed by, and potentially restricted to, certain groups. By gaining an understanding of the various locational contexts of bathhouses, we open a window into the principles of social ordering of the people who utilized these facilities.

How Widespread Was Mixed Bathing?

That both men and women around the Empire utilized the public baths is beyond all doubt, but the extent to which men and women bathed together has been a regular source of debate and disagreement. There can be no doubt that mixed bathing did occur throughout the long history of Roman baths (indeed several emperors and even the Church attempted, unsuccessfully, to legislate against it, with the last decree coming as late as the eighth century CE), but the degree to which it was the norm or how much it varied from place to place over time and facility is uncertain. The available evidence reveals several solutions when it comes to men and women using the baths:

1. Separate establishments for men and women (a phenomenon more common in the earliest and latest Roman baths).
2. A single establishment with separate entrances and duplicated facilities (not necessarily of identical size or quality). Not all facilities were duplicated in some baths, suggesting some shared areas in those instances.
3. A single establishment with different bathing times for men and women. This solution is still seen today in some hammams (Turkish baths).
4. Freely mixed bathing (a regular theme in Martial and Imperial decrees).

Why So Popular?

The vast popularity of the public baths can be explained citing both practical and sociocultural reasons. The core function of public baths was obviously to get clean, and this was an important community service in a time when bathing facilities in many homes were simple or nonexistent. Bathing in water is in itself a physiologically relaxing and pleasurable experience. This experience, coupled with the communal aspects of the baths (socializing, networking, seeing, and being seen), ensured that bathing was a relaxed, potentially intimate, and important social event. Over time, these characteristics led to bathing becoming a daily habit ingrained in the social flow of Roman society, which in turn caused the facilities, both bathing and secondary, to be expanded and improved. As the secondary facilities and services expanded, people would have even more reason to spend more time in the pleasant environment of the baths (they could eat, drink, exercise, primp, study, and socialize all in the one building). The extreme popularity of the baths led emperors, local officials, and other rich benefactors to construct and maintain ever larger and awe-inspiring edifices, for both the public benefit and to increase their reputation among the populous. By offering heavily subsidized or even free entry, they could further enhance the positive effect for both themselves and the baths. This cycle fed on itself for centuries, and the public baths became arguably the dominant social and cultural institution in the Roman world, to the extent that by the late Roman period, the largest baths in some towns had overtaken several of the social and political functions of the forum.

Future Directions

With the relatively recent surge in bath-related scholarship, our knowledge of Roman baths and bathing has increased markedly. However, there is still plenty of important work to do, especially at the individual, local, and regional levels. Thanks to the central and long-lived role baths played in Roman society (both in the heartland and the provinces), their ubiquitousness within most settlements, and the sturdy nature of their construction, new evidence for baths is regularly being uncovered. Improved excavation and data collection techniques ensure that the baths being excavated today can provide us with much more information than was previously possible. This, coupled with an abundance of previously exposed material that has either never been published or only summarily published, means there is fundamental work to do at the level of individual bathing establishments.

Similarly, while many have examined baths at local and regional levels in the past, there is a great disparity in the quantity and quality of work that has been done. By gaining deeper understandings at the local and regional levels (where there is quite a lot of variation), we will be in a much stronger position to discuss how the baths and Roman bathing culture were integrated and utilized in the disparate corners of the Empire.

At the general level, fundamental questions concerning origins, development, transformation, and decline are still open for further discussion, and there remains more to learn about the functioning of baths in their various contexts, their decoration, secondary facilities, and post-Roman existence, particularly in the West.

In a topic so universal and fundamental to the Roman experience as the baths, the potential and importance of continued study is clear. Future directions for balneological studies are almost as numerous as the baths themselves. Evidence, both old and new and archaeological and literary, needs to be (re)appraised using current analytical methods and theoretical frameworks. Coupled with the magnificent opportunities provided by advances in digital technology and cloud computing, there is tremendous potential for different questions to be asked and new perspectives to be gained in the world of Roman bathing.

One such digital project, to be undertaken by the author, is an online catalog of Greek and Roman baths. Previously, two major general catalogs of Roman baths have been compiled featuring baths from throughout the Empire: Manderscheid (1988/2004), which is in essence a collection of bibliographic references but also works as a catalog, and Nielsen (1990), who cataloged 387 baths. Due to their wide-ranging nature, self-imposed limits, and increasing age, these lists are invariably incomplete, but they nevertheless provide an excellent starting point for future research. Building on these solid foundations, the author is in the very early stages of developing and implementing a multirelational online database to allow information on baths, Roman and otherwise, from all over the Mediterranean and beyond to be cataloged and available in a freely accessible and easily updatable website. The author will add more information about this online database as work progresses.

Cross-References

▶ Architecture, Roman
▶ Baths and Bathing, Greek
▶ Urban Planning, Roman

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Battlefield Archaeology

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Introduction

A dedicated archaeological approach to the study of historic battlefields is a recent development, beginning with work at the Little Bighorn, USA battlefield in the 1980s where the methodology of using metal detectors to locate spent bullets was first applied. Since then, it has spread to the UK and mainland Europe, with some work in other parts of the globe. While the battlefield archaeology community is still relatively small, interest in the field has grown so it now can boast regular conference series and a dedicated journal, as well as more than one course of formal study.

Definition

Battlefield archaeology is a term used in two ways. In one – very specific – sense (and the one used in this entry), it is the application of particular techniques to study the material residues of past battles. As used in this sense, it focuses upon sites where armies came together to engage in a formalized style of fighting which was heavily rule bound and sanctioned. Battlefield archaeology generally therefore excludes sites of conflict between less organized bodies of armed people such as uprisings and revolts,

Battlefield Archaeology, Fig. 1 Metal detector survey at the Oudenaarde battlefield, Belgium, September 2011

sieges, and smaller and more fluid military actions such as skirmishes.

In a second, looser, sense it covers the archaeological study of all aspects of conflict from the most ancient to the most recent, regardless of period or style, and not limited to sites of violence but extending to military encampments and bases, issues of logistics, prisoner-of-war camps, and the location and reburial of the dead from past wars. The currently preferred term for this wider concern is "conflict archaeology," with "battlefield archaeology" reserved for its more specific sense (Fig. 1).

The archaeology of historic battlefields requires, as well as the usual skills of the archaeologist, a specific set of techniques and technology. While some battlefields will contain built features – trenches, walls, palisades, and other earthworks, buildings, and mass graves – to be surveyed, excavated, and interpreted in accordance with standard archaeological practice, others do not. For these, the primary evidence will come from scatters of material left in the topsoil or plowsoil and detectable by metal detector. The evidence that is available will depend upon the period of the fight, the weapons used, the type of action – whether mainly infantry or mainly cavalry – and postdeposition factors that will determine survivability. As well as soil chemistry, overbuilding, and changes in land use, the effects of collecting and looting will have significant impacts upon the material.

Historical Background

While battles as events have been the focus of historical interest since the discipline of history was first invented, a specific interest in the material record of battlefields took longer to develop. Early efforts include those of Edward Fitzgerald from 1842, whose work at Naseby in England includes the recording of field names and other topographical features, drawing the contemporary appearance of the landscape, noting where local people had found artifacts from the battle, and recording where local tradition placed particular events of the battle. Fitzgerald's work went on to include the digging of test pits and finding a mass grave. At about the same time, Richard Brooke was pursuing his interest in the battlefields of the Wars of the Roses, inspired in him by his birth near the site of the battle of Stoke. His *Visits to the Battlefields in England of the Fifteenth Century* comprises largely discussions of the historical sources he drew upon and concerns the events of the fight and the names of the prominent killed and wounded. He does, however, provide useful sketch maps of each site, some of which are of more practical use today than more modern ones.

Subsequent interest has largely remained in the realm of Brooke's primary concern, of identifying the places where battles took place, rather than using them as research objects in their own right. Once identified, the tendency is to assume that the landscape as seen today is similar – if not identical – to that on the day of the battle. As Foard makes clear in his criticism of both the standard form of battlefield "guide" and the English Heritage *Register* (1995) which so closely resembles such guides, most publications on battlefields continue to "place stylised battle formations and key topographical features... almost arbitrarily against a modern map base" (Foard 2001: 88). Frequently, however, students of military history have taken the trouble to visit the sites of the battles they discuss and to relate the topography to contemporary accounts. Nevertheless, the primary focus has always been upon the literary evidence for battle action, rather than what evidence the place itself could provide.

However, a group of unrelated twentieth-century research moved closer to a direct concern with the battlefield itself, and while all have much to teach us in pursuing this field, only the last has led to the recent explosion of interest in battlefield archaeology. The first exercise in battlefield archaeology in the twentieth century took place in the late 1950s and early 1960s, when the then military government of Portugal sought – among other things – to celebrate Portugal's military past by promoting the deeds of its medieval chivalry. Excavations in advance of building a monument and a museum at the site of the battle of Aljubarotta, where Portugal first emerged as an independent state, revealed a mass grave and battlefield features. This exercise in battlefield archaeology has gone largely unnoticed by the battlefield archaeology community. A decade later in England, work at Marston Moor (an English Civil War battle site) and roughly contemporary geological work at Maldon (site of a Viking attack on the East Saxons, CE 991), testify to the importance of topographical research and careful reconstruction of the historic landscape by revealing how accounts based upon the modern appearance can be highly misleading. At Marston Moor, the realization that the sunken road which played such a large part in nineteenth- and twentieth-century accounts of the battle was a feature added in the eighteenth century (and therefore was not present on the day of the battle) altered understanding of contemporary seventeenth-century accounts. At Maldon, confirmation that a significant change in sea level had occurred from the tenth century to the twentieth forced a reassessment of the one contemporary account of the battle; this in turn required the removal from the accepted story of the battle several events which had been added later to allow the modern appearance of the site to fit the ancient account (see Carman & Carman 2006: 7-8).

The combination of careful recording of artifact scatters, topographic research, and the search for remains of the dead at the Little Bighorn site in the USA (Scott et al. 1989) finally brought battlefield archaeology attention, and these techniques have since been applied in the USA at Palo Alto, Texas (Haecker & Mauck 1997), in the UK at Towton (Fiorato et al. 2000), and elsewhere (e.g., see Freeman & Pollard 2001; Pollard & Banks 2006; Scott et al. 2007). As a result of successful battlefield archaeology projects in a number of countries, the number of specialist battlefield archaeologists in Europe has grown over the years and the field is increasingly recognized as one of significance. The most recent *Fields of Conflict* conference – the leading conference in the field – held in Germany had participants from 14 countries of Europe as well as the USA and Canada.

Key Issues and Current Debates

Practitioners of battlefield archaeology have in general been more concerned with issues of methodology than other aspects of the field. In part, this is because the techniques are still under development and – although there is general agreement on the approach to be taken – questions arise as to specifics. In part, it is because both the underlying purpose of battlefield archaeology and the underlying theory go unquestioned. The purpose is generally taken to be to provide an insight into past military practice, drawing on inspiration from military history. The theoretical approach, whether acknowledged or not, is an overtly processualist one, deriving directly from the search for "patterns" – as evident in the work on the Little Bighorn site. Despite the expressly anthropological concerns of that research, more recent attempts to incorporate anthropological theories of war into the field (e.g., Carman & Carman 2006) have generally been resisted.

The much-cited book *Archaeological Perspectives on the Battle of the Little Bighorn* (Scott et al. 1989) is largely the inspiration for the rise of battlefield archaeology over the past two decades. Taking advantage of the cutting of the grass at the Custer Memorial site, Scott and his colleagues used metal detectors to trace the fall of bullets and the ejection of cartridges across the space of the fight between units of the seventh US Cavalry and Lakota and Cheyenne warriors. Differences in weapons used by one group of participants from those used by others allowed the researchers to identify Native American shot from that of the soldiers, and the distribution especially of cartridge cases across the space identified the movement of individual weapons – and therefore of men and formations – through the space. From this, a model of the sequence of events emerged which confirmed Native American accounts frequently dismissed. Other work on soldier burial sites allowed also the identification of individuals, the opportunity to infer the location of the bodies of missing soldiers, and the chance to develop a picture of the "typical" soldier for the late nineteenth century in North America. In particular, the researchers sought to identify the "patterns" revealed by the distribution of bullets across the space: the "static" pattern of the present distribution of bullets and casings, the "dynamic" pattern of movement through space this represented, and from this the standardized "post-Civil War battlefield pattern" of military behavior that would provide a model for interpreting other sites of the period.

A combination of discussions by Pratt and Sivilich (see papers in Scott et al. 2007) allows an appreciation of the techniques of battlefield archaeology as they have developed since the 1980s. Pratt outlines an effective survey technique by metal detector, whereby two operators survey an area, each using a different machine and at a 90° angle to one another, locating individual finds on a GPS recorder. As he puts it, by using this survey technique, "coverage [of ground] is improved and typically result[s in an] increase of collected artifacts or more thoroughly substantiates the lack of metal remains" (Scott et al. 2007: 8). Sivilich in the same volume provides a useful survey of what can be learned from musket balls deposited on pre- to mid-nineteenth-century battlefield sites, which (because they are used in smooth-bored weapons and are lacking the distinctive features of rifle markings) cannot be associated with individual weapons. These include an idea of the type of weapon for which the ball was made, derived from its diameter and weight. Similarly, it is possible to identify whether it had been fired – from scorching and powder burns on one side and the distinctive "ring" around the center caused by scraping along the inside of the gun barrel – or dropped, by the continued presence of mold seams and sprues from manufacture. A scatter of fired bullets can be assumed to have been aimed at a target but to have missed it unless deformed and to have traveled beyond it, whereas bullets fired and deformed may have hit the target but with insufficient force to cause harm: A combination of this information may indicate where the soldiers being fired at stood. A scatter of dropped bullets may indicate where firing soldiers stood. A particular development has been experimental work on firearms in order to ascertain what finds of shot on sites of battle may indicate. It is clear that fired bullets discovered by metal detector will mostly have failed to hit a target, but what is not immediately obvious is how far the bullet may have traveled beyond where any target was standing and how it may have been deflected by bouncing. Examples include work on case shot and on eighteenth-century muskets in the USA. Although not – as at Little Bighorn – indicating the movement of weapons and therefore individuals through the battlefield space, this kind of information can inform an understanding of the placement of troops during the action.

A central issue remains the search for sites to investigate. The precise location of battles from earlier historical periods is rarely known from written records, and much effort can be spent in locating them. In recent years, two battles from the Roman period have been securely located entirely by archaeological effort, both in northern Germany: Kalkriese, the site of the destruction of Varus' three legions in CE 9 (Rost 2007; Wilbers-Rost 2007), and a previously unknown action from the third century CE at Harzhorn. In both cases, scatters of material brought archaeologists to the site, and careful analysis of the distribution allowed an understanding of the fight to be constructed. At Kalkriese, excavations brought to light the barrier constructed by the Germans to prevent the escape of Roman troops into the surrounding country, thereby trapping them between attackers and swampy ground.

Elsewhere, a combination of material scatters and close reading of the available textual evidence allowed the identification of the likely site of the eleventh-century CE battle of Fulford in England (Jones 2011). Close reading of topographic descriptions contained in the main contemporary texts allowed the identification of likely locations. Environmental and other survey then established the extent to which each of them might match the description given in those texts. Survey by metal detector then sought to locate the material evidence at each site that a battle of the period had taken place. What was found – rather than scatters of weaponry such as arrowheads, broken swords, and spears – was intensive evidence of metalworking, including artifacts such as anvils and other metalworking tools, the bases of hearths, and incomplete and unfinished metal objects such as arrowheads. In similar vein – but also including an explicit search for evidence of fighting – the much later battle of Bosworth was finally located only in 2009 after extensive topographical research supported by metal detector survey.

The problems of investigating earlier sites are well recognized by battlefield archaeologists. It is therefore no surprise that the bulk of battlefield research focuses on later periods, where the location of actions is more firmly established. Such work covers the periods from the sixteenth to the nineteenth centuries, with clusters around certain periods within that time frame. Here, other questions dominate. In particular, in an effort to establish the value and legitimacy of battlefield research, effort has been spent on proving the techniques of battlefield archaeology to official agencies who are then encouraged to arrange for the preservation of key sites so that they will in turn become available for investigation and study.

However, battlefield archaeology is no more than 15 years old in Europe and is still young as a specialized field. Techniques are increasingly well established, an increasing number of scholars are taking an interest, and broader research questions – such as the development of gunpowder warfare from the fifteenth to seventeenth centuries – are emerging. Although a close-knit community of battlefield archaeologists has been formed, especially through the *Fields of Conflict* conferences from 2001, the largest impact of developments in the field has yet to be recognized, and the recognition by official agencies of the value of this kind of work has also yet to be achieved beyond English-speaking countries.

International Perspectives

Battlefield archaeology was until recently an entirely Anglophone field, limited to American, Irish, and British archaeologists. However, it is now a global field with practitioners from all across Europe and beyond.

In the USA, much work focuses on battles from the nineteenth century. The work at the Little Bighorn site established the basic techniques of battlefield survey by metal detector and established the value of such an approach (Scott et al. 1989). Such work has since expanded to the battles of the American Civil War (Geier & Potter 2001) and to other military actions against Native Americans (see papers in Scott et al. 2007).

In much of Europe, the focus lies upon earlier periods – especially the seventeenth and eighteenth centuries. The last battles in England and Scotland were fought in 1685 and 1746, respectively, and so British battlefield archaeology in particular has focused on these centuries. Foard has worked extensively on the battlefields of Naseby and especially Edgehill, both of the English Civil War of the mid-seventeenth century. Edgehill remains the only early modern battlefield to have been subject to total survey, following extensive historical and topographical research to reconstruct the seventeenth-century landscape. This, together with metal detector survey, established that the traditional accounts of the battle were seriously wrong in the way they positioned troops, affecting any understanding of the course of the action (Foard 2005). Work at Naseby also provided a revised sequence for the battle, including evidence for initial success by Royalist infantry, and their "fighting retreat" after subsequent defeat (http://battlefieldstrust.com/). At Culloden in Scotland, survey in advance of the construction of a new visitor's center soon established that the traditional accounts of the action and its limitation to certain ground only were incorrect (Pollard 2006). Elsewhere in Europe, research on battlefields of these periods has been carried out and is ongoing in Belgium at Oudenaarde, in Germany at Lützen, in the Ukraine at Poltava, in Sweden at Landskrona (Knarrström 2006), and in Spain at Almenar and Talamanca (Rubio 2008).

A limited amount of work has been undertaken beyond North America and Europe, including preliminary surveys of nineteenth-century battlefields in South America (Pollard 2007).

Future Directions

The identification of unknown or disputed sites has led battlefield archaeologists into periods otherwise little examined and where it is uncertain what material residues of conflict may be encountered. These "signatures" (Sutherland & Holst 2005) are well known for battles of the seventeenth to nineteenth centuries where firearms predominate, but for earlier periods are less clear. The work at both Kalkriese (CE 9) and Fulford (1066) suggest that a key indicator of early battle sites may not be deposits of weapons, such as arrowheads, or of human remains, as at Towton (1461), but evidence of prebattle metalworking.

Some historic periods suffer from a lack of explicit focus. The sixteenth century in Europe, although a period that may be considered significant in terms of a shift of warfare style from "shock" to gunpowder and the commencement of Europe's global expansion as a colonizing force, is relatively untouched apart from studies of fortifications or shipping. However, work on sites related to Spanish expeditions into North America in this period provides an interesting alternative approach (see Scott et al. 2007). The late nineteenth century is also low in coverage, except for North American conflict with Native Americans: This may partly be explained by the generally successful exportation of warfare by the major European states to colonial contexts from the close of the Napoleonic Wars to 1914. There are some exceptions to this general rule such as the Crimean War, the Franco-Austrian and Franco-Prussian Wars, and the wars of German and other national unifications from mid-century, although these too remain largely unexamined from an archaeological perspective. Consequently, there is a chronological leap from the eighteenth century to the twentieth century, the latter forming an entirely separate area of study from that of the historic period (Schofield et al. 2002).

Further developments which are beginning to emerge include the recognition that the archaeology of periods beyond those of the historic may have things to contribute to the study of historic battlefields (Carman 2012). However, the battlefield archaeology of more recent periods remains an issue to be addressed: The standard techniques of battlefield archaeology – landscape regression and metal detector survey – do not necessarily lend themselves well to reinterpretations of the sites of the large and highly technological warfare of the last century, confirming this as a separate field of investigation.

Cross-References

► Fortifications, Archaeology of
► Metal Detecting in Archaeology

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Alexander A. Bauer is an archaeologist whose research foci are the archaeology of the Near East and Eurasia, ancient trade, archaeological method and theory, archaeological ethics, and cultural heritage law and policy. Having studied the prehistory of the eastern Mediterranean as an undergraduate in the Department of Classical and Near Eastern Archaeology at Bryn Mawr College with professors James C. Wright and J.P. Dessel, he earned his Ph.D. in anthropology at the University of Pennsylvania in 2006, where he studied interregional interaction during the pre-Colonial period of the Black Sea region, first under the guidance of Dr. Fredrik T. Hiebert and then Dr. Robert W. Preucel. He is currently an assistant professor of anthropology at Queens College and the Graduate Center of the City University of New York.

Major Accomplishments

Since 2005, Dr. Bauer has served as the editor (in chief) of the *International Journal of Cultural Property*, an interdisciplinary journal on cultural heritage law and policy. He has conducted fieldwork in Greece, Israel, Jordan, the United States, and Turkey, where he is currently associate director of the Sinop Regional Archaeological Project, under the direction of Dr. Owen Doonan. He has served as a senior editor of the second edition of the *Oxford Companion to Archaeology* (Oxford University Press, 2012). His 2001 article with Robert W. Preucel entitled "Archaeological Pragmatics" was among the first archaeological engagements with Peircean semiotics, and since then, he has continued to research and write on its utility for archaeology.

Cross-References

▶ Cultural Property, Trade, and Trafficking: Introduction
▶ Ethics in Archaeology
▶ Ethics of Collecting Cultural Heritage
▶ Heritage and Public Policy
▶ Preucel, Robert W.
▶ Semiotics in Archaeological Theory

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Beach, Timothy

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Basic Biographical Information

Timothy Beach is a geographer who uses geoarchaeological techniques, such as archaeological geomorphology and pedology, to illuminate the dynamic interrelationships between ancient humans and their environments. Originally from California, he earned his Ph.D. in Geography from the University of Minnesota in 1989, concentrating on geomorphology, soils, and geology. He has taught at Georgetown University in Washington, DC, since 1993, where he currently holds the Cinco Hermanos Chair in Environment and International Affairs. He is also Professor of Geography and Geoscience in the Science, Technology, and International Affairs program at Georgetown's well-known School of Foreign Service. Previously, he was for 8 years the Director of the Center for the Environment at Georgetown. He has been awarded a John Simon Guggenheim Fellowship and has held a Dumbarton Oaks Fellowship in Pre-Columbian Studies. In 2006, he was elected a Fellow of the American Association for the Advancement of Science.

Beach has worked in the United States, Germany, Syria, and Iceland. He has performed fieldwork at important archaeological sites in Turkey (e.g., Beach & Luzzadder-Beach 2008), but the majority of his research, and that for which he is best known, has been carried out in the ancient Maya lowlands, in Mexico, Guatemala, and Belize. In this region, he has participated in many research projects that have focused on different sites to address varied but interrelated scientific problems using a wide range of field and laboratory techniques. Through interdisciplinary collaborations, he has made major contributions to our understanding of ancient Maya climate, agriculture, agricultural intensification, and the development of anthropogenic soils and landscapes. These studies have allowed him to significantly influence the debates surrounding both the origins and collapse of ancient Maya civilization as well as its economy and adaptation (Fig. 1).

Major Accomplishments

In the state of Yucatán, Mexico, he has worked extensively at the important Classic site of Chunchucmil (e.g., Beach 1998), where he has helped elucidate the paradox of an enormous and populous archaeological site situated in a region with low agricultural potential. At Mayapán, also in Yucatán, he has studied the extensive black earth midden that blankets most of the 4 km^2 ceremonial and residential zone of the site, a mysterious anomaly in the region.

His and his colleagues' extensive work in the Pasión River region around Dos Pilas in the Department of Petén, Guatemala, has helped clarify the complexity of the Classic Maya collapse. In contrast to previous paleoclimatic studies that implicated drought as the primary cause of societal implosion at the end of the Classic period (c. CE 800–900), Beach and his colleagues found little evidence for drying. Nor did they find significant evidence for environmental degradation, such as accelerated soil erosion, during the peak of population in the Late Classic period, another favored environmental explanation of the collapse (e.g., Dunning et al. 1998). Subsequently, Beach's intensive research in northwest Belize has reinforced the inference that the Maya collapse was not triggered by a singular, apocalyptic event, such as a drought, or even by a series of them; instead, it was a complex, long-term, and heterogeneous set of processes without a prime mover (Dunning et al. 2012; Luzzadder-Beach et al. 2012).

His work in northwest Belize in the vicinity of Blue Creek has also helped resolve a sometimes contentious dispute about the nature of Maya agricultural intensification. Previous researchers viewed the ancient Maya wetland fields either as similar to the Aztec raised fields in the Valley of Mexico or as a largely natural phenomenon caused

Beach, Timothy, Fig. 1 Map of the Maya region showing important sites where Timothy Beach has carried out geoarchaeological research

by a combination of sea-level rise and associated landscape aggradation. Beach and his colleagues have shown, however, that their more extensive data sets can be better explained by new models that combine elements of both older models with evidence for additional variations in patterns and methods of field construction (e.g., Beach et al. 2009). This work has also clarified the timing and mechanisms of landscape aggradation in the region, which can now be attributed primarily to gypsum precipitation caused by a rising water table, although other factors contributed to a lesser degree (Luzzadder-Beach & Beach 2009).

Beach and his colleagues' work in the large karst depressions that occupy some 40 % of the Maya lowlands, known locally as *bajos*, has contributed evidence that these features played an important ecological role in the development of Maya civilization in the Preclassic period (Dunning et al. 2002). Previously, some scholars had argued that these wetlands were marginal environments of little direct significance to Maya cultural evolution.

Beach's scholarship cannot be understood in isolation, for he has collaborated closely with a number of geographers and archaeologists. Among these collaborations, the closest and most persistent has been that with his partner, Sheryl Luzzadder-Beach, a Professor of Geography at George Mason University in Virginia who specializes in hydrology and water chemistry. Beach has also worked closely with Nicholas P. Dunning, a geographer with similar interests at the University of Cincinnati. Beach's partnerships with archaeologists such as Stephen Houston, Arthur Demarest, Thomas Guderjan, and the late Bruce Dahlin undoubtedly influenced his research by stimulating interactions with specialists investigating related questions using different approaches.

In summary, Tim Beach has contributed significantly to our understanding of ancient Maya civilization. He has helped to dispel the myth of the "pristine landscape," according to which American Indians had only a minimal impact on their environment. Beach's overarching contribution has been to show how the geosciences can paint a detailed and nuanced portrait of cultural ecological history that does not succumb to an overly simplistic environmental determinism. His work illustrates how such a portrait can be realistic, scientific, and humanistic when colored by a fine appreciation of the complexity of human agency and filled in by sufficiently detailed and diverse data.

Cross-References

- ▶ Agrarian Landscapes: Environmental Archaeological Studies
- ▶ Agricultural Practice: Transformation Through Time
- ▶ Agroforestry: Environmental Archaeological Approaches
- ▶ Amazonian Dark Earths: Geoarchaeology
- ▶ Anthropogenic Environments, Archaeology of
- ▶ Anthropogenic Sediments and Soils: Geoarchaeology
- ▶ Archaeological Chemistry: Definition
- ▶ Chan: A Tropical Rain Forest Site in Belize
- ▶ Environmental Reconstruction in Archaeological Science
- ▶ Geoarchaeology
- ▶ Historical Ecology and Environmental Archaeology
- ▶ Karstic Landscapes: Geoarchaeology
- ▶ Landscape Domestication and Archaeology
- ▶ Mesoamerica in the Preclassic Period: Early, Middle, Late Formative
- ▶ Mesoamerica: Complex Society Development
- ▶ Olmec: Geography and Culture
- ▶ People as Agents of Environmental Change
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Beans: Origins and Development

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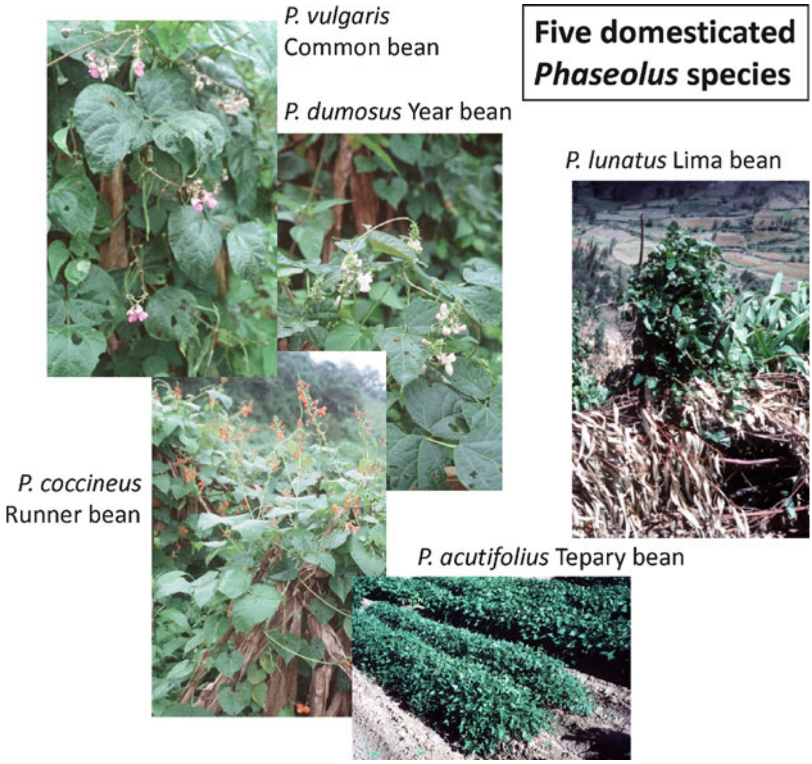
Basic Species Information

The genus *Phaseolus* comprises some 70–80 species (Freytag & Debouck 2002), distributed exclusively in the Americas (Delgado Salinas et al. 2006) but with a clear focal point in Mexico and Central America. This region contains the largest number of species of the genus; it also harbors a very diverse range of environments in which the genus *Phaseolus* radiated following the last major tectonic event, namely, the appearance of the Transverse Volcanic Axis in Mexico. It is in this diverse landscape that five *Phaseolus* species were domesticated (Fig. 1). Of these five species, common bean (*P. vulgaris*) is by far the one with the broadest geographic distribution (Fig. 2) and largest agronomic, nutritional, and economic impact. Other domesticated species are

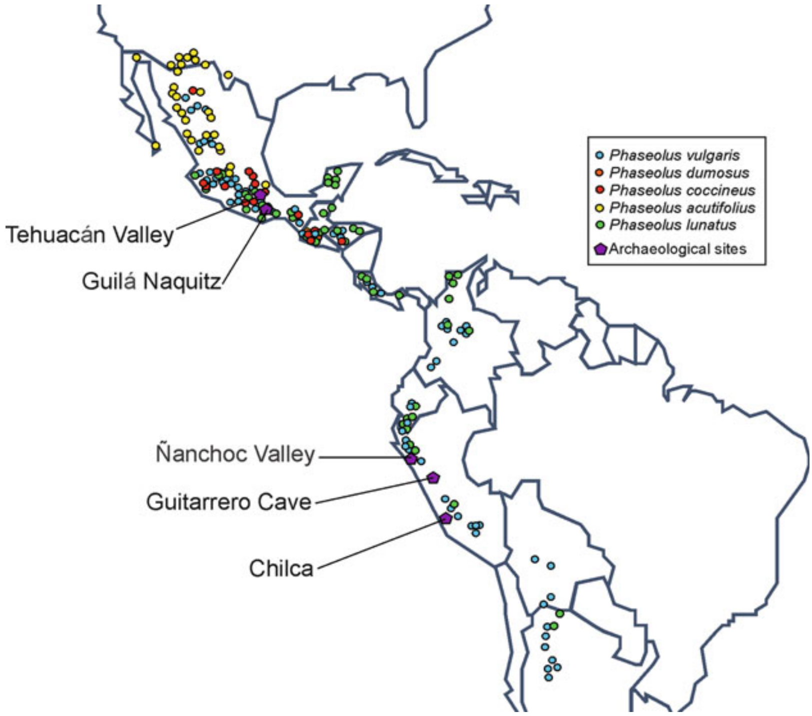


Beans: Origins and Development, Fig. 1 Five domesticated *Phaseolus* species. Lima bean is phylogenetically more distant from the other four species

runner bean (*P. coccineus*), tepary bean (*P. acutifolius*), lima bean (*P. lunatus*), and year bean (*P. dumosus*). In addition to the Mesoamerican domestications, two additional domestications took place in the Andes, one each for common bean (southern Andes, between southern Peru and northwestern Argentina) and lima bean (western Ecuador).

The five domesticated *Phaseolus* species have overlapping, yet distinct, geographic distributions, ecological adaptations, life histories, and reproductive systems (Table 1 and Fig. 2). Common bean grows in mesic environments (i.e., at intermediate temperatures [yearly average of 24 °C] and rainfalls [around 600 mm/year]) at the transition between dry, deciduous, and pine forests. This species is annual with cycle lengths for most varieties from 80 to 120 days. Its reproductive system is primarily autogamous.

Nevertheless, bursts of outcrossing can take place occasionally, which can significantly affect the distribution of genetic diversity within and among populations (Papa et al. 2005; Zizumbo-Villarreal et al. 2005). Runner bean is the domesticated bean species with adaptation to the coolest (and humid) environments. Its tuberous root system, in addition, provides a way for plants to survive winter frosts as new stems can regrow from the roots. Thus, this species is also perennial, surviving for several years. It is an allogamous species, which relies obligatorily on foraging by carpenter bees and humming birds for seed production (Búrquez & Sarukhán 1980). In contrast with runner bean, tepary bean originated in warmer, arid environments. It is a short-lived (part of its drought adaptation) annual species, with a highly selfing (even cleistogamous) reproductive system. Lima bean is perhaps the species with the broadest adaptation of all five domesticated species. It is generally grown in warmer, more humid environments. It is a long-lived, annual species with a mixed autogamous-allogamous reproductive



Beans: Origins and Development, Fig. 2 Geographic distribution of the wild progenitors of the five domesticated *Phaseolus* species and sites with the oldest *Phaseolus* archaeobotanical remains (see Table 2)

Beans: Origins and Development, Table 1 Comparative of five domesticated *Phaseolus* species

	Common bean	Year bean	Runner bean	Tepary bean	Lima bean
Growth habit	Upright bush to climbing; includes bush determinate	Climbing	Mostly climbing; some bush, including bush determinate	Prostrate bush	Upright bush to climbing; includes bush determinate
Reproduction	Predominantly selfing	Predominantly outcrossing	Predominantly outcrossing	Selfing, cleistogamous	Selfing to outcrossing
Adaptation	Mesic	Mesic to cool	Cool, humid	Hot, dry	Selfing to outcrossing
Number of domestications	2	1	1 or 2	1	2
Locations of domestication	West-central Mexico	Guatemala	Mexico	Northwest Mexico	Mesoamerica and Ecuador/N. Peru

system. Finally, as a stabilized hybrid between common and runner beans, the year bean has intermediate characteristics between these two parental species.

Domestication has induced drastic changes in the two most domesticated *Phaseolus* species, common and lima bean. These two species show the full array of traits characteristic of crop domestication (the “domestication syndrome”). In these seed-propagated crops, two domestication traits stand out. Compared to their wild progenitors, domesticated varieties show a reduction or elimination of seed dormancy and dispersal. As a consequence, domesticated common and lima beans have ready germination and limited grain loses from premature pod shattering. In addition, in contrast with wild ancestors, which have exclusively a climbing, viny growth habit with indeterminate branches, these two domesticates’ growth habits range from viny to a more compact growth habit with fewer and shorter branches. In some cases, domesticated varieties have a bush growth habit and determinate branches. This trend to smaller plants correlates with a more precocious life cycle, an essential characteristic of most agricultural production systems. Additional changes included gigantism (increase in organ size, especially pods and seeds); development of photoperiod insensitivity, which broadened latitudinal adaptation; acquisition of broad phenotypic diversity for the principal harvested organ pods and especially seeds (e.g., the colorful array of domesticated bean seeds) as a result of selection for novelty; and reduction in toxic compounds, such as the cyanogenic glycosides in lima bean. The inheritance of the domestication syndrome has been investigated in common bean (Koinange et al. 1996). The results show that the inheritance of the domestication syndrome in common bean was relatively simple genetically; few, major genes were responsible for a majority of the phenotypic variation (i.e., domestication traits have a generally high heritability). In addition, these genes are distributed on few chromosomes, and several crucial genes seem to be loosely linked. This genetic architecture would allow a relatively speedy evolution under domestication, provided selection was applied regularly and with sufficient strength (Gepts 2004).

Timing and Tracking Domestication

Molecular analyses in wild and domesticated forms of the various domesticated *Phaseolus* species have provided a picture of "hyperdomestication" in the genus. Not only are there five different domesticated species, but two species – common and lima bean – have been domesticated twice (Fig. 1). Common bean was domesticated in western Mexico and the southern Andes (Kwak et al. 2009; Kwak & Gepts 2009; Chacón et al. 2005). Likewise, lima bean was domesticated in Mexico and Ecuador (Gutiérrez-Salgado et al. 1995; Serrano-Serrano et al. 2012). In both species, these two domestications occurred in distinct geographic regions from already diverged wild progenitors (named the Mesoamerican and Andean gene pools). Runner bean was domesticated once (and possibly twice) in Mexico (Angioi et al. 2009). In contrast, both tepary and year bean were domesticated only once, in northwestern Mexico and Guatemala, respectively (Schinkel & Gepts 1988, 1989; Freytag & Debouck 2002; Blair et al. 2012). Within species, some traits have appeared multiple times, adding to the picture of hyperdomestication. One example in common bean is the multiple origin of the determinacy, which originated independently four times in the Andean gene pool and once in the Andean gene pool, based on DNA sequence data of the gene responsible for the determinacy phenotype (Kwak et al. 2012). This sequence or a related one is also responsible for the presence of determinacy in Mesoamerican and Andean lima beans and in runner bean.

The overall picture created by these domestication studies is one in which farmers have actively shaped the domesticated diversity of beans at multiple taxonomic levels and times and in different areas of the Americas where the genus *Phaseolus* originated. Rather than relying on a single domesticate such as in maize, farmers have adopted different bean species for cultivation in different environments and have further selected – presumably independently – similar phenotypic variation. This may have been made possible by the relatively young age of the genus *Phaseolus* (4–5 Ma; Delgado Salinas et al. 2006) such that the domestication potential was maintained in part of the genus, while allowing for the development of differential adaptation among species (Kwak et al. 2012).

Archaeological and linguistic data point to the antiquity of bean cultivation both in Mesoamerica and Andean South America. The first archaeobotanical remains of *Phaseolus* were identified in Peru in the nineteenth century (de Candolle 1882). Since then, additional remains have been obtained in both regions (Table 2 and Fig. 2), the oldest of which suggests a presence of domesticated forms by 8,000 years B.P. (^{14}C age) in Peru but only 2,300 years B.P. (^{14}C age) in Mexico. Glottochronological analyses show that

Beans: Origins and Development, Table 2 Oldest archaeobotanical remains of *Phaseolus* spp.

Location	Taxon (status)	Type	^{14}C Age (year B.P.)	Age (year cal. B.P.)	Source
Andes					
Ñanchoc Valley, Peru	*Phaseolus sp.* (domesticated)	Starch grains from teeth calculus	8,210–6,970	8,600–7,000	Piperno & Dillehay 2008
Chilca, Peru	*P. lunatus* (domesticated)	Pod, non-carbonized	5,600	6,400	Kaplan & Lynch 1999
Guitarrero Cave, Peru	*P. vulgaris* (domesticated)	Seed, non-carbonized	4,300	5,000	Kaplan & Lynch 1999
Mesoamerica					
Oaxaca Valley, Mexico	Phaseolinae (wild)	Seed and pod, non-carbonized	7,600	8,300	Kaplan & Lynch 1999
Tehuacán Valley, Mexico	*P. vulgaris* (domesticated)	Pod, non-carbonized	2,285	2,300	Kaplan & Lynch 1999
Tehuacán Valley, Mexico	*P. acutifolius* (domesticated)	Seed, non-carbonized	2,360	2,400	Kaplan & Lynch 1999
Tehuacán Valley, Mexico	*P. coccineus* (domesticated)	Seed, non-carbonized	410	500	Kaplan & Lynch 1999

the oldest language for which a term for bean has been identified is a Proto-Mayan language (3,400 B.P.; Brown 2006).

The fact that the oldest age available was obtained from micro-remains rather than macro-remains and the glottochronological data suggests that current dates for bean domestication are most likely underestimates. Furthermore, many of the remains originated in very arid areas, outside the distribution of wild progenitors and putative domestication areas determined by genetic means (e.g., west-central Mexico for one of the two common bean domestications: Kwak et al. 2009). Thus, a more active search for archaeobotanical micro-remains (starch grains, phytoliths) in late pre-agricultural or early agricultural contexts should be pursued.

Cross-References

▶ Agriculture: Definition and Overview
▶ Andes: Prehistoric Art
▶ Andes: Prehistoric Period
▶ Archaeobotany of Early Agriculture: Macrobotany
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▶ Domestication Syndrome in Plants
▶ Domestication: Definition and Overview
▶ Flannery, Kent Vaughn
▶ Genetics of Early Plant Domestication: DNA and aDNA
▶ Maize: Origins and Development
▶ Mesoamerica: Complex Society Development
▶ Mesoamerica in the Preclassic Period: Early, Middle, Late Formative
▶ Mesoamerica's Archaic Period
▶ Mesoamerica: Strengths and Weaknesses of the Current Classification
▶ Mesoamerica: Subsistence Strategies by Region
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Beaudry, Mary C.

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Basic Biographical Information

Mary Carolyn Beaudry is an anthropological archaeologist who has specialized in historical archaeology, mainly in the eastern United States, and has made broad theoretical and practical contributions to household archaeology, the archaeology of gender and inequality, and archaeological material culture studies.

Beaudry received her first degree in Anthropology from the College of William and Mary (1973) and her M.A. (1975) and Ph.D. (1980) in Anthropology from Brown University. Beaudry was advised at Brown by James Deetz, who made a long-lasting impact on her research: an influence most visible in her doctoral thesis, *"Or What Else You Please to Call It": Folk Semantic Domains in Early Virginia Probate Inventories* – which used probate inventories to study the material culture of Virginian households in the seventeenth and eighteenth centuries.

A period working in the cultural resource management sector during the 1980s led to a series of scholarly publications, most notably the 3-volume *Interdisciplinary Investigations of the Boott Mills, Lowell, Massachusetts*, which was edited by Steve Mrozowski. In this publication, Beaudry pioneered methods of associating excavated assemblages with historical households, reconstructed from documentary sources. In 1996, her account of the "boarding households" of nineteenth-century Lowell, written to Mrozowski and Grace Ziesing, contributed an important empirical case study to the development of the archaeology of gender in the United States. Beaudry's edited volume, *Documentary Archaeology in the New World*, developed her interests in the archaeological use of historical documents further.

Major Accomplishments

Beaudry's research into material culture has developed in both theoretical directions – for example, in her 2001 paper with Anne Yentsch on "American Material Culture in Mind, Thought, and Deed" or in her coedited volume *The Oxford Handbook of Material Culture Studies* (2010, edited with Dan Hicks) – and in more applied directions, for example, with her introduction to *Findings: The Material Culture of Needlework and Sewing* (2006). A central theme in such work has been the idea that archaeological material culture can provide distinctive insights into otherwise undocumented lives.

Her most sustained contributions to archaeology have, however, been a series of influential reflections on method and theory in historical archaeology – from her 1996 account of "reinventing historical archaeology" to her coedited *Cambridge Companion to Historical Archaeology* (2006, edited with Dan Hicks).

Beaudry has been an active member of the Society for Historical Archaeology (serving as President in 1989), as well as the Council for Northeast Historical Archaeology, and has been a leading figure in the development of international collaborations and exchanges in historical archaeology, especially between the UK and the USA. While Beaudry's fieldwork has led her as far afield as the Outer Hebrides and Montserrat, it is her sustained contributions to the archaeology of early American life in the eastern United States and to the archaeology of gender and households that has dominated her publication record.

Cross-References

▶ African Diaspora Archaeology
▶ Archival Research and Historical Archaeology
▶ Capitalism: Historical Archaeology
▶ Consumption, Archaeology of
▶ Deetz, James (Historical Archaeology)
▶ Engendering Historical Archaeology
▶ Households and Domesticity: Historical Archaeology
▶ Industrial Archaeology
▶ Labor Archaeology
▶ Modern World: Historical Archaeology
▶ North America (USA): Historical Archaeology
▶ Plimoth Plantation: Public Archaeology
▶ Semiotics in Archaeological Theory
▶ Social Identity in Historical Archaeology
▶ Society for Historical Archaeology (SHA) (Historical Archaeology)
▶ Urban Archaeology

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Beazley, Sir John Davidson

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Basic Biographical Information

Sir John Davidson Beazley (1885–1970) was a founding figure in the modern study of Greek ceramics. Building on (then innovative) nineteenth-century modes of stylistic analysis, he refined a system of attribution and identification, for Attic pottery with black- and red-figure decoration from the sixth to fourth centuries BCE. He was born in Glasgow, Scotland, to Mark John Murray Beazley and Mary Catherine Davidson. He attended King Edward VI School in Southampton and Christ's Hospital before enrolling in Balliol College, Oxford University. There he excelled and was tutored by the well-known classicists Cyril Bailey and A.W. Pickard-Cambridge. In 1908 he was elected as student and tutor at Christ Church, a position he held until 1925, when he became the Lincoln Professor of Classical Archaeology at Oxford, a position he would hold for the next 30 years. He was knighted in 1949. He met Marie Bloomfield in 1913 and married her on August 13, 1919. They lived and traveled together for forty-eight years, until her death in 1967. Beazley died on May 6, 1970 in Oxford. He and his wife had no children (Ashmole 1970).

Major Accomplishments

Beazley's contribution to the field of Greek archaeology is immense, demonstrated by the publication of over 250 articles and monographs on Greek vase painting and other topics of Classical antiquity (Ashmolean Museum 1967: 177-188). He systematically identified and attributed "hands" of specific vase painters, who were otherwise unknown, by examining the inherent style expressed in their painting. His methodology was based heavily on Giovanni Morelli and Bernard Berenson, who used a similar method to study Renaissance painting (Kurtz 1985: 236). Adolf Fürtwangler, Paul Hartwig, and Friedrich Hauser also influenced his work, although Beazley differentiated himself from these scholars by his emphasis on vase painters of all qualities, not just the masters, and stylistic analysis. Beazley's technique involved the analysis of details such as ears, eyes, drapery of fabric, and decorative details like borders, with the belief that such features were formulaically repeated by an artist (Ashmole 1970: 453-4). In this way, he identified both individual artists and workshops of painters working under one master. His method allowed for the refinement of relative chronology in pottery playing a major role in the dating of archaeological contexts, and his method remains the foundation on which approaches to iconographic and iconological studies in Classical art are based. Scholars such as Martin Robertson and Richard Neer, among others, have since addressed problematic aspects of Beazley's methodology and attributions (Robertson 1976; Neer 1997). Beazley's most substantial publications were volumes on both red- and black-figure Athenian vase painters from the Archaic and Classical periods. These were *Attic Red-Figure Vase-Painters* (1942) and *Attic Black-Figure Vase-Painters* (1956). In addition, he produced monographs on vases in a large number of collections around the world and wrote a number of works on the Berlin Painter, whom he considered to be his favorite (Ashmole 1970: 454). The "Beazley Archive," built from his collection of photographs, drawings, and notes, is housed at the Ashmolean Museum but also exists as a major online database (http://www.beazley.ox.ac.uk/index.htm). It is now one of the quintessential sources for the study of Greek vases (Beazley Archive n.d.). Students of Beazley, who studied under him at Oxford or trained closely in his methodologies, include Humfry Payne, T. J. Dunbabin, Llewelyn Brown, Dietrich von Bothmer, A.D. Trendall, and Martin Robertson (Ashmole 1970: 451-2).

Cross-References

- ▶ Ceramics, Ancient Greek
- ▶ Classical (Greek) Archaeology
- ▶ Classical Greece, Archaeology of (c. 490–323 BCE)
- ▶ Iconography in the Roman World
- ▶ Symposion

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Beck, Wendy E.

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Basic Biographical Information

Wendy Elizabeth Beck is an Australian archaeologist. She grew up in Melbourne, attended Laburnum Primary School, and graduated from Methodist Ladies College, Kew, in 1975. She completed a B.Sc. at the University of Melbourne during 1976–1978 with a double major in microbiology and biochemistry. After attending a Summer School held by the Victorian Archaeological Survey in 1978–1979, she was converted to archaeology and undertook postgraduate study in prehistory at LaTrobe University (1979–1985). While there she took part in several large research excavations (see Fig. 1). In 1981 she was awarded a Visiting Fellowship from the Australian Institute of Aboriginal Studies which funded her research into Aboriginal toxic food plant processing. Her Ph.D. was awarded in 1986 and her principal thesis supervisors were Drs. David Frankel and Neville White, together with AIATSIS mentor Dr. Betty Meehan. Her Ph.D. *Technology, Toxicity and Subsistence: A Study of Australian Aboriginal Plant Food Processing* was the first Victorian doctorate awarded in Australian archaeology and included fieldwork in Arnhem Land in addition to laboratory research. In 1985 she worked as a postdoctoral Fellow (Australian National University) on a bush food dietary project sponsored by the Office of the Supervising Scientist in the Alligator Rivers Region of the Northern Territory. In 1986 she was appointed Lecturer to the Department of Archaeology and Palaeoanthropology, University of New England, NSW, where she is currently employed as Associate Professor.

Beck, Wendy E., Fig. 1 Wendy Beck excavating at Moonlight Head, Victoria, in 1980 (Photo: D. Frankel)

Major Accomplishments

Her most significant contributions to archaeology fall into several fields:

1. Plants and Gendered Archaeology (1981–Present)

   Her Ph.D. research concerned Aboriginal plant knowledge and included analysis of a range of different sources: archaeology, ethnographic fieldwork in northern Australia, and documentary resources, as well as laboratory work in chemistry and genetics. She was also interested in the survival and recovery of macroscopic and microscopic plant remains. She coedited the first volume which comprehensively reviewed practical methods as well as research case studies of archaeological plants in Sahul (Beck et al. 1989). Another related issue is gendered archaeology, and she also researches links between plants and women in prehistory as well as women as archaeologists and researchers (Balme & Beck 1995).

2. Place Studies in Archaeology (1989–Present)

   Major research interests are how archaeology helps to understand how and why people used spaces and the concept of place as an organizing principle. In her research, there are a number of levels from World Heritage areas, through regions, down to the individual site. Her research in Indigenous community archaeology has also included a number of scales, ranging from the spatial analysis of a single rockshelter (Balme & Beck 2002) to spatial patterns at Gumbaingirr nation level (Beck & Somerville 2002) to upland wetland landscapes (Beck 2006a) (see Fig. 2) and World Heritage places (Beck 2006b). This research has been funded by five Australian Research Council grants. The *Yarrawarra Place Book* series was published jointly by UNE and Yarrawarra Aboriginal Corporation and represented a major research outcome for the 1997 ARC Industry Collaborative Grant project "Ecotourism on the Mid-North Coast of NSW." It presents original research results in archaeology, oral history, and history but presented in an accessible interpretative form. The books and accompanying teacher's kit were shortlisted for a publishing award (The Australian Educational Publishing Awards) and awarded the 2001 ATSIC Many Rivers NAIDOC Community Achievement Award. The first book of the series (*Arrawarra: Meeting Place*) was also used to develop a school teaching kit with the Australian Marine Parks Authority in 2006. Professor Rosemary Joyce wrote:

Beck, Wendy E., Fig. 2 Wendy Beck at Barley Fields Lagoon, New South Wales, in October 2012 (Photo: J. Appleton)

> Some of the most engaging contemporary archaeological writing, works that exploit the possibilities of narrative and dialogue to the fullest…a series of five interpretative booklets published by the University of New England and the Yarrawarra Aboriginal Corporation.…Embedded in a narrative of place, the archaeological reports work both as alternative forms of knowing the place, and as clearly positioned voices with a unique, and consequently valuable, perspective (Joyce 2002: 128).

3. Learning and Teaching in Higher Education (2004–Present)

   She has contributed to developing and applying standards in archaeology study, stressing the range of transferable and subject-specific skills which can be gained, as well as how general Humanities degrees can assist students to become employable. In 2009 she was awarded an ongoing Teaching Fellowship by the Australian Learning and Teaching Council for "Improving Graduate Employability by Implementing Subject Benchmarks" which has funded some of her research on standards (Beck & Clarke 2008; Sinclair & Beck in press).

4. Service to the Archaeology Profession (1980–Present)

While in Melbourne as a postgraduate, she was a member and Secretary of the Anthropological and Archaeological Society of Victoria, and after moving to UNE, she became President of the Australian Archaeological Association in 1989–1990. She was founding Chair of the Australian National Committee on Archaeology Learning and Teaching (an AAA subcommittee) in 2005 and continues in an active role. She has been a member of many UNE committees, including Academic Board, Promotions, Ph.D., and Teaching and Learning.

She is a successful earner of competitive research grants and has been awarded over 20 external research grants, worth over $2 million dollars (AUD). Wendy Beck has also been an Australian Research Council (ARC) Assessor for archaeology grant applications from 2001 until the present, and she has reviewed at least 200 ARC applications. She has also completed two large reports for the NSW National Parks and Wildlife Service, *A Cultural Heritage Assessment of Mt. Yarrowyck* (2003 with Somerville, Duley & Kippen) and *Aboriginal Cultural Heritage Offsets in Mining Areas* (2011 with Bartel).

She also has a successful record in fostering the research of others. At UNE she runs successful one-day research writing "retreats" for a wide variety of groups, including both postgraduates as well as Professors (Beck et al. 2008). She has supervised a steady throughput of graduated Higher Degree Research students (D. Donlon, P. Gaynor, R. Cliff, A. Gorman, H. Burke, R. James, D. Vale, S. Martin, R. Fife, C. Clarke) together with B.A. (hons) and dissertation students, most of whom have continued with archaeological careers.

Cross-References

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▶ Frankel, David
▶ Gender, Feminist, and Queer Archaeologies: Australian Perspective
▶ Heritage and Higher Education
▶ Indigenous Archaeologies: Australian Perspective
▶ Meehan, Betty

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Basic Biographical Information

Robert Bednarik (Figs. 1, 2) was born in Vienna but since the 1970s has become a highly regarded Australian-based scholar achieving recognition in the field of prehistoric rock art with a host of publications and projects to his name. His foremost interest lies with the minds of ancient people and how they became human or "civilized;" the origins of the human ability, intellect, and imagination; and in a selection of fields that provide complementary information. This embraces the early stages of art and language and technological growth providing a gauge of early human faculties and capabilities, for example, seafaring,

Bednarik, Robert G., Fig. 1 Robert Bednarik at the entrance shaft of the cave art site near Mount Gambier

Bednarik, Robert G., Fig. 2 Senior Rock Art Custodian Monty Hale at huge eastern Pilbara petroglyph site, with IFRAO President R. G. Bednarik

paleo-art of the Ice Age, stone tools, and the use of beads. This talented scholar retains a wry sense of humor despite his immense success and contributions to the field of archaeology, in particular rock art.

Major Accomplishments

Robert Bednarik has held a number of high-profile positions throughout his career. These include being a cofounder of the International Federation of Rock Art Organizations (IFRAO) in 1988; secretary of the Australian Rock Art Research Association (AURA), which he founded in 1983, and editor of its journal, *Rock Art Research*, and monograph series; a national coordinator of the International Comite pour l'art Rupestre (CAR), for the International Council on Monuments and Sites (ICOMOS); and being a member of the International Union of Prehistoric and Protohistoric Sciences (IUSPP) Commission on Rock Art.

Bednarik is a passionate champion of Aboriginal rights, energetically campaigning for

Aboriginal control of sites of indigenous heritage, and is frequently engaged in endeavoring to thwart the destruction of rock art worldwide. He has also conducted comprehensive ethnographic research among Aborigines.

Bednarik has cultivated novel techniques for assessing weathering of silica minerals and for studying cave climate; has also created an apparatus to measure the porosity of rock; directed the first comprehensive survey of wall markings in caves; is the pioneer in the investigation of Pleistocene seafaring; and established taphonomic logic in 1993 and metamorphology in 1995. He was one of the earliest individuals in the world to date rock art directly with radiometric methods (reprecipitated carbonates in Malangine Cave, Australia); developed the first non-interfering rock art dating method (microerosion method, initially applied at Lake Onega, Russia); and was an advocate for advanced statistics in Australian archaeology (Brainerd-Robinson method).

Many of the key scientific discoveries in several countries, including the oldest known rock art in the world, first Paleolithic art of China, first petroglyphs in central India, principal petroglyph concentration in the world (1967–1970, Dampier Archipelago, Western Australia), and a great deal of the cave art of Australia, are a credit to the remarkable work ethic of Bednarik.

Specialized Projects

Robert Bednarik's specialized projects include research into portable Paleolithic art of Eurasia and the beginnings of art and symbolism; early fieldwork at major Pilbara rock art concentrations in Western Australia, undertaken between 1967 and 1970; Pleistocene seafaring and maritime replication studies; and numerous geomorphological and sedimentary/pedological projects.

Robert Bednarik has published over 400 refereed scientific periodicals, in 32 languages, principally in cognitive epistemology and paleo-art studies, also general and replicative archaeology, soil science, speleology, deontology, semiotics, and geomorphology. His overall publication record is over 1,200 print publications. He has appeared in several film documentaries and given an excess of 200 interviews with print and electronic media, in many parts of the world.

Robert Bednarik has conducted intensive fieldwork in across the world, especially in central, northern, eastern, western, and southern Europe. He has also undertaken fieldwork in Siberia, India, China, Canada, the USA, Mexico, the Caribbean, various South American countries, southern Africa, Morocco, and in all regions of Australia.

Cross-References

▶ Australian Paleoart
▶ Europe: Prehistoric Rock Art

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Behavioral Archaeology

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Introduction

Behavioral archaeology is a social science with a unique approach to the study of human behavior. Inspired by the New Archaeology early in the 1970s, J. Jefferson Reid, William L. Rathje, and Michael B. Schiffer ambitiously redefined archaeology as a discipline that focused on the role objects play in all human activities past and present. By giving material objects an active role in behavior, they could extend the rigor of archaeological analyses of artifacts into other social science arenas, giving archaeology a more central role in the production of method and theory. Not surprisingly, behavioral archaeologists developed new models of inference for handling archaeological evidence and material culture. This has led to detailed studies of how technologies are developed and change as well as the extension of behaviorally oriented studies on subjects such as ritual and communication that have typically not been arenas for object-focused studies of behavior. Indeed, behavioral research anticipated the renewed interest in material culture studies described in the recent materiality literature (Hicks & Beaudry 2010).

Definition

Behavioral archaeology is a social science whose subject matter is the interaction between people and other objects (e.g., people, portable artifacts, architecture, places) in all times and places. At the core of behavioral archaeology is the recognition that material objects are not a separate realm acted upon by people but instead are an attribute of human action. In behavioral archaeology, human behavior is defined as interaction between people and things. The material matrix that envelopes people during their entire lives is the proper subject matter of those seeking to understand organization and change in human activities. Thus, behavioral archaeology, while a necessary component of any traditional archaeological research project, reaches beyond that role to understand the material matrix that is the human world of action.

Historical Background

The roots of this material culture-centered approach to behavior lie in reactions to functionalist (1940s and 1950s) and neoclassical evolutionary social theory (1960s and 1970s). In the 1940s and 1950s, functionalist archaeologists broke with visions of cultures as a historically contingent clustering of culture traits (e.g., pottery types, projectile point types, house forms) created by the migrations, innovations, or borrowing of their participants. By theorizing culture as a set of integrated institutions (kinship, religion, politics, economy), artifacts became indirect traces of human activities comprising these institutions. For example, treating artifacts and architecture as the indirect traces of activity led to settlement pattern studies in the 1950s and stimulated the rise of archaeological survey methods and further inferences about political organization, technology, and human-environment relationships (see Willey & Sabloff 1980). The subsequent 1960s was a revolutionary time in archaeology that inspired many young graduate students to push archaeological boundaries.

New Archaeologists during the 1960s promoted a theoretically driven archaeology, arguing that new questions required new models of culture and its attributes. They redefined cultures as ecologically adapting systems that integrated people, objects, and energy. Employing a neo-evolutionary framework (White 1949), they analytically refashioned functional institutions into adaptive technological, social, and ideological subsystems (Binford 1962). They assumed that technology was at the heart of basic survival, and so these subsystems could be placed in a causal hierarchy with subsistence technologies as the sources of change whose effects rippled up through the social organizational and belief subsystems. New Archaeologists called the generalizations they used to describe causal relationships in these subsystems material correlates or correlates (e.g., Hill 1970). Ethnoarchaeology, which began in the functionalist era, was expanded by the New Archaeology and became a prominent means for developing correlates for building models of past systems and subsystems. It was in this context of change that behavioral archaeology was created.

Two doctoral students working as teaching assistants (J. Jefferson Reid and Michael B. Schiffer) for William L. Rathje at the University of Arizona in the early 1970s argued that archaeology could be its own social science that focused not simply on past peoples or artifacts but instead on the interaction among them in all times and places (Reid et al. 1975). Behavior defined relationally as an interaction with material objects was the analytical lynchpin around which the burgeoning studies of prehistoric, historic, and contemporary societies revolved. They therefore defined behavioral archaeology as "the study of material objects regardless of time and space in order to describe and explain human behavior" (Reid et al. 1975: 210). Their goal was twofold: (1) to systematize what they believed New Archaeology could become and (2) simultaneously address some of its weaknesses.

By the early 1970s, it had become apparent that the systems approach as applied in archaeology tended to obscure or simply ignore lower-scale behavioral variability critical for explaining the structure of archaeological deposits and, arguably, addressing the evolutionary questions that the New Archaeologists posed. Initially, behavioral archaeologists viewed their efforts as consistent with the goals of the New Archaeology.

Trained as a Mayanist, Rathje recognized the symmetry between the study of ancient Maya cities and the study of garbage in contemporary cities and founded the Le Projet du Garbage, applying archaeology to the present (see Rathje & Murphy 1992). Reid and Schiffer developed behavioral archaeology method and theory in their dissertations and subsequent research. Reid (1985, 1995) has largely focused on prehistoric archaeology, while Schiffer has tended to pursue a broader method and theory agenda (see LaMotta & Schiffer 2001). In early work, Schiffer developed a behaviorally based model of inference and applied it in studies of the formation processes of archaeological deposits (Schiffer 1976, 1987). Subsequently he turned his attention to experimental and historical studies of technology (e.g., Schiffer & Skibo 1987; Schiffer et al. 1994a), communication (Schiffer & Miller 1999), and the history of science (e.g., Schiffer 2008). Recent students have expanded the reach of behavioral archaeology to include ritual and religion (Walker 1995, 1998, 2002; Hollenback 2010a), landscapes (Zedeño 1997; Hollenback 2010b), and social power (Walker & Schiffer 2006).

Key Issues/Current Debates

Three broad contributions of behavioral archaeology have shaped debates in the discipline: the synthetic model of inference, a behaviorally based approach to technology studies, and extensions of a behavioral approach to what have traditionally been considered nonbehavioral realms including ritual and religion, communication, and political power.

The Synthetic Model of Inference

Beginning with the New Archaeology's interest in material correlates, behavioralists' initial contributions revolved around systematically laying out a behavioral approach to the material matrix of human activity. They described forms of artifact variability, categories for organizing that variability, and a synthetic model of inference for drawing that variability together in explanations of human behavior. Eventually these studies were pulled together in Schiffer's (1987) *Formation Processes of the Archaeological Record*.

Behavioralists argued that new archaeologists had heavily theorized ongoing cultural systems but that the same could not be said for the proximate activities making up those systems nor for the human and natural actions that instrumentally contributed to the formation of the archaeological record. Initial papers laid out the important distinction between patterning in ongoing cultural systems or "systemic contexts" and patterns in the archaeological record, "archaeological contexts." Behavioralists argued that to link these patterns, we needed to identify the causally connected sequences of behaviors that eventually transformed these patterns from cultural contexts into archaeological contexts (Schiffer 1976; Sullivan 1978). They described these sequences as "behavioral chains" illustrated by flow models. They also used the more anthropocentric term "life histories" in order to emphasize that human behaviors and lives are inseparable from object histories in the material matrix. To measure patterning in these contexts and sequences of behaviors, they defined four dimensions of archaeological variability: formal, spatial, quantitative, and relational (Rathje & Schiffer 1982; Schiffer 1987). The formal category includes any physical measure that can be taken on an object (weight, specific gravity, completeness, length, width, color, etc.); the other dimensions have more constraints. In any given activity, one or more objects are associated with each other (relational), their frequencies (relative and absolute) can be counted, and their location(s) in space measured. The term correlate, adapted from the new archaeology, became the regularities in interactions between people and objects recognizable in these life histories, measured in relation to the four dimensions of variability.

This research revealed that patterns of cultural deposition could be modeled quantitatively for a community by employing variables such as the number of an object type in use, the length of its use life, duration of use period, and rates of reuse (Schiffer 1976). The implications of these and other variables dramatically changed how archaeologists perceived the opportunities afforded by different sites and archaeological contexts. Any archaeological interpretation requires a series of inferences and can be conceptualized as a series of hypothetical people and object life histories. A behavioral consideration of those hypothetical histories can only lead to better, more-informed interpretations. Even seemingly pedestrian inferences about the dates of an assemblage are deeply enmeshed in formation process questions. How do the relative frequencies of pottery in a site reflect known or hypothesized cultural phases, given the variability in ceramic life histories, as denoted by the variables listed above? Similarly, how does the life history of a piece of organic material with a specific radiocarbon date shed light on the dates of materials associated with it in an archaeological context (Dean 1978)?

The synthetic model of inference drew together various sources of actualistic knowledge, including ethnography, ethnoarchaeology, history, and experiments, to create correlates that could be used in inferences about unknown relationships between past peoples and objects. Such a model necessarily assumes continuities between past and present relationships: (1) the sequential nature of behaviors forming objects' histories, (2) the causal contribution objects make to behaviors that propel the forward motion of activities in life histories, and (3) four kinds of measurement that make possible the empirical study of object performances and life histories. To call attention to the generalizations concerning artifact disposal activities and subsequent archaeological patterning, Schiffer coined the terms c- and n-transforms, which denote the effects that natural and human or cultural processes have on the formation of archaeological deposits. The articulation of this model and its parts led to a break between new archaeologists and behavioralists.

The Pompeii Premise

The initial discussion of behavioral chains, systemic and archaeological contexts, and the lawlike relationships between people and artifacts, although offered as contributions to the cause of new archaeology, was quickly recognized as different and even threatening by Binford and other new archaeologists because it demonstrated that a realm of messy behavioral variability had not been accounted for in their broad theoretical perspectives. For some new archaeologists, the behavioral perspective became a subject for puerile satire (Flannery 1982), but for others, it represented a theoretical heresy requiring extirpation (Binford 1981). Binford (1964) had claimed that the archaeological record was like a fossil, preserving the skeleton of past cultural subsystems. Behavioralists, however, knew like any taphonomist that the organization of peoples' relationships with objects changed from their living context (systemic context) to the archaeological context and that understanding how that transformation occurred was central to any archaeological inference. Behavioralists therefore criticized metaphorical references to the archaeological record as a fossilized cultural system, labeling them as the Pompeii premise (e.g., Schiffer 1985).

Binford (1981) took up the challenge and a debate ensued over whether there was a Pompeii premise in archaeology. As it was framed by Schiffer and Binford, the issue was whether the archaeological record accurately reflected the past and its implications for archaeological research. Binford argued that it did, while Schiffer (1987) argued that patterning in the archaeological record was a distortion of past cultural systems. Binford uncritically suggested that because Schiffer highlighted the differences in archaeological and systemic contexts and advocated bridging them through the reconstruction of past object life histories, he would only be satisfied to work with Pompeii-like assemblages where the transformations were purportedly trivial. Schiffer argued that to study the proximate causes of variability in archaeological deposits, one had to consider the archaeological record as transformed in order to take advantage of the information offered by any particular archaeological context. In hindsight, this debate concerned two different visions for material culture study and the role of archaeological research in that study.

For Binford, the archaeological record was analytically conceptualized as the product of the interacting subsystems and therefore necessarily if only vaguely encompassed all the variability in life histories of objects, including their disposal, as attributes of the system. Therefore, the system could not be a transformation of itself. For Schiffer and others, the archaeological record was a creation of specific natural and human interactions that changed through the course of peoples' and objects' lives. As such, the debate exposed the differing scales of analysis that were central to the visions behavioralists and New Archaeologists had for archaeology. New Archaeologists had a priori a causal theory of evolutionary change they sought to implement, while behavioralists had an understanding of the material matrix of human behavior they sought to document and explore. Although it was never explicitly stated, this debate seems to have freed behavioralists to pursue their vision without further attempting to justify it within a unified archaeology. They realized that to pursue studies of the material matrix, they would need to shape their own questions, methods, and data independently of the strictures of social evolutionary theory.

Schiffer and others turned their attention to exploring behavioral approaches to technology and expanding the role of behavioral research to topics such as communication and ritual where the material matrix of behavior had been undertheorized.

Technology

Given the expanded understanding of behavior as interaction with objects, it runs awfully close to general understandings of technology. Technologies being central to understanding the material matrix of behavior, behavioralists have focused on how they perform in particular contexts and how they change over time. They elaborated the concept of performance characteristics for studying activity-based interactions, especially during use (Skibo & Schiffer 2008), and have employed the processes of invention, development, manufacture, and adoption in framing questions about technological change (Schiffer 2011).

Performance Characteristics

Inspired by the work of Braun (1983), behavioralists recognized that to study the behaviors associated with technologies – indeed all interactions with objects – they needed to develop an analytical concept that could capture the causal influences that material objects contribute to interactions with people. Archaeologists had long known that the material properties of objects such as temper in pottery or the toughness of chipped stone tools affected how people used them. Yet analysis of the performance of an object in a specific interaction requires more than a listing of its formal properties. A performance characteristic is a capability, competence, or skill that can be exercised in an activity-specific interaction. Formal properties, influenced by an object's chemical and physical properties, affect performance characteristics. In traditional pottery, for example, temper, surface treatments, and wall thickness affect how rapidly a vessel can heat its contents – a performance characteristic known as heating effectiveness. Heating effectiveness might be favored in cooking pots but not typically in serving vessels. A performance characteristic is a relational construct, not an essential property of an object. Thus, a vessel's closeness to the fire influences its heating effectiveness in a specific cooking activity.

Braun's (1983) interpretation of performance characteristics was focused narrowly on the interactions that an object required in order to perform its utilitarian functions. To accommodate other kinds of interactions, behavioralists have expanded the concept of performance characteristics to include any sort of interaction between objects and other objects, between people and objects, and so forth (Schiffer & Miller 1999; Skibo & Schiffer 2008; Schiffer 2011). And so behavioral archaeologists speak of sensory performance characteristics as relating to basic human senses (sight, sound, touch, taste, smell); performance characteristics also pertain to human competences in, for example, social and economic interactions; thus, an object's replacement cost is a performance characteristic that affects interactions in an acquisition activity. Communication of group identities – indeed any social information – as well as communication with supernatural entities may also be framed in terms of particular performance characteristics. In the hands of behavioral archaeologists, performance characteristics have become a versatile construct essential for studying object interactions of any kind in activities.

Study of Technological Change

In approaching the study of technological change, one of archaeology's oldest preoccupations, behavioralists recognize that generalizations – theories, models, etc. – ought to be process specific, focused either on invention, development, manufacture, or adoption (Schiffer 2011). Thus, in dealing with invention processes, behavioralists have fashioned the cascade and cultural imperative models. The cascade model specifies that during the course of developing a complex technological system (anything from a bow and arrow to a nuclear submarine) performance problems arise. To solve a performance problem requires a burst of inventive activities, which may lead to a solution; further problems are usually encountered, which generate other invention cascades. The cultural imperative model states that the vision of an imagined technology, as defined by anticipated performance characteristics, is held by a constituency, a group of people who believe that its creation is inevitable. Thus, whenever apparently appropriate parts or components become available, a flurry of inventive activities takes place as people strive to materially realize the cultural imperative. It would appear that the cultural imperative model is applicable mainly to industrial societies. Behavioral archaeologists also made contributions to the study of adoption processes by creating the performance matrix – a heuristic for comparing the performance characteristics of two or more technologies among which consumers choose (Schiffer 2010, 2011). A well-constructed performance matrix, which includes all potentially relevant performance characteristics, usually displays patterns, such as one technology that excels in use-related performance characteristics, while another excels in manufacture-related ones. These patterns furnish grist for the archaeologist's explanatory mill. First employed in a study of ceramic change in the eastern United States (Schiffer & Skibo 1987), the performance matrix has been elaborated and employed in diverse studies of technological change (Skibo & Schiffer 2008; Schiffer 2010, 2011).

Performance and the Expansion of Behavioral Studies

Simultaneously with the development of behavioral approaches to archaeological inference and the study of technology, in the 1980s archaeology witnessed the advent of postprocessual archaeology. This new school of thought dramatically changed the landscape of archaeological method and theory. In his postprocessual manifestos, Hodder (e.g., 1985) argued among other ideas that that the "materialist" scientific approaches favored by processualists ignored the roles of peoples' beliefs in shaping their actions, relegating beliefs to the least causal realm of ideology, which left no room for individuals to shape the organization of cultures. Initially this postprocessualism seemed an anathema to behavioral archaeologists who saw themselves as scientists. Many wondered whether the discussion of beliefs and mind would shift attention away from concrete behavioral variability and toward immaterial conceptual variability. However, as debates evolved inside and outside of behavioral archaeology, it became clear that the issue of scale exposed in the Pompeii premise debate was one shared with postprocessualism, as particular behaviors could, independently of the scale of system organization, contribute directly to the formation of archaeological deposits. Further, it was also clear that human behavioral variability extended to any activity involving objects; therefore, activities pertaining to ritual and religion, communication, and technological organization that did not pragmatically relate to subsistence were still interesting and important arenas for behavioral research. Consequently, the postprocessual critiques actually opened up opportunities for behavioralists to show how their approach could be fruitfully applied to these important topics without necessarily accepting the assumptions of postprocessualists concerning the role of science or the centrality of "meaning" as an analytic construct for studying human behavior.

In the 1990s, behavioralists plunged directly into these contested realms. Walker et al. (1995) called this "expanding behavioral archaeology" and referred to themselves as new behavioral archaeologists. They stressed the importance of a relational understanding of behavior and its relevance to a broad range of research topics including ritual site formation processes, political power, and technological change. Given that interactions with material objects take place in ritual and political realms, which also affect archaeological deposits, it made perfect sense to explore how such realms were materially constituted – regardless of one's ultimate stance on evolutionary causal hierarchies. Similarly, given that behavioralists were committed to studying behavior rather than the archaeological record per se, Schiffer could undertake, from a behavioral perspective, case studies of technological change using the history of radios and electric cars (Schiffer 1991; Schiffer et al. 1994b).

Ritual Studies

Walker (1995, 1998, 2002) and others (e.g., Montgomery 1993; Zedeño 2008) have sought to extend the study of behavioral archaeology to include ritual and religion. The lessons learned so far are that – like all behaviors – ritual behaviors contribute to the forward motion of object life histories and that those histories can be identified in the archaeological record because they affect the four dimensions of artifact variability. Like all activity-based interactions, performance characteristics come into play, but they are complicated and cannot be corralled by assumptions about the pragmatic uses of the objects.

A legacy of the New Archaeology's hierarchy of material causality had been a conflation of those activities deemed materially less causal (i.e., ritual practices) and the material evidence of those activities. It was a traditional assumption, well into the 1990s, that ritual activities left little material evidence. Yet this makes no sense in terms of the material matrix created by human behavior. All activities are by definition materially constituted; thus, given the plethora of ritual activities in every society worldwide, it is a physical impossibility that these diverse behaviors leave no archaeological traces. Acting on the basis of the traditional assumption, few traces were found, which only highlights the strength that theoretical assumptions may have over the formation of questions, methods, and data. As behavioralists began to look for evidence of ritual in object life histories, they found it everywhere. In well-documented archaeological contexts such as the pueblos of the American Southwest, it was evident that much time and energy went into the ritual construction, use, and disposal of ceremonial architecture as well as associated artifacts. It also became clear that, by relegating religion to the immaterial realm of ideology without pragmatic consequence rather than treating it as a kind of activity, archaeologists had assumed that ritual artifacts could be identified by default as nonutilitarian objects. Examination of known behavioral contexts such as ethnographies demonstrated that this was far too simplistic. Indeed, in the American Southwest, the houses of all nonpueblo peoples are central to ritual activities; moreover, everyday subsistence staples such as corn and water are the most revered ceremonial objects among many southwestern cultures. Finally, reuse is a critical factor in understanding their life histories, as many artifacts can move into and out of ritual contexts independently of our preconceived notions of utility. What appear to be old, even well-worn cooking pots and water jars are often used by Hopi peoples in their most sacred ceremonies.

Ritual and religious studies are just beginning to take advantage the material matrix. Recent ritual research (Walker 2008, 2009) has begun to combine study of performance characteristics, oral traditions, and interaction with nonhuman beings. Behavioral approaches to communication offer a useful model for integrating these facets of ritual studies.

Communication Studies

In one of the most innovative applications of behavioral archaeology, Schiffer and Miller (1999) designed an object-based model of communication. Typically communication studies focus on the transfer of information between two or more people and prioritize the intentions of the information senders. This move represents the height of common sense, but it fails to take advantage of, and indeed is actually undermined by, the complexity of the material matrix of behavior. Communication – like all other interactions – involves objects, and so an exclusive attention to people leaves out significant parts of the communicative process. What is more, although people may intend to send information, what is actually sent is only as real as what the receiver gets. Therefore, attending only to the sender's intent is fraught with problems. Also, much information is sent and received independently of conscious goals on either end.

Schiffer and Miller as behavioralists were aware of the limitations of conventional formulations based on prioritizing the sender's perspective and called attention to a symmetry between the process of communication and the process of archaeological inference. Archaeologists, after all, receive information about past peoples through interaction with artifacts. The process is often a lot slower than communication in everyday interactions, but they argue that the processes are analogous. Accordingly, they proposed a receiver-oriented approach to the study of communication in which artifacts as well as people are incorporated into the process. They developed a model composed of three information-related roles: senders, emitters, and receivers. In simple formulations similar to traditional "mediated" models of communication, one person (the sender) encodes or inscribes information through interaction with an artifact (the emitter), and from that artifact's subsequent performance, the receiver obtains information. This process of communication would be tracked by studying how receivers reacted to information they gleaned in an interaction with the emitter. However, there is no reason to restrict communication to such a narrow range of possibilities. In theory, these roles could be played by any of the interactors. Thus, an artifact could, while interacting with a person, modify that person who would then nonverbally emit information to another person. A serrated knife (sender), for example, inscribes its signature in a mortal wound (emitter) that emits information to a forensic pathologist (receiver). Perhaps even more interesting is the possibility of passing information about the hidden world of supernatural entities. While the process is a material one, there is no reason that the information need be materially scientific. After all, how much information flowing through the material matrix has been so vetted? In many cultural contexts, evidence of the presence and intentions of witches, spirits, or other nonhuman agents are received regularly.

Future Directions

Behavioral archaeology has consistently fine-tuned its understanding of human behavior as the interaction of people with objects while simultaneously expanding its reach into the material matrix created by that behavior. Likely behavioralists will continue to study formation of archaeological deposits, technology, ritual, landscapes, communication, and social power. Behavioral archaeology like any productive program is constantly building and systematizing its assumptions and their implications for future research. In seeking to bring order to studies of a material matrix that by its very nature changes and moves through time, behavioralists find that a broad range of social and sensory performance characteristics remain only minimally integrated. Recent application of the synthetic model of inference to the study of communication has demonstrated that interactions between people and objects and the attendant performances of interactors highlight a logical equivalence between behavior and flows of information. This equivalence suggests that for some questions interactions are fruitfully studied as behaviors and for other questions as communicative processes. Likely behavioral archaeologists will continue to explore these and other symmetries as they push deeper into the material matrix of human object interactions.

Future directions in behavioral archaeology are only limited by a researcher's creativity in asking and answering behavioral questions about any human behavior in the material matrix. One area that should see much more attention is scientific activities, as practiced in any society. Discovery processes, for example, have been resistant to the generalizations of historians, philosophers, and social scientists. We suggest that a behavioral approach can make useful contributions because it is grounded in the people-artifact interactions that are the settings for discovery.

Cross-References

- ▶ Analogy in Archaeological Theory
- ▶ Ethnoarchaeology
- ▶ Material Culture and Education in Archaeology
- ▶ Materiality in Archaeological Theory
- ▶ Processualism in Archaeological Theory
- ▶ Technological Studies in Archaeological Science

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Bell, Gertrude

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Basic Biographical Information

Gertrude Margaret Lowthian Bell was born on 14 July 1868 in Washington Hall, County Durham, England. She came from a line of wealthy ironmasters. Her grandfather, Sir Isaac

Lowthian Bell, and her father, Sir Hugh Bell, were heavily involved in politics. Her mother died when she was a young child and she was brought up by her stepmother Dame Florence Bell, who was a playwright and author.

Gertrude Bell's early education was at Queen's College in London. She enrolled at Lady Margaret Hall, Oxford University in 1886. She specialized in modern history, becoming the first woman to earn a first-class degree in the subject. She was not formally trained in archaeology, aside from a few weeks spent with Dr. David Hogarth in Greece while on holiday in 1898 (Burgoyne 1958; Winstone 1978). The beginning of her lifelong passion for the Middle East can be traced to a visit in 1892 to her uncle, who was an ambassador serving in Tehran, Iran (Winstone 1978). In 1899, she began a period of sustained travel in Asia, Europe, Mesopotamia, and Arabia. She became fluent in Arabic, Turkish, and Persian and wrote of her experiences in five works that were published in the two decades preceding the First World War (Howell 2006). During this war, Gertrude Bell worked as a spy for the British Government gathering information on Turkish railways and forming alliances with Arab tribes, alongside T.E. Lawrence. Following the British capture of Baghdad in 1917, Bell became heavily involved with the political reinvention of Mesopotamia due to her understanding of the area and fluency in the language. Bell was a passionate believer in Arab independence, and assisted in setting up infrastructure and installing ruler Faisal I as monarch of Iraq (Burgoyne 1958).

Major Accomplishments

Gertrude Bell's career focused on the archaeology of Greater Syria, Mesopotamia, Asia Minor, and Arabia. Her major accomplishments in archaeology include scholarly publications on Byzantine monuments in Asia Minor, the establishment of legislation and methods that significantly improved the protection of cultural heritage in Iraq, and establishment of the National Museum of Iraq. However, she is perhaps best known for her role in developing the political borders in the Middle East after the First World War, particularly those of Jordan and Iraq.

In her own words, Gertrude Bell considered herself "nothing better than an antiquarian at heart" (Bell 1927). However, many of her scholarly works on Byzantine monuments in Asia Minor are still considered the standard works on the subject (Howell 2006). Bell conducted several surveys over the course of her travels, especially during her 1905 trip to western Syria and Anatolia (Lawler 2008). Chief among these surveys was her work at Bibnirkilisse, with the resulting book completed with Sir William Ramsay considered "one of the most enduring works of scholarship" of the area (Ousterhout & Jackson 2008: ix). Bell's book *The Palace and Mosque at Ukhaidir* (1914) is considered by some to be "her most important contribution to archaeology" (Lukitz 2006).

One of Bell's major contributions to archaeology is the early development of practical methods for a government to work with archaeologists to protect a country's cultural heritage. She played an eminent role in setting up the necessary infrastructure needed for serious and scholarly excavation rather than the treasure hunting and amateur excavation seen in the Middle East before the First World War. The stable political climate in Iraq that existed at that time brought renewed interest from archaeologists to conduct excavations in Iraq. Responding to a need for updated antiquities legislation, Bell began writing a Law of Excavations, which was enacted at the end of 1922 (Bell 1927). The progressive attitude of these laws and their favorable conditions for archaeologists allowed the development of new techniques and new methods of excavation. In this way, Bell's work is still relevant and influential on younger generations of archaeologists.

Gertrude Bell pioneered the idea of retaining antiquities in their country of origin rather than transporting them to European museums or collections. In 1926, she established the National Museum of Iraq, which held one of the world's greatest collections of Mesopotamian antiquities prior to the 2003 invasion by the United States and its allies (Wallach 1996; Lawler 2008).

Driven by her love of the country, Bell became Iraq's Honorary Director of Antiquities in 1922. She dedicated the last years of her life to developing Iraqi national identity through ownership of its cultural heritage (Winstone 1978). To implement this, Bell traveled to archaeological sites at the end of each excavation season to divide the finds between the archaeologist and Iraq (Winstone 1978). She also traveled to places where local people were undertaking their own excavations and bought any significant finds (Bell 1927). She left behind a competent record of archaeological sites, including a highly valuable photo record of 7,000 photos, taken between 1900 and 1918.

Gertrude Bell is lauded today as a pioneering woman in archaeology. It is somewhat ironic, however, that she opposed the right of women to vote, contending that women were not ready to vote while they remained confined to the domestic sphere (Bell 1927). This may be due in part to the influence of her stepmother, Dame Florence Bell, who encouraged her involvement in the intellectual activities of the Anti-Suffrage League (O'Brien 2000). Gertrude Bell's commitment to education, however, is demonstrated through her dedicated promotion of the education of Iraqi women.

The times in which Gertrude Bell practiced archaeology were vastly different from those of the modern day. She practiced during a period when the British Empire held great sway over much of the wider world and when archaeology was practiced as an eccentric oddity, with little accountability, except to their intellectuals. Archaeologists of the time were yet to embrace the scientific approaches of "new archaeology," or address the politics of cultural ownership, a matter which is so pressing today. However, Gertrude Bell excelled in both areas. Her thoroughness and attention to detail were congruent with the tenets of scientific archaeology and her political awareness, respect for the people whose cultures she studied and support for repatriation and self-rule is a model for postcolonial archaeology today. Beyond this, Gertrude Bell was a role model for the archaeologist as hero – feminist hero.

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▶ Middle East Archaeology: Sites, Texts, Symbols, and Politics

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Beltrán Martínez, Antonio

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Basic Biographical Information

Antonio Beltrán Martínez became professor at the Department of Archaeology, Epigraphy and Numismatics at the University of Zaragoza in 1949, the place from which he worked most of his academic life. For 60 years and with a clear mind until the very end, he was a prolific university lecturer, manager, and researcher, while at the same time, he was an excellent communicator with an incredible ability to maintain the interest of all kinds of audiences, academic as well as general public. He inspired the creation of publications, museums, and cultural parks and organized 27 archaeology conferences. He founded the series of archaeological monographs for the University of Zaragoza, where he published the majority of his books. Among many other honors, he was named the city's official Chronicler, and he was awarded the Aragón Award. Author of more than a 100 books and more than a 1,000 articles (367 on rock art), he was a true scholar with a knowledge so encyclopedic that he could write numismatics handbooks as well as speak about the food culture of Aragón, the typical dress, or the local patron saint.

However, what made him truly happy was the study of rock art, the subject to which he dedicated his later research career and which brought him international recognition. He was member of the International Rock Art Committee (ICOMOS), represented Spain in the International Union of Prehistoric and Protohistoric Sciences (IUPPS), and chaired the ninth Commission of Prehistoric Art. He travelled wherever there was rock art, like Kakadu National Park in Australia, Serra da Capivara in Brazil, and the paintings in Namibia. He collaborated in the defense of the Portuguese rock art site at Foz Coa. He was always ready to go to the most inaccessible caves, like Los Estrechos in Albalate where, at almost 80 years of age, he rope climbed to study the schematic paintings (Figs. 1, 2, and 3).

Beltrán Martínez, Antonio, Fig. 1 A. Beltran (aged 82)

Beltrán Martínez, Antonio, Fig. 2 A. Beltran (aged 75) climbing up a ladder to take photographs of the schematic rock paintings of Los Estrechos (Albalate del Arzobispo, Spain)

Major Accomplishments

A brief itinerary of his work relating to rock art can be divided into two distinct stages:

1. From 1966 to 1988: Fieldwork outside of Aragón: he studied various Paleolithic caves in the French Pyrenees, and he travelled all the Spanish east coast studying post-Paleolithic art and travelled to the Canary Islands to study its engravings and paintings. Among his publications, three archaeological monographs about Paleolithic art stand out (Le Portel, 1966; Bedeilhac, 1968 y Niaux, 1973), five more about the Levantine rock art (1969: los Grajos; 1970: Valdelcharco; 1972: Cañaíca del Calar y Fuente del Sabuco; 1976: La Sarga; 1988: Peña Rubia) or schematic art (1972: Lecina), and two books about the rock art of the Canary

Beltrán Martínez, Antonio, Fig. 3 A. Beltrán (aged 90) presides his last Ph.D. jury in the University of Zaragoza

Islands (Barranco de Balos, 1971; Gáldar, 1973). His book of synthesis *Arte Rupestre Levantino (Levantine rock art)* (Zaragoza, 1968) provided a global vision about the geographical location, technique, and themes and approached the problem with chronology advocating the most popular sequence, from the most naturalistic to the most schematic, theory that years later he himself would question. He published Italian versions in Milan like *Da cacciatori ad allevatori: l´arte rupestre del Levante spagnolo* (1980) and *Arte rupestre preistorica* (1993), which were also translated into English and French.

2. From 1989 to 2006: At the age of 60, he focused only on Aragón and began doubting his own chronological system. In his book of synthesis *Arte prehistórico en Aragón* (1993) (*Prehistoric Art in Aragón*), he includes surprising results about the chronology of schematic art. This versatile style that he believed to be typical of the Bronze Age acquired an apparent great antiquity with the appearance of geometric figures at Riparo Villabruna, similar to those from Chaparros site, located below "open-legged" Levantine motifs, which brought him to speak of a continuity since the end of Paleolithic art. On the other hand, the appearance of the sealed figures of Porto Badisco (Port Badisco) or the discovery of the Petracos style in Alicante forced him to outline the Neolithic chronology and to distinguish the semi-naturalist from the purely schematic.

Although he studied the schematic paintings of Estadilla in Huesca (1989), he focused with great eagerness on Bajo Aragón (lower Aragón, Teruel) where he led the creation of Río Martín's Cultural Park, the place he was most fond of. He dedicated his last eight monographs to the Levantine rock art sites located within this park (1994: La Higuera; 1995: Tía Chula y Cañada de Marco; 1989 and 1997: Los Chaparros y los Estrechos de Albalate; 1998: El Mortero; 2000: Garroso; 2002: Valdelcharco; 2005: Cerro Felío). In 2005 he finally published a complete catalogue of Río Martín. The impatient octogenarian seemed to want to quickly wrap up his knowledge before taking his final breath, which he did few months later, at 90 years of age.

Cross-References

▶ Côa Valley Rock Art Sites
▶ Europe: Prehistoric Rock Art
▶ Iberian Mediterranean Basin: Rock Art
▶ Rock Art, Forms of

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Berenike, Archaeology of

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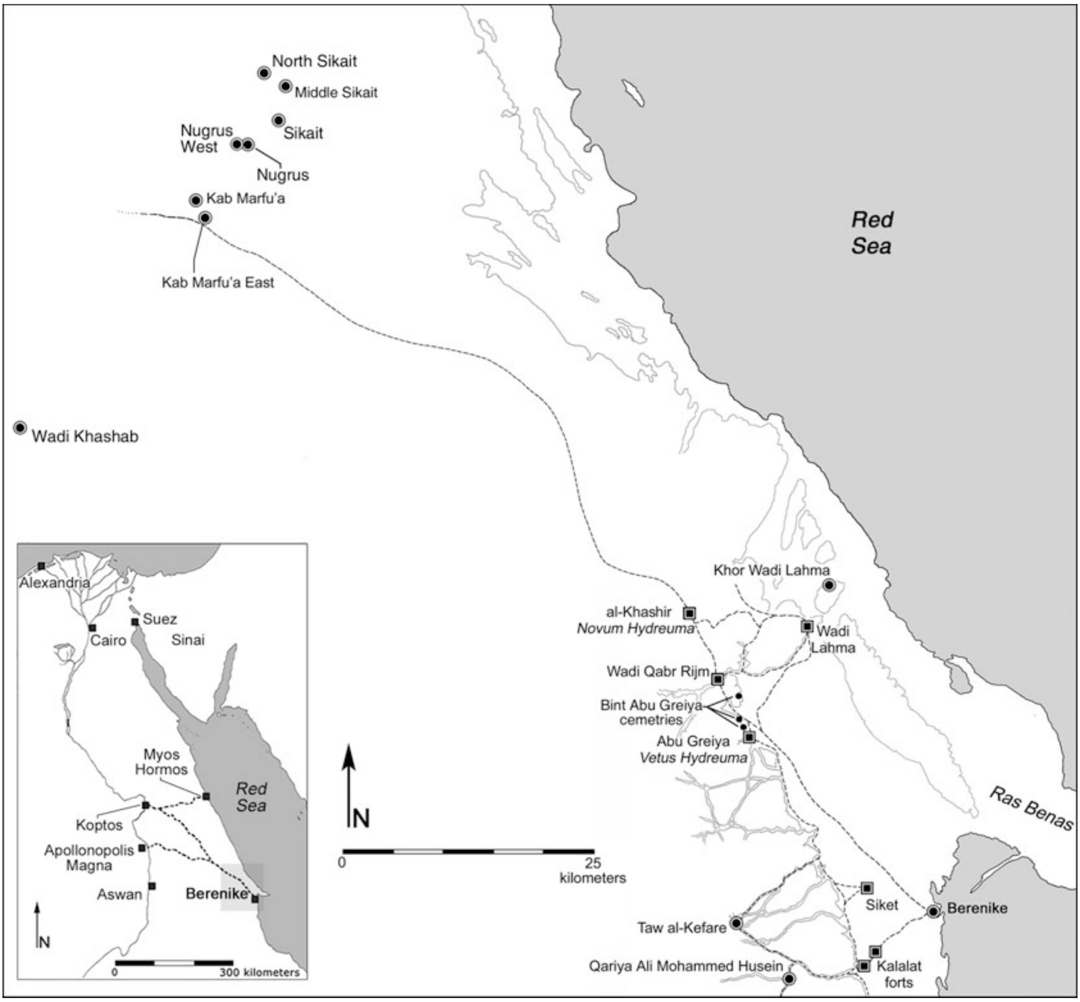
Introduction

Ptolemy II Philadelphus founded the Egyptian Red Sea emporium of Berenike (23° 54.62’ N/35° 28.42’ E) in c. 275 BCE. Berenike, approximately 825 km south southeast of Suez and c. 260 km east of Aswan, was the southern-most Red Sea emporium in Ptolemaic and Roman Egypt (Fig. 1). This entrepôt functioned for approximately eight centuries until abandoned sometime before the mid-sixth century CE. Building this settlement was part of a larger infrastructure project, which included excavating a Nile-Red Sea canal (termini at/near Bubastis-near Suez; at Babylon-near Suez in Roman times), establishing other ports along the Red Sea coast (both in Egypt and farther south on the African littoral), creating roads – and forts and watering stations – in the Eastern Desert of Egypt linking Red Sea ports to counterparts on the Nile, and exploiting the desert primarily for gold and some amethysts. The Romans increased exploitation of mineral wealth in the Eastern Desert (beryls/emeralds, amethysts, gold, and hard stone for building and statuary, including marble). The Romans enlarged Red Sea ports in Egypt and expanded the desert highway system. The latter included renovation/extension of old roads and construction of new ones with additional watering points, *praesidia* (forts) and *skopeloi* (watch and signal towers). Roads in the Eastern Desert in both Ptolemaic and Roman times consisted of cleared tracks of varying widths with surface debris pushed to the edges forming windrows; none of the highways appears to have been paved and few, if any, milestones were erected.

G.B. Belzoni (re)discovered Berenike in 1818 and throughout the nineteenth and early twentieth centuries European visitors (including J.G. Wilkinson, J.R. Wellsted, W. Golénischeff, and T. Bent) conducted cursory examinations and cleared portions of the so-called Serapis Temple on the highest part of the site. The current project, 1994–2001 (University of Delaware, USA-Leiden University, the Netherlands/UCLA) and 2008-present (University of Delaware-Polish Centre of Mediterranean Archaeology, University of Warsaw), has undertaken systematic, scientific surveys, excavations, documentation, and extensive publication (Fig. 2).

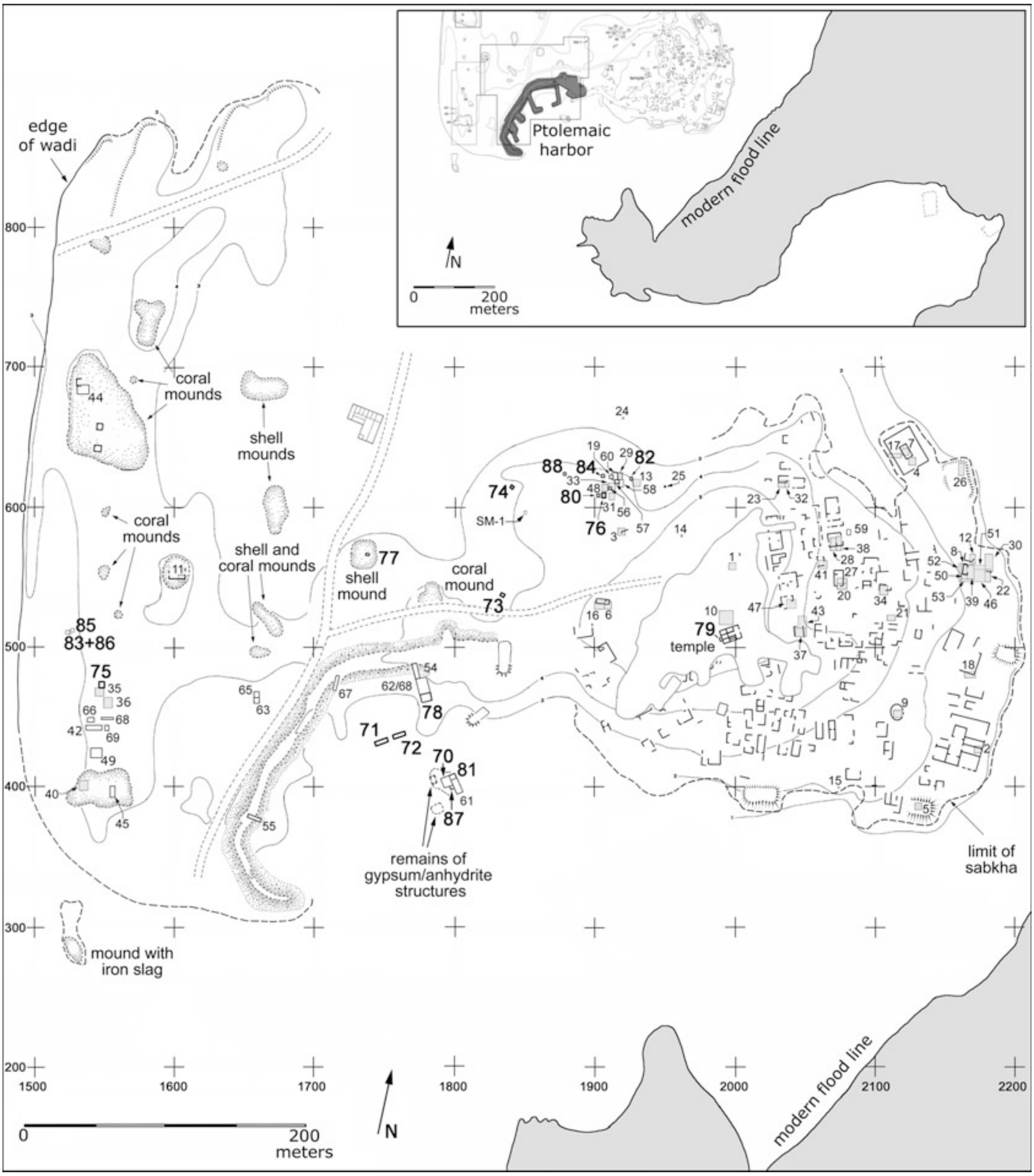
The ruins of Berenike cover approximately 28.5 ha with a maximum east-west length of about 700 m × 400 m (in one area an additional 5,000 m^2) north-south. Geological coring



Berenike, Archaeology of, Fig. 1 Map of Egypt showing location of Berenike and environs. Drawn by M. Hense

combined with studies of seismic and tectonic activities in the Red Sea in general indicates sea level changes over the past two millennia; inflow of sediments via wadis debouching into the Red Sea immediately north and south of Berenike resulted in silting of the northern, southern, and southwestern harbors. The ancient inhabitants made no attempt, apparently, to dredge (as was the case at Myos Hormos, a Roman – and likely Ptolemaic – port c. 300 km north of Berenike) to keep the harbors operational; instead, due to progradation of the coastline, residents moved the settlement eastward. Excavations thus far have shown that the Ptolemaic settlement lay farthest west, the early Roman community was east of that and the late Roman city lay the farthest east of all (Figs. 2 and 3).

Archaeological evidence indicates three peak periods at Berenike: early-middle Ptolemaic (mid-third to mid-second centuries BCE), early Roman (first to early second century CE), and late Roman (mid-fourth through fifth centuries CE). These were interspersed with nadirs (late Ptolemaic: second-first centuries BCE, middle Roman: much of the second to fourth centuries CE and later Roman: mid-late fifth to mid-sixth centuries CE) until abandonment sometime before the mid-sixth century CE.

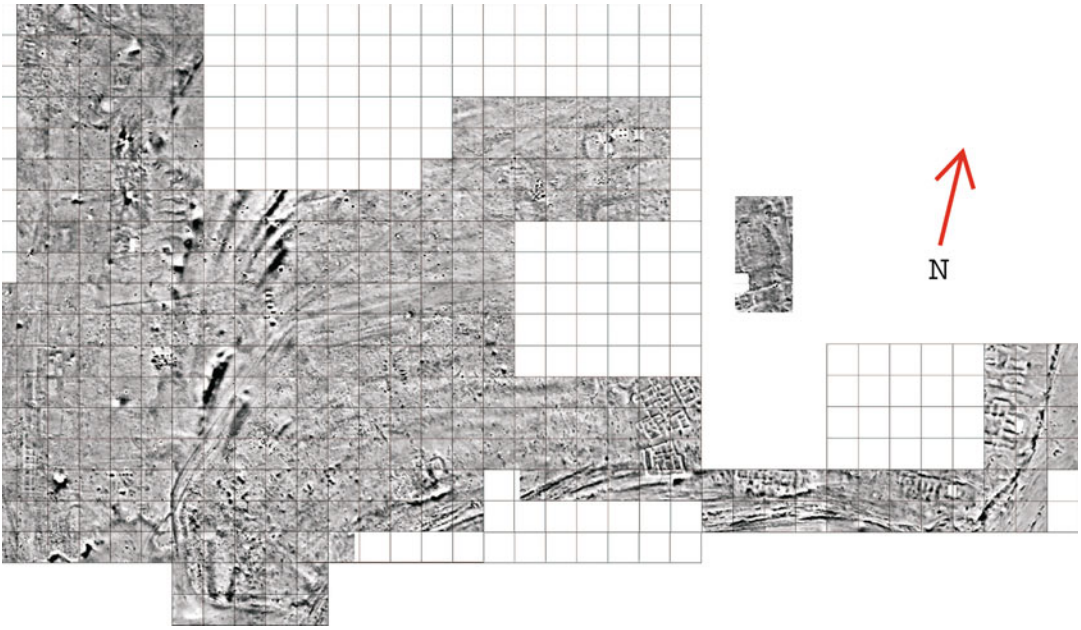


Berenike, Archaeology of, Fig. 2 Plan of Berenike with numbers indicating trenches excavated 1994–2001 and 2009–2012. Drawn by M. Hense and S. Maslak

Definition

Ptolemaic Era

Initially, Berenike's raison d'être was to meet the needs of the Ptolemaic government and military: importation of elephants (likely either the bush: *Loxodonta africana* or forest: *Loxodonta cyclotis* species) for the army, gold, and ivory. Some merchandise for civilian consumption also passed through Berenike on which the government levied substantial taxes. In Ptolemaic times there was contact mainly with other areas of



Berenike, Archaeology of, Fig. 3 Geophysical map of Berenike showing those areas examined (in *gray*) and those unexamined (in *white*). Prepared by T. Herbich

Egypt, Nilotic and Red Sea coastal Africa, and the Eastern Mediterranean/Levant. There were diplomatic exchanges between Ptolemaic Egypt and Aśoka, the Mauryan king of India, in the third century BCE and some contact with southern Arabia. A road across the Eastern Desert linked Berenike to Apollonopolis Magna (modern Edfu) on the Nile c. 340 km to the northwest.

Ptolemaic areas of Berenike lay primarily in the western part of the site, also some in the northern and central portions, and include zones for manufacturing activities (brick making, the production of lead, copper alloy, iron, creation of small-scale sculpture), a ditch (possibly for retaining elephants), and remains of a tower/other fortification (now badly robbed); the latter suggests military presence at this time. There are human skeletons deposited at some unknown date in antiquity atop some of the Ptolemaic ruins. Ptolemaic trash deposits lay north of the southwestern-most harbor. Building materials include gypsum/anhydrite, limestone, and assorted stones. Fired brick appears in a section of a cistern; this material is not evident in other excavated structures on the site though individual loose fired bricks appear throughout the archaeological record in the Roman period.

Artifacts and ecofacts from the Ptolemaic era are mainly amphora sherds (some with stamped handles: mainly from Rhodes), lead sheets (sheathing for ships' hulls), copper alloy and iron nails and tacks, some sculpture, beads, ostraka written in Demotic, burned industrial waste and some organic remains (faunal, botanical, basketry, cordage, matting). There are also some Ptolemaic silver and *aes* coins. The oldest artifact documented thus far is a fragment of a faience scarab-heirloom with a hieroglyphic text from the tenth century BCE (twenty-first Dynasty Pharaoh Siamun) excavated from an early Ptolemaic trash deposit. Faunal analysis indicates mainly an Egyptian and desert dwelling population at this time.

Early Roman Era

Roman (30 BCE to mid-sixth century CE) activities were more commercial and civilian in nature than under the Ptolemies. The volume of trade also increased. During the Roman occupation networks expanded geographically throughout much of the Mediterranean basin. In early Roman times these stretched as far west as Gaul and the Iberian Peninsula and at least as far east as India and Sri Lanka on a regular basis. Interaction with the Persian Gulf was minimal and indirect via emporia in southern Arabia (Sumhuram, Qana'); there appears to have been little exchange with the Indian Ocean coast of Africa. At this time Berenike was one conduit in a network that included routes (intra-Mediterranean, trans-Saharan, Amber, trans-Arabian, and so-called Silk) linking portions of Africa, Asia, and Europe together. There are numerous ancient literary references to Berenike and its importance in the commerce of this era (e.g., Strabo, Pliny the Elder, *Periplus Maris Erythraei*). The Roman government profited handsomely from taxes and tolls levied on merchandise and its transport across the desert. In the Roman period the main thoroughfare connected Berenike to the Nile emporium of Koptos (modern Quft), c. 381 km to the northwest (north of Apollonopolis Magna).

Early Roman remains at Berenike comprise portions of the southwestern harbor with putative wharfs/quays and other unidentifiable structures including one sunken and made of white gypsum/anhydrite ashlars. The appearance and method of construction of the latter closely resemble those of the so-called Serapis Temple at the topmost part of the city, which may be Ptolemaic or early Roman in its original construction. There are early Roman (mainly second and third quarters of the first century CE) rubbish deposits north of the city, edifices in the city center (so-called Serapis Temple and associated structures), and eastern edge of the inhabited area (including waterfront walls/a wharf) near the modern shore line. The scant remains of early Roman era structures indicate construction from limestone boulders and gypsum/anhydrite ashlars quarried from nearby sources.

Early Roman period finds include extensive organic and inorganic remains of artifacts and ecofacts (faunal and floral) mainly, but not exclusively, from the early Roman rubbish deposits north of the city. Most written documents from the site date from this era (ostraka, papyri, inscriptions on stone and dipinti on wood and shell, and stamped and/or painted plaster jar stoppers). Most ostraka are public documents, while the majority of papyri detail private affairs. Several ostraka archives contain information on the Roman customs house in the city at this time. Quantitatively, most identifiable coins found from all phases of site occupation (both billion and *aes*) also date from this era. Finds from the southwestern harbor include ship timbers made of cedar wood, rigging, lead hull sheathing, and ships' ballast comprising vesicular basalt imported from Qana' in Southern Arabia. There is also redeposited industrial waste: stone – including large amounts of imported obsidian – some sard, selenite, beryl, worked turtle and mother-of-pearl shell, and extensive burned deposits: likely evidence of charcoal manufacture using discarded ships' timbers. The population at this time came from throughout the Mediterranean basin (Europe, North Africa, Middle East), Egypt, the Red Sea, and Indian Ocean littorals.

In early Roman times and later, there was military presence both at the port and in *praesidia* in the environs. Ten *praesidia*, ranging from southwest to northwest of the city and varying from 7.2 to about 25 km distant, protected approaches to Berenike in the early Roman period. Some of these installations witnessed Ptolemaic occupation and later Roman use as well. Several hundred early Roman era ostraka from the trash dump north of the city center indicate that the Roman army secured, transported, and distributed potable water from some *praesidia* for consumption at Berenike and, perhaps, for use aboard outbound ships. Military and police units also guarded/patrolled the route between Berenike and the Nile at Koptos and some of the mines (notably beryl/emerald, and likely gold) in the region.

Late Roman Era

In the late Roman period Berenike's network contracted in the north and west to include primarily the eastern Mediterranean/Levant, but remained extensive in the Red Sea-Indian Ocean basin (there is also a bead from Jatim, eastern Java). The main Nile terminus for the late Roman-era road lay at Koptos. The latest literary reference to Berenike is in 524/525 CE in the *Martyrium Sancti Arethae* (27–29), but the port had clearly declined in importance by that time. By the mid-sixth century Berenike lay abandoned due, perhaps, to continued harbor silting, a plague (bubonic), which Procopius mentions passing through the region and/or increased competition from South Arabian and Axumite middlemen. There is no evidence of Islamic occupation.

The bulk of the visible remains at the eastern edge and central parts of the site are late Roman structures (mid-fourth into the fifth century CE) built primarily of fossilized coral heads; these buildings have quoins, staircases, and some thresholds made from gypsum/anhydrite ashlars – including at least one bilingual (Greek-Latin) inscription built into a wall – recovered from earlier edifices. Teak and cedar wood timbers, likely recycled from dismantled ships, often appear as supports built into the walls or forming partial roofing for buildings in this period. The structures in this part of the site comprise cult centers, small-scale industrial areas, commercial-residential buildings, and trash dumps; the latter were deposited atop, inside, and outside of abandoned buildings. In the southwestern harbor are remains of a late fourth to fifth century CE temple adjacent to a sunken structure of unknown function built of white gypsum/anhydrite ashlars (see supra). The only formal necropolis thus far identified in/near the city dates from the late Roman era. In addition, hundreds of late Roman era tombs lay west/west southwest of Berenike; most of these have been robbed.

Late Roman era finds include many floral and faunal remains, both organic and inorganic artifacts (especially ceramics, textiles, basketry, matting and cordage, glass, beads, industrial waste and coins). Roman *aes* coins, mainly of the smaller denominations, are the second most abundant on site (after the early Roman issues). A few non-Roman coins date from this era: an issue of the Axumite King Aphilas (c. 270/290-before 330 CE), a silver example of Rudrasena III of the Kshatrapa Dynasty in India (dating 362 CE) and a few, apparently, barbarous *aes* productions of unknown provenance. The few written (non-numismatic) documents from this era of the city's history comprise laconic dipinti and graffiti on sherds. The population was primarily Egyptian (both desert dwelling and marine oriented based on faunal analysis of items they consumed) though there is evidence of contact with and, perhaps, people from Axum, Southern Arabia, and the Indian subcontinent/Sri Lanka who were trading with, passing through, or dwelling in the city.

Key Issues/Current Debates

General Observations

Berenike was very cosmopolitan. Twelve different written languages (European, African, and Asian, also an early second century CE inscription in Greek recording an interpreter/translator), a variety of religious practices and an array of floral and faunal remains (a reflection of diet and, often ethnicity) indicate the presence of diverse groups of men, women, and children, as do burial practices/skeletal remains. Texts indicate that some women played a prominent role in the life of the city, at least in early Roman times. Cats and dogs were among some of the pets of the residents in the early Roman era. In addition to commercial activities, there must have been cultural interaction among the diverse populations.

The port's ethnically diverse inhabitants ranged from those of lesser means to relatively wealthy (e.g., gold and pearl earring, undecorated and decorated gemstones from signet rings, Proconnesian marble imported from Asia Minor used as floor/wall revetment, consumption of escargots from southern France/Northern Italy, fancy tapestries used as wall hangings/furniture or floor coverings, other semiprecious stones – including a nice sapphire – and beads, many made of semiprecious stones and gold foil). Merchandise not only passed through Berenike enroute to markets in the Red Sea-Indian Ocean littorals or to Egypt and the wider Mediterranean world, but was also consumed at the emporium itself.

Berenike had some industrial activities: brick manufacture, production of lead, copper alloy and iron nails, tacks and fittings (for ship repair, furniture making and likely some architectural applications), recycling of glass, making items from mica, beryl, sard, obsidian, selenite and turtle and mother-of-pearl shell, manufacture of cordage, basketry and matting, wood, leather and animal horn working, and small-scale sculptural production in both Ptolemaic and Roman times.

Scholars have debated extensively the nature of the commerce passing through Berenike, and the trade between the ancient Mediterranean basin on the one hand and the "East"/northeastern Indian Ocean littoral (Southern Arabia, East Africa, South Asia, to a much lesser extent the Persian Gulf) on the other. The long held view that this was mainly a "luxury" trade for the elite must be reconsidered/discarded in light of all the evidence (literary and archaeological) pertaining to Berenike and other contemporary Red Sea and Indian Ocean emporia. This commerce included both "necessities" and also more "exotic" items. The term "luxury" must be used with great caution as it often reflects modern cultural bias rather than ancient sensibilities.

Some of the more noteworthy/unusual imports found in excavations at Berenike, mainly from the Roman era, were black peppercorns, coconut, rice, bamboo, jobs' tears (grass seeds from northeast India), rosary beads (*abrus precatorius* seeds from India), mung beans, *boswellia* (genus of frankincense), seeds of the baobab tree, mastic, camphora, perhaps sandalwood, teakwood (from south India), and cedar wood (from Lebanon). The teak and cedar, for the most part, appear to have been the remains of dismantled ships recycled into the walls of buildings. There was a long Egyptian tradition for such reuse of ship timbers. Other imports included Indian textiles, Syrian fir tree resin (used in mummification), sapphires (from south India/Sri Lanka), pearls (including five on a gold wire earring), lapis lazuli, beads (many from India, one from Java, some perhaps from Vietnam/Thailand), banded agate cameo blanks (from northwest India), travertine (from southern Arabia) balsam, Indian (both fine wares and cooking/coarse wares) and Axumite pottery, as well as some sherds of Persian Gulf provenance. No extant literary evidence mentions some of these, while others were not trade items per se (the pottery), but likely ancillaries to commerce (containers for commodities) or were personal baggage. The bulk of the pottery from Berenike is amphorae deriving from throughout the Mediterranean basin and Middle East.

Conclusion

Excavations at Berenike and elsewhere in the Red Sea and Indian Ocean basins over the past 25–30 years have shown that the scale of this global exchange was commercially greater in volume, involving a wider array of items and more extensive geographically than previously believed especially in the Roman period. The cultural exchanges are more difficult to identify and measure, but most certainly occurred.

Concomitant to work at Berenike the project has also conducted wide ranging surveys and excavations in the environs and farther afield in the Eastern Desert, between the Red Sea coast and the Nile. This research provides a wider context in which to understand better Berenike's interaction with and importance to local and regional settlements as well as with the broader network within Egypt, the Mediterranean basin, and the Red Sea-Indian Ocean regions.

The American-Polish project will continue excavations at Berenike and survey-excavation in the desert hinterland for the foreseeable future.

Cross-References

▶ Economy, Roman
▶ Hellenistic and Roman Egypt, Archaeology of
▶ Indian Ocean: Maritime Archaeology
▶ Late Antique Egypt, Archaeology of
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Berlin Wall

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Introduction

In a surprise action during the night of August 12/13, 1961, the Communist government of East Germany (the German Democratic Republic or GDR) erected barbed-wire barriers to stop all traffic between East and West Berlin (Hertle 2011). These linked up with a system of barriers already in existence along the border between West Berlin and the GDR, effectively isolating West Berlin and controlling all access to it. The closed border quickly grew into a fortification system that became universally known as the Berlin Wall.

Since 1945, Berlin as the capital of Germany had been under Four-Power administration, internally divided into the Soviet sector (East Berlin) and the American, British, and French sectors (West Berlin). While the inner German border between the GDR in the east and the Federal Republic of Germany in the west (both founded in 1949) had been effectively sealed since 1952 as part of the Iron Curtain, communication and traffic between the western and eastern sectors of Berlin had remained practically unhindered, with many East Berliners crossing daily into West Berlin to work or to study and West Berliners buying cheap goods in East Berlin, thus adding to the pressures on East German economy. Even more problematic was the fact that Berlin remained, all through the 1950s, the one loophole in the Iron Curtain: East Germans could travel to East Berlin, the capital of the GDR: once in East Berlin, they could cross to West Berlin, be registered as fugitives from the GDR, receive West German citizenship and move out to West Germany via the official transit routes,

Berlin Wall, Fig. 1 Section of the Berlin Wall built in 1961 (Michael-Reiner Ernst)

particularly the air corridors. Until 1961, not less than 2.7 million East Germans had left in this way – a dramatic loss for a country of roughly 17 million inhabitants (Wilke 2011).

The East German decision to close the border in Berlin depended on Soviet approval which was finally granted in the summer of 1961 (Harrison 2005). Part of the power play between the Soviet leader Nikita Khrushchev and US President John F. Kennedy, the closing of the border, and the propagandistically effective move of erecting a wall in the center of Berlin were not initially meant to be permanent, but to intimidate the West into agreeing to proposals of turning West Berlin into a "Free City" evacuated by the Western powers and dominated by the East. When it became clear that this strategy had failed, the GDR was faced with the task of turning the improvised barriers into a permanent "border regime" (Schmidt 2011a).

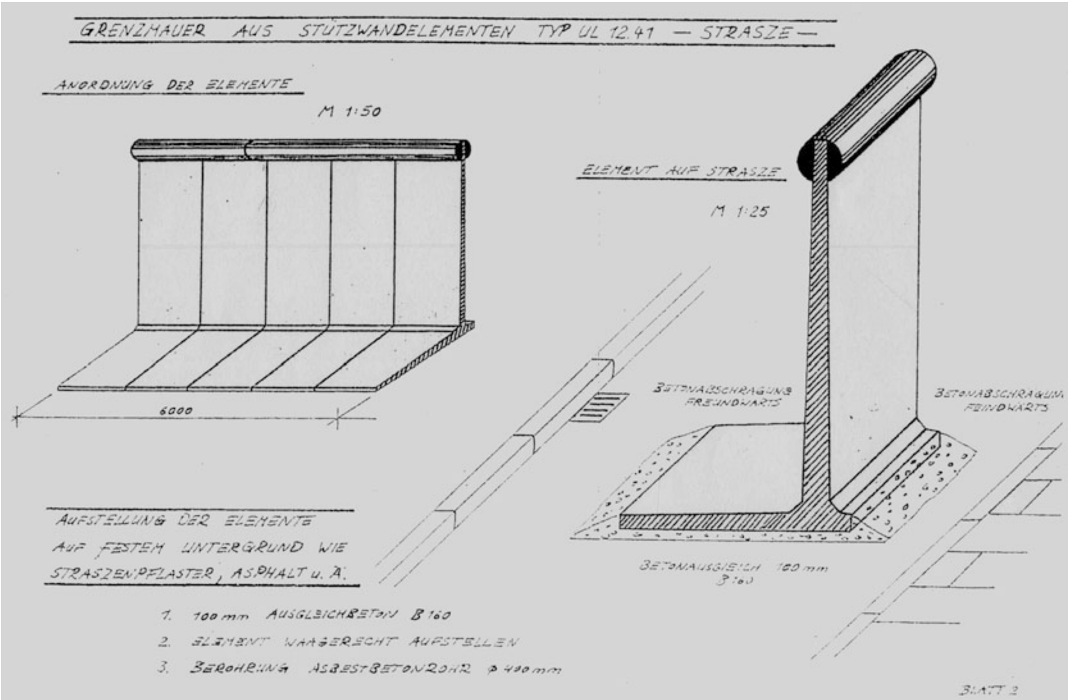
Key Issues/Current Debates/Future Directions/Examples

The Berlin Wall as a Structure

Within days, the barbed-wire barrier erected through Berlin was replaced by a wall – although it is worth noting that this first wall never extended beyond the city center. This first border wall was composed of breeze-block elements that were available in large numbers as they had been produced for the early prefabricated apartment houses of the GDR. This wall, usually about 2 m high, was topped by barbed wire strung along Y-shaped metal stakes (Fig. 1). Its perhaps deliberately brutal design and the fact that it was very unstable support the interpretation that this wall was largely built for propaganda purposes: It is known that the East German military favored the barbed-wire fencing that surrounded most of West Berlin and that it was Party Chief Ulbricht who insisted on a wall, presumably because it was more impressive visually.

During the following months, this initial structure was fortified and augmented in a number of ways, and in many places, the wall was raised by adding of extra courses. As a reaction to several successful escapes by fugitives breaching the wall with heavy vehicles, the breeze-block wall was sometimes replaced by barriers made of massive concrete slabs. Equally solid concrete elements were also employed in other locations, notably in Bernauer Strasse after the demolition of houses which stood directly on the border. Although involving only a limited modification of the earlier breeze-block structure, this concrete barrier has been termed the "second generation" Wall.

When it gradually became clear that the West was not going to give in to the Communists'



Berlin Wall, Fig. 2 Construction principles of 'Border Wall 75' (BTU)

demands and that the closed border in Berlin would become a permanent feature, the GDR began to devise a border system. In mid-1962, a border zone was institutionalized. Many buildings were demolished to make space for a death strip of varying depths – mostly about 50 m. A patrol road and a light strip parallel to the border were laid out, rough observation towers built of masonry or as wooden structures were erected, and the rear of the border strip, facing east, was secured by fences and a restricted area (Feversham & Schmidt 1999).

From the mid-1960s onward, all these border structures were superseded by a system of new border elements, consisting of a border wall constructed from concrete slabs set between concrete posts and topped by a sewage pipe (rendering it impossible for fugitives to get a grip on the top of the wall), a series of specially designed watchtowers featuring polygonal observation cabins on top of slender cylindrical concrete shafts, various anti-vehicle ditches and other obstacles such as "area barriers" consisting of metal grids with large steel spikes to impale fugitives trying to jump into the death strip from its eastern wall. Guard dogs in specially constructed runs also were an important feature, but – unlike the inner German border – no mines were ever used along the Berlin Wall.

Whilst this "third generation" Wall constituted a definite improvement over the improvised first version both in visual and structural terms, it proved to have so many defects and weaknesses that it was superseded, from the mid-1970s onward, by a "fourth generation," dubbed Grenzmauer 75 by its builders ("Border Wall 75"). This format was the result of an extensive research and trial program. Test walls were assembled from various prefabricated concrete elements – originally developed for agricultural purposes – and were exposed to simulated attacks. As a result of these tests, the L-shaped element UL12.41 – 1.2-m wide and 3.6-m high – was deemed most suitable for the border purposes (Fig. 2).

The "Border Wall 75" needed no foundations and was far stronger than its predecessor. Furthermore, it presented a smooth face toward

West Berlin: an aspect of some significance to the GDR rulers who, from the early1970s onwards, became increasingly preoccupied with the image of their state toward the international public – an image tainted by the all-too obvious brutality of the border fortifications (Schmidt 2011a). The seamless and smooth western face of the "Border Wall 75" was quickly perceived as a limitless public canvas that seemed to invite the application of graffiti (Gründer 2007).

It should be noted that the structures of the border strip visible in Berlin – such as the border wall and the watchtowers – only constituted a part of all the elements that constituted the border system as this also comprised the extensive infrastructure required to control the border, such as the barracks for the border guards (roughly 10,000 soldiers) who patrolled the border with orders to shoot "border perpetrators" on sight rather than let them escape (Maurer 2011). The barracks of the five border regiments of Border Command Centre were arranged at different locations around West Berlin (Klausmeier 2009).

The Fall and Rise of the Wall

The story of the bloodless revolution that led to the sudden fall of the wall on November 9, 1989, has often been told (Henke 2009). In spite of warning voices, there was a broad consensus in favor of clearing away the hated border surrounding West Berlin as thoroughly as possible. Official demolition, carried out mostly by GDR Border Guards, began on June 13, 1990, in Bernauer Strasse, and was largely completed by the October 3, 1990, the day of German reunification. Thanks to efforts initiated by GDR Institute for Heritage Conservation as early as December 1989 and continued by the Berlin State Conservation Authority, a total of seven sections of the Wall and other border installations were listed and preserved as Historic Monuments by 1992. By 2011, this number had risen to 27, following intensive field research in and around Berlin (from Baker 1993 and Klausmeier & Schmidt 2004 to Cramer 2011; Berlin Wall GIS n.d.). While Berliners and their politicians had, all through the 1990s, mostly tried to forget the time of the division and to ignore the remnants and scars of the Wall in their city, the 2000s saw the rise of a new awareness of the Wall's significance, culminating in the celebrations of the 20th anniversary of the fall of the Wall. The Stiftung Berliner Mauer (Berlin Wall Foundation) funded in 2008 jointly by the Federal Republic of Germany and the Land of Berlin and its Landscape of Memory and Documentation Centre in Bernauer Strasse, both grown out of a private initiative in the 1990s, are a result of this new policy (Stiftung Berliner Mauer n.d.).

Perception and Cultural Significance

From the very start, public perception of the Berlin Wall was clouded and distorted by propaganda efforts. For example, even today, most people worldwide, when they think of the Berlin Wall, only ever imagine its western aspect. This is due to the fact that the GDR, whose name for the Wall was the "Anti-Fascist Protection Rampart," was interested in sustaining the fiction that the Wall was facing west – to repel the GDR's external enemies – rather than admitting that it was in fact facing east and had the primary purpose to prevent East Germans from leaving their own country. This fiction was upheld by rigorous control of any visual representation of the border's eastern aspect (hidden deeply within a restricted area) and aided by an attitude of the West of accepting the Border Wall they could see and touch as the only important element of the complex border fortifications.

By contrast, the eastern-facing wall – misleadingly called the "hinterland security wall" although it was, in functional terms, the main facade of the border installation – was never pictured or published in East or West. Therefore, the view of the border from the east must today be reconstructed as a computer visualization (Fig. 3). Perhaps ironically, the fact that the Berlin Wall was largely identified with the border wall and the watchtowers led to the effect that these elements were demolished with particular thoroughness whereas considerably more survived of the "hinterland wall" and other largely unnoticed border elements.

Berlin Wall, Fig. 3 Computer visualization of the border seen from the east (BTU)

Archaeological field research was able to identify previously unknown but revealing elements such as the "perimeter defenses": concrete walls, fences, and various obstacles (such as the heavy square concrete tubs known as "flower bowl barricades"); there were also metal grids barring windows close to the border strip, various spiky obstacles to prevent people from scaling fences and walls as well as additional light installations illuminating any possible hiding places in the vicinity of the hinterland Wall.

The color markings for Vordere Postenbegrenzung ('patrol limit') may be seen as a particularly graphic element of the border system revealed by archaeological field research and interpreted through oral history (Klausmeier & Schmidt 2004: 26). These markings, usually displayed on the lamp-post along the western side of the patrol road (Fig. 4), signified the line which ordinary border guards were not allowed to cross: If they did, they would themselves be regarded and treated as border violators. In fact, many Border Guards did attempt to flee, some of them either killing comrades or losing their own lives in the attempt (Hertle & Nooke 2011).

Berlin Wall, Fig. 4 'Patrol limit', color marking on lamp-posts along the patrol road (BTU)

The exaggerated, even exclusive importance of the border wall in public perception is reflected in the curious phenomenon of the cult of Wall fragments. These are taken invariably from the Border Wall, and more specifically from its graffiti'd western face: No Wall fragment is deemed authentic unless it shows the colorful traces of paint layers. Immediately after the fall of the Wall in November 1989, "wallpeckers" began to hack fragments from the Wall; millions of these fragments were taken away by tourists and sold all over the world – like splinters from the True Cross, proof of our deliverance from the Cold War. The cult of Wall fragments is the result of a radical change of identity experienced by the Wall on November 9, 1990: From a symbol of oppression and death it had, by its unheralded fall, suddenly become an icon of liberation and hope. But not only small fragments of the Wall found their way to countless places around the globe: At least 120 Berlin Wall monuments, mostly made of full-size elements of the Border Wall, exist outside Germany, most of them in public, often very prominent spaces, but also within museums and public buildings – a unique case of a building or monument dispersed in authentic elements over all continents and recontextualized in many different forms (Kaminsky 2009; Schmidt 2011).

The Berlin Wall has been a symbol and icon for many things (Kuhrmann et al. 2011) although the joyful memory of its fall overlays, for most people and particularly non-Germans, the memory of oppression and death. It is often used in comparison with other painful borders in the world although it should be pointed out that, unlike most other walls and fortified borders throughout history, the Berlin Wall was built to keep people in, not out.

Cross-References

- ► Cold War
- ► Social Archaeology
- ► Social Memory in Archaeological Theory

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Basic Biographical Information

Robert "Bob" Bettinger (known simply as "Dr. Bob" to students of any age or degree) was born in Berkeley in 1949 and raised in the boom years of postwar California. Regular family expe-ditions from the Bay Area north to Fortuna (along the Eel River, in the redwood timber country of northern California) induced lifelong interests in archaeology and ethnography. Indeed, it was the splendor and mystery of Native California that drew him to the prospects of anthropology in the first place, and to this day his research in archaeology is notable for its attention to ethnographic detail and insight.

As a college student at the University of California, Riverside, he was introduced to the challenges of archaeological fieldwork and to faculty commitments to economic anthropology, ecology, and analytical parsimony. Graduating Phi Beta Kappa in 1970, he continued his education at Riverside, completing a Ph.D. in 1975 under the guidance of Sylvia Broadbent, Erv Taylor, James O'Connell, and Martin Orans. During this time, O'Connell sent him to the Reese River Valley of Nevada to work with David Hurst Thomas on a pioneering effort to test hypotheses built from ethnographic records with systematic archaeological survey, sampling, and quantitative analysis. Bettinger's own dissertation (Bettinger 1975) expanded Thomas's Reese River program to the Owens Valley of California where better archaeological and ethnographic data helped to refine the analysis and interpretation of spatial patterns in hunter-gatherer activity.

By 1974 he was on faculty at New York University, where he made tenure in 1980. During the years at NYU, Bettinger and Thomas (also in New York, at the American Museum of Natural History) made the cross-country trek with their families to work in the Great Basin on a variety of collaborations and independent projects including excavations at Gatecliff Rockshelter, and systematic surveys in Monitor Valley, Nevada and Owens Valley, California. In addition to the volumes of first-rate research that came of it, the Great Basin archaeology of the 1960s and 1970s earned a separate reputation: a generation of archaeologists trained in western North America was raised on the preposterous exploits of these desert expeditions; subsequent generations were raised on the equally preposterous mythology of them.

A move to an untenured position at the University of California, Davis in 1980 brought him closer to home, closer to work, and on to a new research program in the White Mountains of eastern California. Some of the most enduring legacies of this period were the discovery of the highest elevation villages in North America and the behavioral logic explaining their existence (Bettinger 1991a). Tenure came quickly (by 1982) and this he attributes largely to the impact of a theoretical collaboration with the late Martin Baumhoff that explained the spread of the Numa, and the Uto-Aztecan language family, across the desert West (Bettinger & Baumhoff 1982).

In 1989, Bettinger and Great Basin veterans Robert Elston and David Madsen traveled to the interior of China on an invitation to apply the method and theory of Americanist archaeology to the Alashan Desert of Inner Mongolia (Bettinger et al. 1994). This international collaboration continues today and has expanded into neighboring Chinese provinces of Ningxia and Gansu, while remaining focused on late Pleistocene and early Holocene adaptive strategies and the origins of agriculture (Bettinger et al. 2010).

Major Accomplishments

Coursing through these regional, temporal, and topical foci is a career-long effort to refine and improve the theoretical foundations of hunter-gatherer archaeology. At the root of this effort is old-fashioned cultural ecology: Julian Steward's ethnography and interpretation of aboriginal life in the Great Basin permeate Bettinger's writing, from his dissertation on "man-land relationships" to some of his most recent work on the origins of private property. However, the early 1970s were awash in novel, elegant approaches to the biology of social organisms, and Bettinger (along with many other scholars) was unsatisfied with Steward's understanding of change through time. From this dissatisfaction emerged a new paradigm in human evolutionary ecology, and Bob Bettinger has been part of it ever since. Both his explanation for the Numic Spread, and the papers that preceded it were pioneering efforts to combine the economic logic of evolution in rational actors with the time-space dynamics of a multi-peaked adaptive landscape. His ground-breaking, green-covered handbook on the evolutionary ecology of hunter-gatherers (Bettinger 1991b) continues to guide students through the simplifying logic of foraging theory and economic modeling. A more recent manual of step-by-step instructions, exercises, and practical applications (Bettinger 2009) makes the foraging models easier to learn. Critics of rational actor economic models often argue that their simplicity is unrealistic and that humans (indeed, any organisms) are too complex and too unprogrammed to follow such reductionist logic. Proponents of evolutionary ecology are of course aware of this complexity but prefer to approach the evolutionary consequences of it conservatively. They might instead begin with the insights of the basic evolutionary framework, expanding piecemeal to explore more complicating features of human behavior affecting inheritance, adoption, variation, and survival. For example, if the very mechanics of human learning and information-transfer affect the evolutionary process, how might these patterns of learning and evolution be detected in the archaeological record? Bettinger and colleague Jelmer Eerkens (1999) provide us with one of the earliest and to date one of the best applications of this cultural transmission theory in archaeology, by evaluating Great Basin projectile points and the spread of bow-and-arrow technology.

Underpinning this career-long dedication to the patterns of human cultural evolution is a very general philosophy for archaeology: "good science can handle meager data with excellent theory, but without really good theory you better have damn-good data." To students and colleagues from California to China and Argentina to Siberia, this oft repeated dictum is known as "Robert's Rule."

In 2007 Bettinger received the annual Award for Excellence in Archaeological Analysis from the Society for American Archaeology.

Cross-References

- ▶ Altitude Environments in Archaeology
- ▶ Analogy in Archaeological Theory
- ▶ Cultural Ecology in Archaeology
- ▶ East Asia: Paleolithic
- ▶ Foraging to Farming Transition: Global Health Impacts, Trends, and Variation
- ▶ Hunter-Gatherer Settlement and Mobility
- ▶ Hunter-Gatherer Subsistence Variation and Intensification
- ▶ Hunter-Gatherers, Archaeology of
- ▶ Lithic Technology, Paleolithic
- ▶ Middle-Range Theory in Archaeology
- ▶ Millets: Origins and Development
- ▶ Northern Asia: Origins and Development of Agriculture
- ▶ Surface Survey: Method and Strategies

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Basic Biographical Information

Dibyendu Kanti Bhattacharya (Fig. 1) was born on June 28, 1939. He was the son of Mr. Jitendra Mohan Bhattacharya and his wife Manorama. He has five brothers and two sisters. When he was 5 years of age, he was not a healthy person, and he once heard his parents discussing that he could not survive for long and he should be allowed to do whatever he wished while he was alive. This whisper affected him strongly, and he would never give in to his weakness. Even today, in the throes of severe asthma during certain parts of the year, he has never stinted from his teaching, research, and fieldwork. In May 1958, he ran away from home and joined the Bhoodan movement under Vinoba Bhave because he wished sincerely to work for the people. He remained in there for 6 months travelling all over Sholapur district in Maharashtra. Due to this, he had trouble in getting admitted to the University of Delhi in the M.Sc. course. He completed his M.Sc. in 1960, securing a first division, and was awarded a Ph.D. in 1965, his thesis titled *A Study of ABO, RH-HR, MN Blood Groups Among the Anglo-Indians of India With a Note on Some Other Morphological Traits* from the Department of Anthropology, University of Delhi.

Bhattacharya, Dibyendu Kanti, Fig. 1 Photo of Bhattacharya, Dibyendu Kanti

He was the lecturer at the Department of Anthropology, Lucknow University, in 1965–1966. In 1966, he joined as a lecturer at the Department of Anthropology in the University of Delhi. In 1969, he was married to Pratibha, a grandniece of Veer Savarkar. In December 1971, he went to Germany and stayed there for 3 years. He also went to Great Britain, Denmark, Norway, Sweden, Austria, and Switzerland.

In August 1974, his daughter was born. He became a reader in 1985 and in 1991 became a Professor in the Department of Anthropology, University of Delhi. Between 1993 and 1996, he was the Head of the Department, Department of Anthropology, and University of Delhi. He was the visiting Professor at the Department of Anthropology, Lucknow University (in April 1997), at the Karnataka University, Dharwad (September, 2002) S.V. University, Tirupati, in October 2002.

He was the member of the UGC's visiting team to evaluate the tenth plan at Vidyasagar University, Midnapur, in November 2002. He is an associate of the Journal Current Anthropology, published by the Wenner-Gren Foundation from the USA. He is a member of the Anthropological Society of Nippon, Japan, and a life member of the Indian Science Congress Association, Kolkata; the Indian Anthropological Association, Delhi (of which he was one of the founders); the Ethnographic and Folk Culture Society, Lucknow; the Indian Society for Prehistory and Quaternary Studies, Pune; the Indian Archaeological Society, New Delhi; and the S. C. Roy Institute of Anthropological Studies, Ranchi.

Bhattacharya speaks English, Hindi, Bengali, German, and Marathi fluently. His major geological areas of interest include in other areas of Madhya Pradesh, the Chotanagpur region, and West Bengal, though he has also worked in other areas including Rajasthan, Orissa, Gujarat, and Maharashtra.

Major Accomplishments

Professor Bhattacharya has spanned a career in Indian Archaeology for almost 40 years. In his career, he has been bestowed with many honors. During his time at the Department of Anthropology in the Lucknow University, he was assigned an almirah in which he found several bones. On asking he was informed that these bones were from a place called Roopkund in the Uttaranchal Himalayan region. After reading up on the mysteries of this region, he had decided to work on this and other materials found from the region. This was awarded recently, when he and others worked on this material in 2001 for the National Geographic Program to give a summary on the findings of the Roopkund Mystery.

In 1972 he had written the first of his textbooks on this subject. He was awarded a D.Litt. from Ranchi University in 1983, in which he worked on a major outline of European prehistory entitled Paleolithic Europe. This book was later published by the Humanities Press. When Prof. Bhattacharya came back to India, he had written a book on stone tool typology, realizing that such a work was unique and had not been systematized. In India, under the guidance of Prof. Bhattacharya, the first such typo-technologies of Stone Age tools were available. Till date, even in many foreign universities, such a typo-technology is not aught and is expected often to be worked out by the students on their own. As a result, his special interest ranged from Physical Anthropology, Palaeoanthropology, Prehistoric Archaeology, and Human Ecology.

He delivered the Panchanan Mitra lecture at the Asiatic Society, Kolkata, in 1993. He was granted the Dharni Dhar Memorial Plaque by the Department of Anthropology, Calcutta University, on March 13, 1997. He was unanimously selected the President of the Anthropology and Archaeology Section of the 86th Indian Science Congress held in Chennai in January 1999.

He also delivered the first D.N. Majumdar Memorial Lecture at Lucknow on March 2, 2003. He was also the coordinating author for the chapter on "Cultural Services" sponsored by the Millennium Ecosystem Assessment. As a result, he visited Indiana University, Bloomington and Indianapolis, USA (in January 2003); Frankfurt, Germany (in May 2003); and Czech Republic (in October 2003).

Cross-References

▶ Archaeology and Anthropology
▶ Archaeology as Anthropology
▶ Bone Tools, Paleolithic
▶ Heritage and Archaeology
▶ Interpretation in Archaeological Theory
▶ Material Culture and Education in Archaeology
▶ Mousterian Industry Tradition

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Bhimbetka Rockshelters

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Introduction

Bhimbetka is a hill containing over 200 caves and rockshelters located 45 km south of Bhopal, of Raisen district, near the Bhiyapura village of Madhya Pradesh, situated along the Bhopal-Hoshangabad highway, in the northern fringes of the ancient Vindhyachal range. The rock paintings were discovered by V. S. Wakankar, who surveyed the area in 1957. Since 1990, this complex of sites is protected and maintained by the Archaeological Survey of India and recognized as World Heritage by UNESCO. Other adjoining hills are equally rich in caves and rockshelters, and altogether there are over 1,300 of them in an area of 10 km length from east to west. More than 500 of these sites contain paintings. Excavations in over a dozen shelters at Bhimbetka have revealed a continuous occupational history from Acheulian to Mesolithic times. The paintings are found on walls and ceilings of the shelters, usually on large even surfaces but sometimes also in small hollows or niches. The majority are within easy reach but some are situated at considerable heights and also at inconvenient places where standing support would be needed.

Key Issues/Current Debates/Future Directions/Examples

Content and Style of the Art

The majority of the paintings are in red or white colors but some are also in green. Based on the Raman spectra and the elemental analysis, mineral-based pigments such as calcite, gypsum, hematite, whewellite, and goethite could be identified to have been used for painting. The latter are most poorly preserved and are probably the oldest. Broadly the paintings can be divided into two cultural and chronological phases: (1) prehistoric and (2) historic. The prehistoric paintings are dominated by the depiction of wildlife, which includes various species of deer, antelopes, wild boar, elephant, rhinoceros, tiger, wild buffalo, wild cattle, fox, jackal, and fish. Birds are shown but are rare. The animals are shown individually as well as in groups and in standing, grazing, moving, and running positions. Some animal figures are marked by composite characters, like those of a boar and a bull, and probably represent mythical creatures. There are frequent hunting scenes with men hunting individually or in groups and using spears, bows and arrows, traps, and snares. The spears and arrows are tipped and barbed with what appear to be microliths. Other food-gathering activities shown include men and women fishing and climbing trees with baskets suspended on their backs to collect fruit, flowers, and honey. There are scenes

Bhimbetka Rockshelters, Fig. 1 Deer of Bhimbetka

of human life like group dances, drinking, pregnancy, care of the sick, and mourning. Two petroglyphs excavated in Auditorium Cave (Bhimbetka III-24) were covered by the uppermost part of a substantial Acheulian layer, which according to R. Bednarik must be the oldest rock art in the world. This assertion remains controversial and has yet to see wide acceptance by rock art researchers in India and beyond. The later and historic paintings, which are often superimposed over earlier paintings, have limited repertoire of themes. They mostly depict royal processions and battle scenes with men riding caparisoned horses and elephants and fighting with metal tipped spears, bows and arrows, swords, and shields (Figs. 1–3).

A brief description of seven periods of the rock art in Bhimbetka is as follows:

Period I-(Upper Paleolithic) These are linear representing, in green and dark red, huge figures of animals, such as bison and boar beside stick-like human figures.

Period II-(Mesolithic) Smaller in size compared to the earlier period, the stylized figures using symbols in this group show linear decorations on the body containing animals, human figures, and hunting scenes giving a clear picture of the weapons they used like barbed spears, pointed sticks, bows, and arrows. The depiction of communal dances, birds, musical instruments, mother and child, pregnant women carrying dead animals, drinking, and burials appear to capture motion in different situations.

Period III-(Chalcolithic) Similar to the paintings on the pottery of the Chalcolithic, these drawings reveal that during the period, the cave dwellers of this area were in contact with the agricultural communities of the Malwa plains and exchanged goods with them moving towards more civilized societal colony.

Periods IV and V-(Early Historic) The figures of this group have a schematic and decorative style and are painted mainly in red, white, and green. The presentation of riders, depiction of religious symbols, tunic-like dresses, and the existence of scripts of different periods are significant departure from the earlier period. The religious beliefs are represented by figures of Yaksha, tree gods, and magical sky chariots.

Periods VI and VII-(Medieval) These paintings are formed out of geometric, linear, and more schematic, but they show degenerations and crudeness in their artistic style compared to the earlier stage may be due to mass production of routine themes. The colors used by the cave dwellers were prepared combining manganese, hematite (soft red stone), and wooden coal. Paintings on the concepts of Brahmanical gods like Ganesh and Nataraja are considered the contribution of this period.

There is considerable variety in the portrayal of animal figures of the earlier phase. The animal body is drawn only in outline, or it is wholly or partially filled with color or is decorated by geometric patterns like straight or wavy lines, dots, crisscrosses, and other more complex designs. The animal figures are characterized by naturalism, vitality, and vigor. The majority of these paintings are highly mature artistic creations and suggest a long evolutionary period behind them. In contrast, the paintings of the historic phase are stylized, repetitive, and devoid of realism. The latest among them depict animals in a highly distorted and conventionalized manner. It is obvious that the artists who drew them were no longer inspired by natural life around them but were only repeating traditionally accepted motifs.

Bhimbetka Rockshelters, Fig. 2 Mail Hall of Bhimbetka

Bhimbetka Rockshelters, Fig. 3 Bull of Bhimbetka

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- ► Art, Paleolithic
- ► Australian Paleoart
- ► Australian Rock Art
- ► Europe: Paleolithic Art
- ► Iberian Mediterranean Basin: Rock Art
- ► Willendorf II: Geography and Culture

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Binford, Lewis R. (Hunter-Gatherer and Mid-Range Societies)

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Basic Biographical Information

Lewis R. Binford (1931–2011) was born November 21, 1931 in Norfolk, Virginia.

He studied wildlife biology at Virginia Polytechnic Institute. But military service in Japan during the Korean War led him to an interest in other cultures, and, after the war, he studied anthropology and archaeology at the University of North Carolina. He attended graduate school at the University of Michigan, graduating in 1964 with a dissertation on the archaeology and ethnohistory of coastal Virginia.

Binford taught at the Universities of Chicago, California (Santa Barbara and Los Angeles), New Mexico, and Southern Methodist University. He published over 150 papers, books, reviews, and comments and received much recognition, including election to the National Academy of Sciences.

Major Accomplishments

Binford was the chief architect of the *new* or *processual* archaeology. In the 1950s, archaeologists focused on artifact classification, and they saw artifacts as reflections of mental templates, useful for tracking the migration of cultures or the diffusion of ideas. Through a series of papers, Binford (1962, 1964, 1965, 1967, 1968a) challenged archaeologists to do more, to fully participate in anthropology, and to rely on scientific methods. Revolutionary at the time, Binford's approach became *de rigueur* by the 1970s (see compendiums of his papers in Binford 1972, 1983b, 1989).

Binford took a materialist approach to prehistory, relying on Leslie White's concept of culture as *man's extrasomatic means of adaptation*. He focused on hunter-gatherer societies and helped pioneer ethnoarchaeology (with research among the Nunamiut and Australian Aborigines), as well as faunal analysis, sampling, spatial analysis, and the use of statistical methods. He introduced concepts that are now so common in archaeology that one forgets he invented them, e.g., residential and logistical mobility, foragers and collectors, curated and expedient tools, technological organization, and, most importantly, middle-range theory (e.g., 1978a, 1979, 1980).

Middle-range theory was aimed at making reliable inferences from archaeological remains. Binford argued that archaeologists relied on simple rules of thumb for interpretations (1977, 1981a, 1983a). Using the geological principle of uniformitarianism, he sought unambiguous links between human behavior or natural processes and their material traces. His work with the Nunamiut was pivotal here (1978b). Grounded in the food utility of different parts of animal anatomy, he used Nunamiut butchering practices to show how faunal assemblages differed depending on circumstances (e.g., fall hunts designed to store food vs. spring hunts for immediate consumption). The resulting patterns in Nunamiut faunal assemblages could then be used to interpret archaeological assemblages – not as analogues but as middle-range theory because the *causes* of the patterns were sought and explained in terms of the intrinsic elements of animal anatomy. As long as ancient and modern animal anatomy was the same, the patterns of different butchering goals should also remain the same.

Binford was not interested in an ethnographic reconstruction of the past. Instead, he argued that archaeology's power lay in its ability to see processes on a scale that ethnography could not – time spans of thousands of years and spatial variation across continents. He used specific archaeological cases to understand processes of change and causes of diversity among hunter-gatherers. Consequently, he was never a prehistorian of a particular region. Nonetheless, he contributed seminal research to several important questions, including the meaning of variability in Mousterian stone tool assemblages, the origins of agriculture, and the role of hunting in human evolution.

French archaeologist François Bordes argued that variability in Mousterian stone tool assemblages reflected different mental templates and hence different *tribes* of Neanderthals. Binford (Binford & Binford 1966) argued that the assemblages reflected different functional uses of a cave as the settlement system shifted to adapt to changing circumstances (1982). Likewise, he argued that agriculture was not the inevitable product of the accumulation of knowledge but was instead an adaptation to high population density (1968b). In the 1980s, he used ethnoarchaeological and taphonomic research on faunal remains to argue that our earliest human ancestors were not hunters of large game, who foraged in much the same manner as modern hunter-gatherers, but were instead lowly scavengers of the animal carcasses left behind by large carnivores (1981b, 1983a). His studies of variability in lower Paleolithic stone tool assemblages led him to argue that those early makers of stone tools were not simply shorter, hairier versions of ourselves but hominins who were not human in the way we know humans.

His magnus opus, *Constructing Frames of Reference* (2001), was the result of a lifelong effort to compile ethnographic data on hunter-gatherer societies and environmental data in order to model prehistoric life based on paleoclimatic reconstructions.

Binford was a thinker who thrived on challenging orthodoxy and authority. He was a prolific writer, a mesmerizing speaker, an excellent teacher, and a theoretician who understood dirt archaeology. While many of his specific interpretations may not stand the test of time, he helped shape archaeology into the field it is today.

Cross-References

- ▶ Archaeological Theory: Paradigm Shift
- ▶ Archaeology and Anthropology
- ▶ Archaeology as Anthropology
- ▶ East Asia: Paleolithic
- ▶ Ethnoarchaeology: Building Frames of Reference for Research
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- ▶ Hunter-Gatherer Settlement and Mobility
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Binford, Lewis R. (Theory)

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Basic Biographical Information

Lewis Roberts Binford was born on November 21, 1931, to J. Lewis Binford, from rural Appalachia, and Eoline Roberts Binford, of the genteel Tidewater area of Virginia. When he died on 11 April 2011, newspapers around the world noted his passing and memorialized his accomplishments. Binford was the quintessential southern gentleman, a charismatic lecturer, and an inspirational teacher, who, through force of personality, great intellect, and roll-up-your sleeves hard work, transformed the conduct of archaeology. He loved life and living, which for him was synonymous with learning and challenging. Everything he did during his time on the faculties of the University of Chicago (1961–1965), University of California–Santa Barbara (1965–1966), University of California–Los Angeles (1966–1968), University of New Mexico (1968–1991), and Southern Methodist University (1991–2003) was accomplished with infectious gusto, attracting both loyal admirers and some detractors, too.

Binford's formal education included undergraduate studies in wildlife management and wildlife biology at Virginia Polytechnic Institute, laying a foundation for his scientific ecological approach. From 1952 through 1954, he served in the US Army as an interpreter to anthropologists charged with the post-World War II transition in the western Pacific, which exposed him to new career possibilities. When he returned to school at the University of North Carolina, he shifted to anthropology, studying with Joffre Coe and completing a B.A. (1957). His M.A. (1958) and Ph.D. (1964) were completed at the University of Michigan, where he was influenced by Leslie White, champion of the scientific study of culture change, and where he challenged James Griffin, dean of eastern North American culture history.

Family and the school of hard knocks also shaped Binford. His father was an important influence, and, like others, Binford's family circumstances during the Great Depression and after were difficult; even as a boy he was working to help his family get by. There were no handouts for Binford and anything that came his way was through hard work, which continued throughout his life. His skills as a carpenter fed him during graduate school and served as a counterpoint for his writing; students in the 1970s and 1980s saw him transform his house in Corrales, New Mexico, by day and, by night, transform archaeology as he crafted *Nunamiut Ethnoarchaeology, Bones: Ancient Men and Modern Myth*, and other tracts. And, from an early age, Binford was keen observer of the human condition, noting the tensions between class and privilege (associated with his mother's family) and getting the job done so one could eat (seen in his father's family) (Sabloff 1998). The challenges to voices of authority for their insistence on privilege over substance, unmistakable in Binford's early career, perhaps emanated from these formative experiences.

Major Accomplishments

In 1962, Lewis Binford (1962a) published "Archaeology as Anthropology" in the flagship journal for archaeology in the United States, *American Antiquity*. Adapting Leslie White's (1959) definition of culture as a system, with material culture viewed as simultaneously operating in technomic, socio-technic, and ideotechnic cultural subsystems, Binford argued that ALL aspects of culture were archaeologically accessible, fundamentally transforming archaeological discourse (Watson 1995).

"The most competitive people are the ones who do the most similar things" noted Binford (Sabloff 1998: 8), referring to the late 1950s debates between Julian Steward and Leslie White. This also described his own working style. For Binford, insights emerged not from the discovery of facts in the field but from thinking about and through these encounters with the real world. To this end, public debate with other competent thinking debaters – in print or, better still, in person – was a vital learning tool. Thus, he challenged Robert Braidwood, preeminent Near Eastern scholar, on the nature of the origins of agriculture there (Binford 1968); sparred with François Bordes, master of the French Middle Paleolithic, over the interpretation of Mousterian assemblages (referred to as the form vs. function debate, authored with his third wife, Sally Binford; Binford & Binford 1966); and jousted with Glynn Isaac, the reigning expert on early hominid behavior in East Africa, over interpretation of east African materials (Binford 1987). His 2001 book, *Constructing Frames of Reference* (for which he acknowledges the substantial assistance of his fifth wife, Nancy Medaris Stone) represents in part his response to the critique of Processual Archaeology offered by Ian Hodder and others beginning in the 1980s. Binford rarely passed up a good argument, and, after putting away the boxing gloves, he often supped and celebrated with his opponent.

Binford's accomplishments and contributions are best described as fundamental and groundbreaking. He is often acknowledged for launching, with collaborators at the University of Chicago, the New Archaeology (later, Processual Archaeology), a self-styled movement within archaeology that asserted that archaeology could contribute fully to the project of anthropology and need not be the hapless sibling of cultural anthropology, crippled by an impoverished data set. The 1968 edited volume, *New Perspectives in Archaeology* (coedited with Sally Binford), presented early challenging case studies. As part of this large and continuing effort to refashion archaeology, Binford laid several metaphysical, paradigmatic, conceptual, and methodological foundations that the discipline continues to build upon today.

Metaphysically, Binford (and others, notably, David Clarke and Michael Schiffer) moved the discipline from one based in simple synchronic reconstruction, consistent with functional goals, to one situated in a taphonomic or formational metaphysic, i.e., recognizing and exploiting the many agents that interact to form archaeological deposits. His work with Middle Paleolithic and hominid deposits emphasized that others besides protohumans accumulate and arrange bones in caves and that fire was not a gift uniquely given to humans (*Bone: Ancient Men and Modern Myths*, 1981). This less often acknowledged metaphysical transformation has greatly expanded archaeological interpretative possibilities.

From the inception of archaeology, debate has ensued over the nature of archaeological science. In the 1950s, archaeological science involved an eminent authority amassing observations on archaeological deposits and, from these, weaving a comprehensive interpretation based in common sense (sensu Dunnell 1982). Binford argued for a very different version of archaeological science. For him, science was solely about the evaluation of ideas, whatever their source, with experience. This meant that one had to identify what one securely knew (both archaeologically and in the contemporary world), identify the domains of ignorance, and then build bridges from knowledge to illuminate ignorance. *Constructing Frames of Reference* (Binford 2001) is an explicit statement and extended example of Binford's version of science. Here, in an effort he worked on throughout his career (see Binford 1980), Binford organized and presented two sets of information about hunter-gatherer-fishers between which he tacked to identify provocative patterns in need of further exploration. The first includes basic structural information on physical environments, along with an energy-based model of how clever human predators deploying different organizational structures operate in those environments. The second includes a compendium of ethnographically documented hunter-gather-fishers and how in fact they are found to have behaved in different environments. Binford moves back and forth between these two domains, identifying patterned variation seen in foragers through time, proposing explanations for this variation, and, contra his earlier critics, recognizing the contingent role of prior organizational poses.

Buttressing his metaphysical and paradigmatic innovations, Binford's methodological innovations are many. Two stand out. The first are various tools for managing archaeological variation. Certainly, a budding appreciation for the important role of variation in phenomenon under scientific scrutiny is evident in the work of 1950s archaeologists (e.g., see the Ford-Spaulding debate). With his 1964 *American Antiquity* article, "A Consideration of Archaeological Research Design", Binford brought to archaeology the parlance of sampling, which has since been reified in practice in heritage archaeology. His 1966 paper with Sally Binford, "A Preliminary Analysis of Functional Variability in the Mousterian of Levallois Facies", was one of the early applications of multivariate analysis in archaeology, identifying dimensions of variation in Near Eastern Middle Paleolithic assemblages. With the desktop computing revolution in the 1980s, such applications have become more routine and sophisticated.

In addition, Binford enlightened a critical component of the archaeological enterprise, which he referred to early on as middle-range theory (1977; see also formation theory, middle-range research, midrange theory, source-side knowledge, bodies of reference knowledge). That is, recognizing that archaeological materials cannot speak for themselves, Binford emphasized that archaeologists must give archaeological materials a language with which to speak. This language comes from the contemporary world and requires development by archaeologists for archaeological interpretation. Binford's 1967 *American Antiquity* article, "Smudge Pits and Hide Smoking: The Use of Analogy in Archaeological Reasoning", was his first article expressly concerned with how archaeologists assign meaning to archaeological materials. Thinking on this topic matured as Binford confronted Middle Paleolithic assemblage variation and its interpretation, recognizing that the functional interpretation he and Sally Binford had offered represented a "just so story" slightly more compelling than that offered by Bordes. As illustrated in his *Nunamiut Ethnoarchaeology* (1978b), middle-range work proceeded on two fronts. Binford turned to work with contemporary native hunters in the Brooks Range of Alaska not as analog for the Middle Paleolithic ice age but to understand some of the many conditions under which variation was introduced into faunal assemblages. In addition, he undertook experimental studies to map the economic dimensions of carcasses, against which assemblage variation could be assessed. Ethnoarchaeological, experimental, and other taphonomic studies established what Binford referred to as intellectual anchors to be used in interpreting archaeological patterning. Construction of similar intellectual anchors was attempted for spatial data (Binford 1978a) and chipped stone assemblages (Binford & O'Connell 1984).

Further maturation on this topic is clear in his *Constructing Frames of Reference*, in which he moved beyond "middle-range theory" as a simple Rosetta stone connecting pattern and process. In part, this is owed to his enduring interest in culture systems, how they are organized and how they change through time. Middle-range research, confined as it is to ethnographic scale phenomenon, could not illuminate the supra-generational phenomena that so interested Binford. *Constructing Frames of Reference* offers a research strategy for such phenomena.

Throughout his career, Binford was an innovator and a pioneer. His 1962 regression formula for dating pipestems is still widely cited in historical North American archaeology (Binford 1962a).

And, while employed by the National Park Service on the Carlyle Dam project in southern Illinois, he collaborated in pioneering systematic surface collection (Binford et al. 1970).

Over the last several decades, the contributions of Lewis Binford, the provocateur and the scientist, have been increasingly recognized. Binford received honorary degrees from the University of Southampton (1983), Pierre Mendez France University (1999), the University of Leiden (2000), and the University of Verona (2005). In 1986, he received the Huxley Medal from the Royal Anthropological Institute. He was elected a corresponding fellow of the British Academy in 1997 and elected to the US National Academy of Sciences in 2001. In 2008, he received the Lifetime Achievement Award from the Society for American Archaeology. An asteroid (213629 Binford = 2002 QK67) orbiting the Sun between Mars and Jupiter was named for him in 2010. His 1984 book *In Pursuit of the Past*, distilled by John Cherry and Robin Torrence from a series of lectures delivered in Europe in the early 1980s, has been reissued (2002) and translated into multiple languages.

Cross-References

▶ Hunter-Gatherer Settlement and Mobility
▶ Hunter-Gatherers, Archaeology of
▶ Hypothesis Testing in Archaeological Theory
▶ Middle-Range Theory in Archaeology
▶ Post-Processual Archaeology

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Bioarchaeology in the Roman Empire

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Introduction

Much of a person's life history is written on his or her bones. Skeletal remains of past populations are palimpsests of information about the behaviors people engaged in during their lives. The bioarchaeological study of burials from around the Roman Empire is a relatively new undertaking but has proven to be an essential line of evidence for understanding the demographic makeup, health status, and dietary regimes of the heterogeneous peoples that comprised the imperial population. Owing to a growing database of skeletal remains, bioarchaeologists are leading the way in answering questions about migration and urban life in the Roman Empire. Through an integration of bioarchaeological studies with traditional analyses of material culture and texts, the diversity of the Romans in all areas of the empire is becoming apparent.

Definition

Bioarchaeology is the study of skeletal remains from archaeological sites. The term osteoarchaeology is also used, primarily in Europe, and through the years, both terms have been broadly defined as including skeletal material from both humans and animals. Owing to the influence of New Archaeology, however, since the 1970s, bioarchaeology has conventionally dealt with the physical remains of humans from burials found in the archaeological record. In the United States, bioarchaeology is considered a subspecialty of biological anthropology, whereas in Europe the field is more closely allied with archaeology and anatomy.

An individual skeleton is the unit of analysis in bioarchaeology, but inferences about past behavior can only be reconstructed through a survey of the population and its sociocultural context. As such, bioarchaeology is an interdisciplinary field, incorporating techniques and theoretical approaches drawn largely from biology, anatomy, demography, anthropology, and archaeology. When used as a way to study the people of the Roman Empire, bioarchaeology also draws from classical philology, historiography, epigraphy, architecture, and artifact studies in order to situate the skeletal population under consideration within a cultural milieu.

Historical Background

In one sense, the roots of classical bioarchaeology can be found in ancient authors. In the mid-fifth century BCE, Herodotus, reporting on the aftermath of a Persian War battle (*Histories* 3.12.2-3), noticed that the skulls of the Persians were brittle whereas those of the Ethiopians were quite strong, and he attributed this difference to sun exposure by the Africans. While Herodotus was not correct in this correlation, his observation foreshadowed discussions in biological anthropology of the effects of the environment on the human skeleton.

The osteological study of burials has been a part of Roman archaeology since at least the nineteenth century. At this time, cursory analysis of skeletons with the objective of culling demographic histories was always subsumed by publication of grave goods in large site reports, sending biological material to languish in appendices. The sex of a skeleton was assigned based on associated artifacts as often as estimated by biological markers.

In the early twentieth century, biological anthropology in the United States and Europe developed similarly, as researchers attempted to look at skeletons, especially the skull, for evidence of diffusionary traits. Coupled with such pseudoscientific tools as Retzius' cephalic index, biological anthropology in Italy, for example, became heavily invested in discovering the "true race" of the Italians and explaining the Mezzogiorno, and American anthropology in finding a biological basis to support the practices of slavery, racism, and forced removal of natives. Skeletal measurements, when twisted to fit preconceived notions of racial superiority, represented both a reliance on early empiricism and the rise of nationalist movements in Europe and America. This legacy of cranial indices and cephalic suffixes, unfortunately, is still seen today in some Mediterranean bioarchaeological publications, but the field has evolved immensely just in the last decade.

Bioarchaeology arose as an independent field of research in the 1970s under the guidance of Jane Buikstra and other proponents of the science-focused New Archaeology. Researchers began to study skeletal collections housed around the world in order to answer research questions beyond chronology and typology of burials. In the 1980s, with the advent of post-processual archaeology, bioarchaeologists started asking how diet, behavior, and disease differed along the lines of status and gender. By the 1990s, bioarchaeology was coming into its own. Data recording practices and techniques were standardized in the United States, but many European researchers still use a variety of data standards. At the end of the twentieth century, several international laboratories and research centers that deal with classical bioarchaeology had been established, such as the Wiener Laboratory at the American School of Classical Studies at Athens, the Servizio di Antropologia of the Soprintendenza Speciale per i Beni Archeologici di Roma, the Centre National de la Recherche Scientifique in France, and English Heritage in the United Kingdom.

Within the last decade, bioarchaeology has entered the twenty-first century by increasingly employing chemical techniques such as isotope and DNA analyses to answer questions about population interaction, dietary differences, and the origin and spread of disease. There has also been a trend toward osteobiography, or creating detailed, individualized life histories from skeletal remains, often accompanied by a forensics-based facial reconstruction. Classical bioarchaeology today is balancing scientific and humanistic approaches in order to understand life in antiquity.

Key Issues and Current Debates

Today's Roman bioarchaeologists ask questions about what life was like in ancient times, in part to provide a history to those segments of society that did not merit inclusion in elite writing, such as women, children, immigrants, and slaves. Key areas of Roman bioarchaeology research in the past decade have focused on questions about diet, migration, and disease in the empire. The majority of this research has been done on skeletal assemblages from Rome and from Britain and has been published in the traditional venue of peer-reviewed anthropology journals. There is a growing movement toward synthetic treatment of bioarchaeological data from the classical world, however, that is reaching an interdisciplinary audience.

Variation in the Roman Diet

The imperial Roman diet, particularly for the lower classes, has been reconstructed primarily through the agricultural writings of authors such as Cato, Varro, and Columella. People in all parts of the empire subsisted on cereals, fruits, and vegetables generally in the form of bread, olive oil, and wine. There is little evidence, however, of the diversity that existed in the Roman diet, and there has been disagreement about the role of seafood and the consumption of millet. Bioarchaeologists have weighed in with chemical analyses of skeletal tissue in an effort to demonstrate that different imperial populations used different alimentary resources.

Carbon and nitrogen isotope analyses from bone collagen yield a general picture of a person's diet in the years leading up to death. Because carbon enters the food chain through photosynthesis, a human's carbon isotope ratio is largely affected by the kind of plants he or she ate. Additionally, there are two major photosynthetic pathways, which mean that carbon isotopes can distinguish a diet reliant on temperate grasses such as wheat and barley from a diet reliant on tropical grasses such as millet and sorghum. Nitrogen in the human diet is obtained primarily through consumption of other organisms, so understanding nitrogen isotopes means understanding an organism's position in the food chain. The values of nitrogen isotopes therefore range from very low, indicating a diet composed of legumes, to very high, indicating a diet composed primarily of aquatic resources.

Isotope research on skeletons from Imperial Italy has shown great differences in diet. In the shadow of the city walls of Rome, people were eating more millet and less seafood than were people from Portus Romae (Prowse 2001; Killgrove 2010). Skeletons from the early Christian necropolis of San Callixtus in the Roman suburbs revealed an ascetic diet for this religious group, with consumption of freshwater fish from the Tiber River (Rutgers et al. 2009). Correlation between frequency of external auricular exostosis, an ear pathology related to cold-water immersion, and nitrogen isotope values for people from Portus and Velia, a site on the Tyrrhenian coast, further demonstrates that the population of Imperial Italy was indeed consuming both freshwater and saltwater resources (Crowe et al. 2010). Differences in diet at Portus have also been found to reflect age, with children eating more terrestrial food and older adults consuming more olive oil and wine (Prowse et al. 2005), and there is evidence that foreigners at Rome changed their diet after immigrating (Killgrove 2010). Diet also varied within populations and through time in Roman Britain (Müldner & Richards 2007); nevertheless, isotope studies on several skeletal series have revealed that Romano-British people ate a largely terrestrial diet composed of plants, meat from herbivores, and a small amount of marine or freshwater fish. Chemical analyses of skeletal remains are therefore providing bioarchaeologists with information at the individual and population level, giving new insight particularly into the diet of lower-class imperial residents.

Demographic Effects of Migration

The phenomenon of migration and its implication for the demographic structure of the empire has previously been investigated through census records and inscriptions on tombstones. As the center of imperial power, Rome itself had a great number of free immigrants and slaves who hailed from elsewhere. Identifying immigrants and slaves in the archaeological record has been challenging, however, because most were not noted as such in inscriptions or through artifact assemblages in graves. A major contribution of bioarchaeology in recent years has been the application of chemical techniques to identify population diasporas within the empire.

Isotopes of strontium and oxygen are most commonly used to distinguish immigrants from locals in a skeletal assemblage. Strontium is incorporated into the human body during growth via groundwater, and the strontium isotope ratio derived from a human's dental enamel reflects the geology of the area in which the person grew up. Lower strontium values generally indicate younger geology, such as volcanic areas, while higher values are indicative of older rock. Oxygen isotopes incorporated during tissue development are related to the overall climate of the area; lower values suggest a person grew up in a colder, wetter climate, and higher values suggest life in a warmer, drier climate. Some strontium and oxygen isotope studies have been done in the Roman Empire, but until significantly more data are available, interpretations are necessarily conservative in nature.

In the Roman suburbs, a strontium and oxygen study of dental enamel from the first molar, which forms between birth and three years of age, showed that roughly one-third of the people tested arrived at Rome from elsewhere (Killgrove 2010). Interestingly, these immigrants to Rome did not have significantly more diseases than the locals, but the two groups ate different diets as children. Similarly, an oxygen isotope analysis of the first and third molars from individuals buried at Portus Romae suggested one-third of the population moved there during childhood (Prowse et al. 2007). It is not currently possible to pinpoint an immigrant's homeland, but general trends in the data from Rome and Portus suggest that people were arriving in these cities from nearby areas such as the Apennines but also from areas with strikingly different geology and climate. Further, research on migration in the Roman suburbs suggests that the practice was not confined to young men, as there is ample evidence of immigrant women and children in the bioarchaeological record.

Migration did not occur just to Rome and to other large urban centers (Eckardt 2010). In southern Italy, a combination of oxygen isotope analysis and ancient DNA analysis revealed an adult female with east Asian ancestry, whose burial form and grave goods otherwise did not indicate she originated elsewhere. In the Romano-British burial ground of Spitalfields, a woman who was buried in a decorated lead coffin was shown through lead (Pb) isotope analysis to have originated in Rome. Several strontium and/or oxygen isotope studies have been conducted on Romano-British skeletal series in the past decade; by and large they reveal a great deal of mobility in the area. At the sites of York, Gloucester, and Lankhills, for example, only about half of the people studied could be considered locals, while about 15–20 % were from elsewhere in England, and 20–35 % were long-distance migrants. In Bavaria during the later empire, a skeletal series affiliated with a Roman fort at Neuburg revealed through strontium isotope analysis that approximately 30 % of the population came from elsewhere; women and children immigrated to the site in addition to men (Schweissing & Grupe 2003).

Isotope analyses of skeletal tissue are yielding new information on patterns of migration within the Roman Empire as well as on the demographic makeup of both urban and rural settlements. Physical mobility within the empire was quite high, and immigration was not by any means unidirectional. The reasons for population mobility, however, are still uncertain. Diasporas of people likely occurred with slavery and to a lesser extent with military service, but migration may also have been an option for families and for free individuals looking for work or for a spouse. The growing database of strontium and oxygen isotope data is revealing the great distances that people migrated in antiquity, and new applications of DNA analysis point the way forward for bioarchaeologists interested in contributing to the conversation about mobility and migration in the empire. In the future, the challenge will be to integrate the scientific data drawn from chemical analyses of skeletons with the historical evidence from inscriptions and censuses to glean new information about the demographic fluctuations of imperial populations.

Health and Disease in the Empire

Only within the last 10–15 years have reports of trauma and disease in the archaeological record evolved from case studies of pathological conditions to large-scale research into the prevalence of specific diseases in imperial populations. The recent debate on health in the Roman Empire starts with a look at systemic factors that may have increased people's stress, including urbanization, malnutrition, hygiene, and sanitation, as well as the comorbidity of various infectious diseases and parasites. The health of an individual and of a population is multifaceted, and researchers have employed skeletal remains from both Rome and Britain, in addition to primary and secondary source material, to argue that the empire was not a particularly salubrious place to live.

Pathological data from several skeletal series in Rome have been published (Catalano et al. 2008; Eckardt 2010). Most suggest that there were significant health stressors for people living in the city and suburbs, as evidenced by high frequencies of enamel hypoplasia and cribra orbitalia and by a decrease in overall stature during the empire. Hypoplasias are defects in the formation of dental enamel and can be caused by a number of health issues, including malnutrition, disease, and weaning; cribra orbitalia is generally considered to result from iron-deficiency anemia, which in turn can be caused by nutritional deficiencies or disease; and variation in adult stature, particularly a trend in shorter stature, results when an individual is stressed during childhood, as from disease or malnutrition. In general, skeletal series from Rome show higher frequencies of enamel hypoplasia and cribra orbitalia and shorter stature than do series from Britain, likely owing to the urban nature of Rome, which had high population density and unequal resource allocation. Through time, the British skeletal series also provide evidence for a decrease in stature as well as increased exposure to anthropogenic lead in the Roman period. One suggestion for the decline in health during the Roman Empire is the presence of endemic malaria in the Mediterranean. Malaria in antiquity has been the subject of debate for a number of years; however, the skeletal evidence is still inconclusive, particularly since not all Roman skeletal series show high frequencies of cribra orbitalia. Also problematic in the debate about disease in the empire is the current lack of standardization in data collection practices, particularly for lesions that may indicate anemia and, by extension, malaria.

Morbidity and mortality in a population are complicated processes dependent on a variety of environmental and sociocultural factors. With few fully published skeletal series outside of Roman Britain, the disease ecology within the empire as a whole is still largely unknown. Research that synthesizes the available historical and osteological information on population size, sanitation, nutrition, and disease is becoming more common in bioarchaeological research in general, opening up a worldwide discussion about health and disease in antiquity. Combined with the growing use of chemical techniques to identify pathogens, bioarchaeological research is beginning to produce novel information about health in the Roman Empire.

In the past decade, bioarchaeological research in the Roman Empire has surged from basically nothing to an active international research program tackling difficult questions about diet, disease, and demographics from a scientific standpoint. Bioarchaeologists in the Roman world have only recently begun to reflect on the accumulated data, however. Synthetic works that explicate current osteological knowledge about diet, health, and foreigners in the empire have not yet been created, meaning the historical and epigraphic records are still the primary sources for these topics. Yet bioarchaeological approaches have already clearly demonstrated that the Roman Empire was a strikingly diverse place. Heterogeneous groups of people from different homelands lived in cities, rural outposts, and forts on the *limes*. Their diets were composed primarily of cereals, meat, and plants, but the proportions of these resources and the types consumed varied dramatically. The people likely differed biologically in their risk of mortality and culturally in their attempts to mitigate disease and maintain health. Recent research has demonstrated that literature frames our understanding of life in the Roman Empire but that bioarchaeology adds necessary details to complete the picture.

International Perspectives

For most of the twentieth century, North American researchers led the field of bioarchaeology in the classical world. J. Lawrence Angel published scores of articles between the 1940s and 1970s, many on the paleopathology of skeletal remains from the eastern Mediterranean, at sites such as Athens, Corinth, Pylos, Olynthus, and Troy. In the 1980s, Sarah Bisel tackled the remains from Nichoria and the Kerameikos and also delved into the skeletal remains from Herculaneum. Marshall Becker has been prolific in his research throughout the Italian peninsula and Sicily. By the 1990s, however, an international group of scholars was engaging in the bioarchaeology of Greece, Italy, and Britain, including Sherry Fox, Luigi Capasso, Gino Fornaciari, Anna Maria Bietti Sestieri, Loretana Salvadei, Giorgio Manzi, Simona Minozzi, Estelle Lazer, Renata and Maciej Henneberg, and Simon Mays.

The international picture of imperial Roman bioarchaeology in the twenty-first century is still primarily focused on Italy, Greece, and Britain, which have produced a wealth of skeletal remains in the past few decades, but research is also being undertaken by bioarchaeologists in far-flung provinces of the empire, including Egypt (Tosha Dupras), Bavaria (Gisela Grupe), Croatia (Mario Šlaus), and Tunisia (Anne Keenleyside). Although the population of bioarchaeological practitioners has diversified since the end of the twentieth century, British researchers remain at the forefront of the field, particularly those at Durham University (Charlotte Roberts, Janet Montgomery, and Rebecca Gowland), the University of Reading (Hella Eckardt, Mary Lewis, and Gundula Müldner), the British Geological Survey (Janet Evans and Carolyn Chenery), the

Museum of London (Rebecca Redfern), and English Heritage (Simon Mays). With large skeletal series such as the population from Poundbury Camp and cutting-edge technology, the bioarchaeology of Roman Britain is yielding in-depth reports on paleopathology, demography, mobility, and diet. New techniques in chemical analysis are just beginning to be applied to Rome and Ostia Antica by Italian researchers affiliated with the Servizio di Antropologia in Rome (Paola Catalano, Walter Pantano, and Carla Calderini) and the Museo Nazionale Preistorico Etnografico (Luca Bondioli and Alessandra Sperduti), as well as by North American scholars (Tracy Prowse and Kristina Killgrove).

In this age of digital connections, however, information on classical bioarchaeology is being shared across linguistic divides not just at international conferences but also through social networking, newsgroups, blogs, and interdisciplinary journals. Although there is not yet an international database of Roman skeletons, a movement toward data sharing and open access is underway in American biological anthropology, which will pave the way for synthetic treatments of bioarchaeological information by its international creators.

Future Directions

The past decade has seen bioarchaeological research expand from the core of the Roman world to the lesser-investigated provinces of the empire. More work is needed, however, in places like Hispania, Gaul, Illyricum, Asia Minor, Syria, and Judaea. The city of Rome itself has produced thousands of skeletons in recent years, but most cemeteries remain unpublished, making synthetic treatments challenging at the moment. Future studies at both the center and periphery of the empire will make it easier to understand the diversity of the heterogeneous peoples who comprised the imperial population.

As the publication of case studies of diet and demographic trends has picked up in the last few years, synthesis of this information is needed. Knowing the dietary proclivities of a handful of average Romans is useful, but bioarchaeologists would do well to produce a volume or series of volumes on isotopic evidence of dietary practices. In this way, bioarchaeological data can be integrated with texts and artwork to create the most in-depth understanding of the ancient diet to date. Similarly, demographic trends have been published from a few sites in Roman Britain and in the Roman suburbs, but the bioarchaeological data have not been commanded in the same way as census records and tombstone inscriptions have been by historical demographers. The time is right for producing synthetic works that incorporate bones, texts, and material culture in a new and exciting way.

Moving forward, Roman bioarchaeologists can address research questions about disease ecology, identity formation, and population interaction. Paleopathological research has primarily been focused on identifying diseases in the skeletal record of the Roman Empire, but more could be done to understand the ecology of those diseases. In Rome, for example, wildly varying frequencies of skeletal markers of stress and infection suggest living in different areas of the city and suburbs put people at different risk for diseases such as malaria. Investigating the topography, climate, and water sources of Rome is just as important as doing macroscopic and chemical analyses of skeletons for understanding morbidity patterns, and a bioarchaeological approach that incorporates disease ecology will move the study of Roman health forward.

Isotope and DNA analyses have already yielded key information about migration within the Roman Empire, by isolating individuals who traveled to and from Italy during their lifetimes. These data, however, have seldom been used to draw conclusions about identity formation in the multiethnic empire, which would be a key step forward for Roman bioarchaeology. Pushed even further, data from chemical analyses combined with material remains and demographic models may allow Roman bioarchaeologists to investigate the practice of slavery in a novel manner. With more isotope analyses and additional DNA studies, a bioarchaeological approach to understanding Roman slavery cannot be far off.

Thirty years ago, Colin Renfrew wrote that there was a place "for anyone who can command the data and the scholarship of the Great Tradition while employing the problem-orientation and the research methods of current anthropological archaeology" (Renfrew 1980: 297). Bioarchaeologists who work in the Roman Empire have taken up this challenge and are weaving together scientific and humanistic data on a daily basis. Roman archaeology has already benefitted immensely from a bioarchaeological approach that integrates textual, artistic, and other material evidence with biological remains to create a more holistic picture of all levels of life and culture in the Roman world. There is a great deal more work to do in the bioarchaeology of the Roman Empire, but the amount of research that has already been produced demonstrates the promising future of this field.

Cross-References

► Burial Practices and Tombs in the Roman World
► Tombs, Etruscan

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Bioarchaeology, Human Osteology, and Forensic Anthropology: Definitions and Developments

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Introduction and Definition

The analysis and interpretation of human skeletal remains focuses largely on what can be learned from these remnants, as well as the individuals and populations they represent. The terms bioarchaeology, human osteology, and human skeletal biology all refer to scholarly inquiry in this area, but each conveys a distinct emphasis. Osteology represents the most traditional term used, with its accent on comparative morphology. Skeletal biology also refers to comparative morphological study but recognizes the dynamic nature of skeletal growth and maintenance, as well as biomechanical and environmental factors that shape bone morphology. Bioarchaeology includes all of the above, but focuses on remains recovered from archaeological contexts with special consideration to the associations of biological and cultural factors.

Historical Background

The academic roots of this discipline extend back primarily to Europe and Asia with an interest in the evidence for human evolution (paleoanthropology) linked with the recovery of ancient human remains. The early discovery and interpretation of fossil hominids required knowledge of comparative skeletal anatomy. Such perspective could be ascertained from collections of modern human remains recovered from archaeological contexts.

Although some human remains were recovered through construction activities and other accidental encounters, increasingly collections were assembled from systematic archaeological excavations. Such excavations not only yielded human skeletal material but usually abundant associated cultural information as well. This information frequently enabled the remains to be dated and placed in cultural context. As these collections grew in number and size, they facilitated the development, growth, and evolution of the discipline.

Academic interest in skeletal analysis during the nineteenth century focused largely on the skull with the general belief that it presented the primary evidence for the topics of research at the time, including human variation and documentation of regional physical types. The evidence for disease was also of interest due to the medical background of many of the field’s practitioners.

A key historical development in the emergence of human skeletal biology was the 1855 formation of the Society of Anthropology of Paris by Paul Broca (1824–1880). A surgeon by profession and an expert in neuroanatomy, Broca called together key professionals in the fields of medicine, anthropology, archaeology, and related areas to focus on academic advancements relating to the interpretation of human skeletal remains. This effort led to the development of measuring techniques, instrumentation, and training. Most importantly, it provided a forum for scholarly discussion and interaction, with a stress on human skeletal anatomy and its interpretation.

Shortly thereafter (1861), German physical anthropologists gathered in Göttingen for scientific interaction and to discuss standardization of methodology. Subsequent meetings led to the 1866 formation of the journal Archiv für Anthropologie, a publication later sponsored by the Deutsche Gesellschaft für Anthropologie (DGA). Prior to that time, the noted German scientist Johann Friedrich Blumenbach (1752–1840) had assembled large international collections of human remains in Göttingen. Other large nineteenth century German collections were organized by pathologist Rudolf Virchow (1821–1902) in Berlin and Alexander Ecker (1816–1887) in Freiburg. German efforts to promote standardization in methodology led to the 1882 Frankfort agreement in which the Frankfort horizontal was defined, a standard for cranial orientation still of universal acceptance today. Another key contribution consists of the 1914 publication of Lehrbuch der Anthropologie, written by Rudolf Martin (1864–1925), which contained a detailed presentation of standard techniques of analysis.

The developments in France and Germany described above were echoed in varying ways throughout Europe and other areas of the world in the nineteenth and early twentieth centuries. Globally, academics assembled collections of human remains, developed scholarly organizations and publications, and initiated training programs. Research inquiries continued to conform to those established in the early nineteenth century.

Aleš Hrdlička (1869–1943) represents a key figure in the historical development of human skeletal studies in the Americas. An 1881 immigrant from Bohemia (now the Czech Republic) to the United States, Hrdlička assembled large collections of human remains at the Smithsonian Institution in Washington, D.C. Although medically trained, he had studied in Paris with Broca and developed a strong interest in anthropology. His own 1920 publication Practical Anthropometry complemented Martin's work and contributed to the standardization of methodology. He also founded the American Journal of Physical Anthropology in 1918 and later the American Association of Physical Anthropologists in 1930.

By the mid-twentieth century, scholarly institutions around the world had assembled large collections of human remains, developed standard approaches for recording data, initiated training programs, and inaugurated publication programs with a strong focus on comparative human osteology. Much of the goal of this effort was to collect skeletal data in a standard format to facilitate comparative studies. Compilations of measurements and observations frequently were presented as appendices to archaeological reports and tabulated in monographs. Throughout these advancements in comparative studies, work within the field remained tied to its traditional topics of investigation.

As data and collection sizes grew, researchers, particularly in North America, gradually recognized the value of a more problem-oriented approach to skeletal analysis and interpretation. Although comparative morphological studies continued, researchers began to emphasize the dynamic nature of bone growth, development, and maintenance. This emphasis led to studies of bone remodeling, histological age changes, details of bone response to disease insult, and environmental influences. Biomechanical factors were considered in more elaborate research designs that evaluated bone strength and stress factors. Skeletal collections continued to be regarded as reservoirs of information on past population relationships. However, a new emphasis appeared, recognizing that bone morphology also reflected factors of the environment, nutrition, disease, and human behavior, including occupation/habitual use of the skeleton. This perspective is generally reflected in the shift to use of the term "skeletal biology" to define the field. Sorting out the factors of genetics and environment on skeletal morphology became a major issue and subject of research.

A related key historical development involves strengthening of statistical rigor in analysis of skeletal morphology. Much of this effort can be traced to the biometric school established by Karl Pearson (1857–1936) in 1903. Enhanced statistical treatment of skeletal biology data enabled more robust interpretation and assessment of the probabilities involved.

The general trend toward more problem-oriented studies also stimulated novel methods of recording data and observations. These were designed to address specific research issues and moved away from the standardized approaches previously adhered to.

Key Issues/Current Debates

The use of cranial indices and recognition of cranial variation gradually gave way to biological distance studies. These problem-oriented approaches also recognized the genetic component in skeletal, especially cranial, morphology but utilized large, well-documented samples and statistical analyses that presented the variation and probabilities involved. The traditional use of cranial measurements continued, enhanced with observations of discrete traits on the skeleton, dental measurement, and dental observations. Very recently, distance studies have included three-dimensional shape analysis made possible by sophisticated computer software and new instrumentation. These approaches not only enabled a more powerful and revealing look at likely population relationships of the past but also a more nuanced presentation of the variability involved. The recent amplification and analysis of ancient human DNA recovered from archaeological contexts provides modern perspective on past population relationships.

Many of the areas of new interest in skeletal biology relate to the realization that the nongenetic influences on skeletal morphology present opportunities for expanded research. Historically, those interested in using cranial morphology to assess human variation either ignored environmental influences or regarded them as undesirable factors detracting from the research mission. However, others emphasized that these influences presented valuable information on human behavior, adaptation, occupation, and habitual posture. This functional orientation also had deep roots, especially in Germany with the work of Virchow, Julius Wolff (1836–1902), and others. These early researchers recognized the relationship between structural features of bone and the nature of the external stresses/forces acting upon it. Investigators in more modern times built upon the knowledge advanced by these early workers to examine cross-sectional geometry, patterns of trauma, and arthritic alterations as well as other indicators of musculoskeletal stress. Bones are shaped by how they are used; thus, shape analysis potentially reveals information on use.

Routine analysis of remains from archaeological contexts calls not only for detailed inventory but also estimates of sex and age. Methodology for the estimation of sex and age continues to evolve and recognizes the dynamics of growth and development as well as human variation in the expression of sexual dimorphism and the process and timing of adult ageing. Data on the age and sex distribution of skeletal samples have led to advances in the field of paleodemography. Modeled after the demographic study of living populations, paleodemography utilizes age and sex information to construct life tables, mortality curves, survivorship curves, and related expressions of demographic profiles. Such formulations produce valuable projections of life expectancy, age-specific mortality, and similar statistics of past populations that can be compared with those of modern times. However, procedures in this field have sparked lively debate, especially regarding the accuracy of age estimation and sampling issues.

Paleopathology has remained an area of interest throughout the history of skeletal inquiry. Much of the early history of paleopathology studies focused on the evidence for and history of specific diseases, especially leprosy, tuberculosis, and syphilis. Such interest has been sustained and continues today. Modern developments include more sophisticated models of differential diagnosis, improved documentation of studied samples, and new molecular approaches aimed at identification of specific pathogens.

A significant development also has been a population approach to the study of disease. Termed paleoepidemiology, this approach consists of examining the prevalence of expressions of mortality in the past, especially viewed in cultural, geographic, and temporal context. This research focus departs from attempts to diagnose particular diseases in favor of gathering population data on categories of disease/morbidity that reflect such factors as population size and density, diet, nutrition, sedentism, and sanitation. Such research has proven especially valuable in examining long-term temporal trends of morbidity and mortality in specific regions of the world. The endeavor is closely linked with the methodology and results of paleodemography and regional studies of adaptation, including those in archaeology. Research in this area also has addressed quality of life factors and added thoughtful perspective to traditional analyses.

The term bioarchaeology emphasizes the integration of biological information gleaned from skeletal analysis with the cultural/archaeological information available from the provenience. This term recognizes the nature of many of the large skeletal collections throughout the world and their known archaeological contexts. Data on sex, age at death, disease alterations, cultural effects on the skeleton, estimates of living stature, and other biological variables can be correlated with cultural mortuary site information when working with well-documented collections. Such research enables studies of status, gender roles, social relationships, and factors contributing to mortuary site complexity. In broader context, related studies contribute to understanding of dietary adjustment, environmental adaptation, demographic patterns, migration, and regional disease expression. Such studies are completely dependent on sufficient archaeological documentation, not only regarding burial provenience but site and regional complexity as well.

Advances in the discipline of bioarchaeology depend extensively not only on the availability of adequate documented collections but also appropriate interpretive models and methodology. Methodology has grown increasingly technological and sophisticated in recent decades. Early studies in this discipline focused primarily on procedures and instruments to manually gather data. This approach recognized the interests of the time but also the limitations of data analysis. Data synthesis was limited by what could be processed using adding machines and simple calculations. In more recent times, computers have enabled sophisticated approaches including the formulation of large databases and complex statistical analyses.

Technological advances in other areas have also opened up new approaches to research. Advances in microscopy and thin-section preparation brought histological analysis into prominence within the discipline. Impacts were especially evident in methodology for age at death estimation and disease diagnosis. Scanning electron microscopy facilitated studies of microwear on occlusal tooth surfaces, contributing to interpretations of diet and the use of teeth as tools. Radiocarbon dating enabled more exact chronological placement of skeletal collections and improved interpretation of the associated cultural information. In forensic anthropology, radiocarbon analysis with reference to the modern bomb curve also has facilitated time since death determination.

Dietary reconstruction became possible through analysis of elemental isotopes and trace elements. In particular, the isotopes of carbon, nitrogen, hydrogen, oxygen, and strontium potentially reveal dietary food chain information. Carbon isotope analysis has been used to identify consumption of plants with distinct photosynthetic pathways. The availability of dietary information enabled the use of more sophisticated bioarchaeological studies of associations of disease, diet, and environmental context. These in turn could be related to paleodemographic information for a more holistic approach to understanding past populations.

Radiographs and X-ray technology in general have proven very important for skeletal biology research. Radiographic techniques have enabled nondestructive studies of mummified remains and a more sophisticated analysis of skeletal structure. Examples include recognition and interpretation of lines of arrested growth in long bones, patterns of cortical thickness in studies of age change and cross-sectional biometrical analyses, and trauma interpretation. Recent computerized tomography (CT) scan technology has improved the precision of such analysis and offered three-dimensional approaches.

Forensic anthropology shares many of the techniques of other areas of skeletal biology but includes some methods that are unique to its own field. Forensic anthropology refers to the application of knowledge and methodology in physical anthropology to medicolegal problems. Such problems usually involve identification of recovered human remains and deciphering what happened to them. This interpretation consists of determining if recovered evidence represents skeletal or dental tissue; recognizing species; estimating age at death, sex, living stature, time since death, and ancestry; evaluating evidence for identification; assessing postmortem alterations (taphonomy); and interpreting any evidence for foul play.

The history of forensic anthropology closely follows that of skeletal biology/osteology in general with a stronger North American focus. The academic roots extend back to early European pioneers but much of the development occurred in North America as a response to needs within the medicolegal community. Although Aleš Hrdlička was involved in some forensic application, his successors in the United States, T. D. Stewart (1901–1997), J. Lawrence Angel (1915–1986), Wilton Krogman (1903–1987), Mildred Trotter (1899–1991), Ellis R. Kerley (1924–1998), William M. Bass, Clyde Snow, and others, provided momentum. Key administrative developments include the formation of the Physical Anthropology Section of the American Academy of Forensic Sciences in 1972 and the American Board of Forensic Anthropology in 1977. The former provided an annual forum for discussion and presentation of research results in forensic anthropology. The latter offered a certification program for qualified forensic anthropologists who had a Ph.D. degree, experience, and could pass a written and practical examination. In 2011, membership in the physical anthropology section of the AAFS totaled 423 and 88 forensic anthropologists had been awarded diplomate status by the ABFA.

Global interest in forensic anthropology has strengthened in recent years due to augmented training programs, growing recognition of the value of incorporating forensic anthropological perspective with medicolegal initiatives, and the investigation of human rights issues. Anthropologists are especially needed in recovery efforts and have been utilized extensively by such organizations as the International Commission on Missing Persons (ICMP), the International Committee of the Red Cross (ICRC), the Argentine Forensic Anthropology Team (EEAF) and many others.

Work in forensic anthropology relates very closely with other areas of skeletal biology. Most of the techniques of human skeletal biology are needed in the analysis of human remains in a forensic context. Information garnered from forensic analysis and research improves interpretation in the more general field of skeletal biology, especially in regards to trauma interpretation.

Future Directions

From its inception, the discipline has been dependent on the availability of well-documented collections of human remains throughout key areas of the world. Through the work of pioneers like Blumenbach, Virchow, Hrdlička, Samuel Morton (1799–1851), Bass, and many archaeologists worldwide, documented collections of human remains have been compiled and made available for research. These assemblages include key reference collections of individuals, whose age at death, sex, and partial life histories are documented, providing a strong foundation for the development of methodology. The bulk of the collections are from archaeological contexts and store the information about past lives and living conditions that can potentially be made available through research. Further advances in the field are dependent upon their growth and continued availability to researchers.

Fortunately, well-documented collections continue to be assembled worldwide. This development reflects the growing recognition of how much can be learned from them and how vital that knowledge is to forensic applications, justice, and understanding of the human condition, past, and present. In addition, these collections are originating from previously underrepresented areas of the world. They provide new perspective on human variation in all of the science areas investigated. They also allow regional development of methodology that meets the needs of anthropologists working in the area.

In contrast, some areas of the world have witnessed developments regarding repatriation and/or other constraints on the growth of skeletal collections. A strong expression in this development has occurred in the United States through policies and laws that affect continued curation of some collections of human remains. In the USA, many collections relating to the American Indian communities, including some of great antiquity, have been transferred to American Indian groups desiring custody. Similar developments have occurred in Australia and other parts of the world on a lesser scale. Likewise, policies and laws have also affected the disposition of recently recovered ancient human remains, limiting growth of new collections.

While these developments appear to restrict future expansion and maintenance of some collections in particular world areas, they also have stimulated systematic data collection. Recognizing that the affected collections may not be available to future researchers, thoughtful protocols have been development to capture key measurements, observations, and images that likely will be useful for future research. These initiatives have stimulated attempts to develop standards for data collection, reminiscent of the efforts by the early pioneers of Broca, Martin, Hrdlička, and others. With the availability today of computer technology, large databases can be assembled that will hopefully facilitate the work of future physical anthropologists.

The discipline has evolved extensively over the centuries and continues to change. The future appears bright as many highly motivated and intelligent students continue to enter the field, especially in the areas of paleopathology and forensic anthropology. New technology and improved interpretive models enable novel issues to be addressed, with growing applications in forensic anthropology. Research has become increasingly interdisciplinary, frequently involving teams of specialists. The early pioneers would be amazed at how far this field has advanced, but likely pleased that their work enabled so much of the progress to be made.

Cross-References

- ▶ Age Estimation
- ▶ Ancestry Assessment
- ▶ Archaeology: Definition
- ▶ Bioarchaeology: Definition
- ▶ Biological Distance in Bioarchaeology and Human Osteology
- ▶ Bone, Trauma in
- ▶ Dental Anthropology
- ▶ Forensic and Archaeological Analyses: Similarities and Differences
- ▶ Forensic Anthropology: Definition
- ▶ Human Skeletal Remains: Identification of Individuals
- ▶ Osteology Reference Collections
- ▶ Osteology: Definition
- ▶ Pathological Conditions and Anomalies in Archaeological Investigations
- ▶ Sex Assessment
- ▶ Skeletal Biology: Definition
- ▶ Stature Estimation
- ▶ Taphonomy in Bioarchaeology and Human Osteology
- ▶ Taphonomy: Definition

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Bioarchaeology: Definition

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Brief Definition of the Topic

Bioarchaeology is the study of human remains from archaeological contexts. Although the term was first used in reference to the study of animal remains, it has generally become exclusive to human remains, but sometimes called human osteoarchaeology or human bioarchaeology. The field emphasizes integrative, interdisciplinary analysis of the links between biology and culture in past societies. This approach has contributed to an informed understanding of the range of social, behavioral, and economic conditions and circumstances that have shaped the human experience – especially health and well-being, lifestyle, and quality of life – during the last 10,000 years of human evolutionary history.

Cross-References

- ▶ Biological Distance in Bioarchaeology and Human Osteology
- ▶ Evolutionary Anthropology: Issues, News, and Reviews
- ▶ Osteology: Definition
- ▶ Pathological Conditions and Anomalies in Archaeological Investigations
- ▶ Skeletal Biology: Definition

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Biological Distance in Bioarchaeology and Human Osteology

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Introduction

Biological distance, or biodistance, is a measure of relatedness or divergence among groups separated by time and/or geography based on morphological variation (Buikstra et al. 1990). Biological distance studies, which are undertaken to reconstruct population history and to assess ancestry, dominated bioarchaeological research during the nineteenth and early twentieth centuries. The earliest attempts to comprehend human variation and measure relatedness among human groups, through the construction of typological racial classifications, fell short of their predicted goals. These early attempts were flawed due to limitations of the approach, which included the mistaken belief that humanity could be divided into a finite number of pure races, and the lack of adequate quantitative methods. Advances in evolutionary theory, including quantitative and population genetics, and improvements in computing and statistical procedures in the early twentieth century provided a much sounder basis for measuring and interpreting morphological variation within and between human groups.

Because of the demonstrated correlation between phenotypic and genotypic similarities, measures of biological distance in bioarchaeology are generally determined through the application of quantitative methods to metric and nonmetric variation recorded in skulls, teeth, and skeletons. Ancient DNA (aDNA) and other biochemical and geochemical traits are beginning to find their way into biodistance studies.

Studies of cranial form, most notably cranial measurements (or craniometrics) that quantify morphology, figured prominently in the early development of the discipline and continue to occupy a central role in modern biological distance studies. While morphological variation, especially quantitative variation, is subject to nongenetic or environmental influences, this category of variation is generally assumed to reflect genetic similarity resulting from neutral evolutionary forces (genetic drift, gene flow, and mutation). There is now an emerging consensus that craniometric data can be used as a proxy to genetic data, hence the popularity of this category of variation in biodistance studies.

The continuing interest in cranial form for reconstructing population history is supported by a number of factors including the precision and repeatability of measurements, the conservative nature of craniometric variation, the direct link with the past, and the demonstration of a genetic component for this category of biological variation. Likewise, the strong geographic patterning (e.g., Howells 1973), selective neutrality of phenotypic (craniometric) variation (e.g., Relethford 2009), and the amenability of continuous variation to multivariate statistical analysis have ensured the continued use of this category of variation in biodistance analyses.

Teeth, especially dental nonmetric traits, have also figured prominently in assessing biological distance among ancient and modern populations. Standardization of dental scoring methods, high genetic component, and conservatism of this category of variation have made the dentition a popular choice for reconstructing population history.

Mathematically based methods, which are often based on quantitative and population genetic analyses, allow bioarchaeologists to address a broad array of research topics that include:

- Tracing biological relationships, temporally and spatially, for reconstructing past population history, origins, and movement of human groups
- Investigating microevolutionary processes (e.g., gene flow, genetic drift, selection) and the influence of geography and other isolating mechanisms on the observed patterns of biological relatedness
- Identification of postmartial residence patterns, familial and kin groupings, cemetery structure, social status, immigrants, and admixture
- Sorting of commingled skeletal and dental remains
- Assignment of an unknown individual (or skull) to a known reference group in repatriation claims and forensic cases

By identifying the population structure, biological distance studies provide an important context for addressing other topics in bioarchaeology such as paleopathology, paleodemography, health, and diet.

Definition

Biological distance, or biodistance, is the measure of biological relatedness (or divergence) between and within human groups, living and past, based on human skeletal and dental variation.

Key Issues

Although equally applicable to morphological/phenotypic variation, the discussion of the key issues in biological distance studies will focus on the use of cranial measurements, or craniometrics, unless otherwise noted.

Underlying Assumptions

While morphological variation, including craniometric variation, is subject to nongenetic or environmental influences, this category of variation is generally viewed as reflecting genetic similarity. It is assumed that groups that display more phenotypic similarity are the most closely related. Additionally, various studies have demonstrated a significant genetic component for many cranial measurements (e.g., Martínez-Abadías et al. 2009).

Geographic Patterning and Neutrality of Craniometric/Phenotypic Variation

Beginning with the pioneering work of W.W. Howells (1973), there is now near universal acceptance that human cranial variation is geographically structured making it highly attractive for reconstructing population history and for assessing ancestry.

While some aspects of cranial morphology (i.e., face and nose, Hubbe et al. 2009) are susceptible to climatic adaptation, numerous studies have demonstrated that phenotypic distance and global patterns of craniometric variation, on average, correlate with neutral genetic distance globally and are consistent with neutral traits under an isolation by distance model (Relethford 2004; Roseman 2004; Harvati & Weaver 2006; von Cramon-Taubadel 2009; Betti et al. 2010). Studies such as these reiterate that cranial form provides valuable information about past population history and for investigating microevolutionary processes (Smith 2011). Furthermore, that craniometric variation is geographically structured allows high levels of classification accuracy when crania from different parts of the world are compared (Relethford 2009).

Variables and Methods

Studies of biological distance, beginning in the 1970s, increasingly relied on the application of multivariate statistical procedures to craniometric data. Multivariate statistical procedures comprise a family of related mathematical procedures that allow the simultaneous analysis of many random but interrelated variables whose effects cannot be interpreted individually in a meaningful manner. These procedures are exceptionally well suited for investigating patterns of biological variation, measuring relatedness among groups, and making other inferences of the variables and groups selected. The primary multivariate statistical procedures applied to craniometric traits in biological distance studies include principal components analysis, stepwise discriminant function (canonical) analysis, and Mahalanobis' generalized distance statistic. Various clustering algorithms, such as the unweighted pair group method algorithm (UPGMA), facilitate interpretation of relatedness between groups through the construction of dendrograms (see Case Study 1). A more detailed discussion of the methods used for analyzing metric data is provided in Pietrusewsky (2008a). C.A.B. Smith's mean measure of divergence (MMD) remains one of the most popular distance statistics for analyzing dental and cranial nonmetric traits.

In addition to traditional landmark measurements (linear distances, areas, volume, angles), the use of Cartesian coordinates of cranial landmarks recorded in two or three dimensions using digitizing equipment is a recent alternative approach for quantifying size and shape. Geometric morphometric techniques, including Procrustes analysis, have become standard tools for analyzing coordinate data (Slice 2005).

Model-Free and Model-Bound Approaches

The earliest biological distance studies were largely model-free approaches that focused more on the overall similarities among groups than on the causes of the observed patterns of variation. Later studies applied a population genetic framework for analyzing quantitative traits (e.g., Relethford & Blangero 1990; Roseman 2004; Smith 2011). These model-bound approaches allowed the estimation of microevolutionary processes such as gene flow and genetic drift.

Selection of Samples and Variables

Because skeletal series represent only samples of past biological populations, which often span considerable periods of time and may be biased in their representation, extreme caution should be exercised when skeletal (cranial) samples are used in biological distance studies. Using relatively large samples that are free of systematic bias helps to alleviate some of the concerns. Likewise, the selection of traits that are less susceptible to environmental and cultural influences further ensures that the results of biological distance analysis more faithfully estimate genetic relatedness. Recent studies (e.g., von Cramon-Taubadel 2009; Smith 2011) suggest that some bones of the neurocranium such as the temporal bone because of its stronger correlation with neutral genetic data might be more reliable for reconstructing human population history than other regions of the cranium.

Current Debates

Origin and Dispersal of Modern Humans/New Hominin Species

Refinements in methods and techniques continue to influence work in biological distance studies. Some of the recent developments are associated with the debate over the origin and pattern of dispersal of anatomically modern humans (e.g., Smith 2011). The association of craniometric variation and geography has been viewed within the context of this larger debate. The question of whether long distance gene flow mediated by geographic distance (isolation by distance model) or population dispersal, such as with the spread of modern humans out of Africa 100,000–150,000 years ago, is responsible for this observed correlation has been examined (e.g., Weaver et al. 2008).

Biological distance studies have also been used to evaluate claims for the designation of new hominin species, such as *Homo floresiensis*, in paleoanthropology.

Origins of Native Americans

Studies in biological distance contribute to reconstructions of population history at both the global and regional levels. Craniometric variation studies addressing the origin and dispersal of the first humans to reach the Americas are illustrative of regional analysis (e.g., Ross et al. 2003). Many other studies examining the population history of various regions and time periods, too numerous to cite in this entry, have appeared in the literature in recent years.

Transition from Hunting-Gathering to Agriculture

Another debate that biological distance studies have contributed to in recent years is the transition to farming in Europe and whether indigenous hunter-gatherers were replaced (demic diffusion model) by agriculturalists from the Near East or whether these indigenous groups adopted farming practices (cultural diffusion model) from their neighbors (e.g., von Cramon-Taubadel 2011). Studies that focus on the transition to farming in other regions of the world have also appeared.

Boas' Immigration Studies and Cranial Plasticity/Climate and Environmental Influences

Several recent investigations (e.g., Sparks & Jantz 2002) examined the statistical and biological significance of Franz Boas' immigration studies as they relate to cranial plasticity. Often, these studies are discussed within the broader context of the debate over genetic and environmental influences on craniometric variation and the degree to which skeletal and dental morphology are influenced by environmental and/or selection pressures (e.g., Harvati & Weaver 2006; Hubbe et al. 2009).

In the field of forensic anthropology, discussion continues over the existence of races and the use of computer software programs (e.g., FORDISC & CRANID) designed to assign unknown individuals to a reference group.

Individual Bones of the Skull and Biodistance Studies

Several recent studies have identified the possible influence of environmental factors that may affect craniofacial morphology. These, in turn, have led to specialized studies that examine the shape of individual bones of the cranium to identify which are more strongly correlated with neutral genetic expectation and thus better suited for use in reconstructing human population history and primate phylogeny (e.g., von Cramon-Taubadel 2009; Smith 2011).

Future Directions

Future work in studies of biological distance is anticipated to build on previous work in evolutionary quantitative genetics and contribute to a broad array of evolutionary questions in bioarchaeology and biological anthropology. Refinements in quantitative methods including Bayesian statistical modeling and new imaging technology will continue to shape future work in this field. The use of geometric morphometrics and Cartesian coordinates of cranial landmarks for analyzing size and shape will likely witness an increased presence in the field. While the use of digitizing equipment for recording 3D coordinate data is expected to become more common in future work, reliance on traditional landmark measurements made with calipers will persist as an attractive and convenient alternative.

The multivariate statistical procedures associated with traditional morphometric analyses, such as principal components analysis, discriminant (canonical) analysis, and Mahalanobis' distance, will continue to occupy an important role in future biodistance studies. The reliance on multivariate methods associated with biological distance studies, old and new, reinforces the need for students to be adequately trained in statistical and quantitative methods.

Biological Distance in Bioarchaeology and Human Osteology, Table 1 Fifty-six male cranial samples used in the example

Series Name (abbrev.)[a]	No. of Crania	Location[b] and Number of Crania	Remarks
Polynesia			
1. Tonga-Samoa (TOG)	19	BER-3; AMS-2; DRE-1; PAR-1 BPB-4; AIM-2; AUK-5; SIM-1	Fourteen specimens are from Tonga and five are from Samoa. Included in the Tongan series are three skulls from Pongaimotu excavated by McKern in 1920; two from To-At-1 and To-At-2 excavated by Janet Davidson in 1965; and five from To-At-36 excavated by Dirk Spennemann in 1985/1986. The remaining specimens are from museums in Berlin, Paris and Sydney. Although the exact dates for a few specimens are not known, the majority are believed to be prehistoric
2. Easter Island (EAS)	50	BER-5; DRE-9; PAR-36	Most of the crania in Paris were collected by Pinart in 1887 at Vaihu and La Perouse Bay, Rapa Nui (Easter Island). The exact dates of these specimens are not known
3. Hawai'i (HAW)	60	BPB-20; HON-20; SIM-20	An equal number of specimens have been randomly chosen from three different skeletal series: Mōkapu (O'ahu), Honokahua (Maui), and Kaua'i. All specimens are presumed to be prehistoric (pre-1778)
4. Marquesas (MRQ)	63	PAR-49; LEP-1; BLU-1; BPB-12	Crania are from four islands, Fatu Hiva, Tahuata, Nuku Hiva and Hiva Oa. The exact dates of these specimens are not known
5. New Zealand (NZ)	50	BRE-3; PAR-21; SAM-1; AIM-13; GOT-1; ZUR-5; DRE-6	A representative sample of New Zealand Maori crania from the North and South Islands of New Zealand. The exact dates of these specimens are not known
6. Chatham Islands (CHT)	45	DUN-8; OTM-2 WEL-4; CAN-10 AIM-3; DRE-5 AMS-2; DAS-3 GOT-4; PAR-4	Moriori crania from the Chatham Islands, New Zealand. The exact dates of these specimens are not known
7. Society Islands (SOC)	44	PAR-33; BPB-11	Crania are from the island of Tahiti, Society Islands. The exact dates of these specimens are not known
8. Tuamotu Archipelago (TUA)	18	PAR-18	The majority of the specimens are from Makatea in the Tuamotu Archipelago. The exact dates of these specimens are not known
Island Melanesia			
9. Fiji (FIJ)	42	BER-1; SAM-3 ; QMB-1; DRE-4 FRE-3; CHA-1; BPB-11; PAR-7 AMS-3; DUN-6; SIM-2	Crania are from all major islands including the Lau Group in the Fiji Islands. The exact dates of these specimens are not known
10. Vanuatu (VAN)	47	BAS-47	Most of the specimens were collected by Felix Speiser in 1912 from Malo, Pentecost and Espirtu Santo Islands, Vanuatu. The exact dates of these specimens are not known
11. Loyalty Islands (LOY)	50	BAS-43; PAR-7	Crania are from Mare, Lifou, and Ouvea Island Groups, Loyalty Islands The exact dates of these specimens are not known
12. New Caledonia (NCL)	50	BAS-34; PAR-16	Crania are from several coastal and inland locations on New Caledonia. The majority of these specimens were collected in the late nineteenth century. The exact dates of these specimens are not known

(*continued*)

Biological Distance in Bioarchaeology and Human Osteology, Table 1 (continued)

Series Name (abbrev.)[a]	No. of Crania	Location[b] and Number of Crania	Remarks
13. Santa Cruz Islands (SCR)	46	SAM-4; AMS-2; BAS-40	The crania in Basel were collected by Felix Speiser in 1912. The exact dates of these specimens are not known
14. Solomon Islands (SOL)	49	DRE-3; BER-1; NMV-1; QMB-3; AMS-16; DAS-10; BAS-14; GOT-1	Crania are from New Georgia (5), Guadacanal (9), San Cristobal Island (7), and other locations in the Solomon Islands. The exact dates of these specimens are not known
15. New Britain (NBR)	50	CHA-20; DRE-30	The specimens from New Britain in Dresden were collected by A. Baessler in 1900 and those in Berlin were collected by R. Parkinson in 1911. The specimens were collected from trading posts near Rabul in the Gazelle Peninsula and most likely represent Tolai crania. The exact dates of these specimens are not known
16. New Ireland (NIR)	53	AMS-4; BER-2; BLU-6; DRE-18; GOT-15; QMB-1; SAM-6; TUB-1	Most of the crania in Dresden were collected by Pöhl in 1887–1888 from the northern end of the island; the specimens in Göttingen were collected during the Südsee Expedition in 1908. The exact dates of these specimens are not known
17. Admiralty Islands (ADR)	50	DRE-20; GOT-9; CHA-6; TUB-15;	Specimens from Hermit, Kaniet and Manus Islands of the Admiralty Islands. The exact dates of these specimens are not known
New Guinea			
18. Sepik R. (SEP)	50	DRE-33; GOT-10; TUB-7	The specimens in Dresden were collected by Otto Schlaginhaufen in 1909 from various locations along the Sepik River, Papua New Guinea. The exact dates of these specimens are not known
19. Biak Island (BIK)	48	DRE-48	Most (45) of the specimens were collected by A.B. Meyer in 1873 on Biak Island (Mysore), Geelvink Bay, Irian Jaya. The exact dates of these specimens are not known
20. Purari Delta (PUR)	50	DRE-50	Decorated (engraved) skulls obtained by Gerard and Webster between 1900 and 1902 are from along the Purari River and Purari Delta regions, Papua New Guinea. The exact dates of these specimens are not known
Australia/Tasmania			
21. Murray R. (MRB)	50	AIA-39; DAM-11	Australian Aboriginal crania were collected by G.M. Black along the Murray River (Chowilla to Coobool) in New South Wales between 1929–1950. The exact dates of these specimens are not known
22. New South Wales (NSW)	62	AMS-21; DAS-41	Australian Aboriginal crania from the coastal locations in New South Wales. The exact dates of these specimens are not known
23. Queensland (QLD)	54	AMS-21; DAS-3; QMB-30	Australian Aboriginal crania from the southeastern and middle-eastern regions of Queensland. The exact dates of these specimens are not known
24. Northern Territory (NT)	50	AIA-4; AMS-3; MMS-1; NMV-38; QMB-1; SAM-3	Australian Aboriginal crania from Port Darwin (14) and Arnhemland (36) in the Northern Territory, Australia. The exact dates of these specimens are not known

25. Swanport, S.A. (SAS)	36	SAM-36	Australian Aboriginal crania representing the Tarildekald and Warki-Korowalde tribes in the lower Murray River basin. The specimens were collected by F. R. Zeitz in 1911 from an aboriginal cemetery located approximately 10 km southeast of the Murray Bridge in South Australia (Howells 1973:21). The exact dates of these specimens are not known
26. Western Australia (WA)	47	WAM-47	Australian Aboriginal crania from central (20), eastern (4), northern (14), and southern (9) regions of Western Australia. The exact dates of these specimens are not known
27. Tasmania (TAS)	26	THM-22; CHA-1; SAM-2; NMV-1	The crania represent Tasmanian Aborigines. The exact dates of these specimens are not known
Micronesia			
28. Guam (GUA)	46	BPB-42; PAR-4	Pre-Spanish Chamorro crania associated with *latte* structures collected in the 1920s by Hans Hornbostel along Tumon Beach, Tumon Bay, Guam. The majority of these specimens represent prehistoric (pre-1521) Chamorro
Island Southeast Asia			
29. Sumatra (SUM)	39	BER-1; BRE-1; DRE-5; LEP-4; PAR-3; ZUR-25	The specimens in Zürich are designated “Battak,” specific locations within the island of Sumatra are not known. The exact dates of these specimens are not known
30. Java (JAV)	50	BER-1; BLU-8; CHA-9; DRE-1; LEP-24; PAR-7	Crania were collected from several different localities in Java. The exact dates of these specimens are not known
31. Borneo (BOR)	34	BER-2; BRE-2; DRE-6; FRE-4; LEP-8; PAR-12	A great many of the specimens are indicated as representing Dayak tribes, some have elaborate decorations. The exact dates of these specimens are not known
32. Sulawesi (SLW)	41	BAS-7; BER-10; DRE-4; FRE-7; LEP-5; PAR-8	An exact location is known for many of these specimens. The exact dates of these specimens are not known
33. Lesser Sunda Islands (LSN)	61	BAS-5; BER-15; BLU-2; CHA-1; DRE-24; LEP-1; PAR-6; ZUR-7	Crania from Bali (13), Flores (9), Sumba (1), Lomblem (2), Alor (2), Timor (11), Wetar (2), Leti (4), Barbar (1), Tanimbar (13), Kai (2) and Aru (1) Islands of the Lesser Sunda Islands. The exact dates of these specimens are not known.
34. Southern Moluccas Islands (SML)	65	FRE-48; DRE-17	Crania are from Seram (48) and Buru (17) Islands of the Southern Moluccas Islands. The exact dates of these specimens are not known
35. Sulu (SUL)	38	LEP-1; PAR-37	The specimens in Paris were collected by Montano-Rey c. 1900. The exact dates of these specimens are not known
36. Philippines (PHL)	28	BER-9; DRE-19	Most specimens are from Luzon Island. The exact dates of these specimens are not known
Mainland Southeast Asia			
37. Vietnam (VTN)	49	HCM-49	Near modern crania from Hanoi (Van Dien Cemetery) and Ho Chi Minh City
38. Bachuc Village, (BAC)	51	BAC-51	Victims of the 1978 Khmer Rouge massacre in Bachuc Village in western Angiang Province, Vietnam

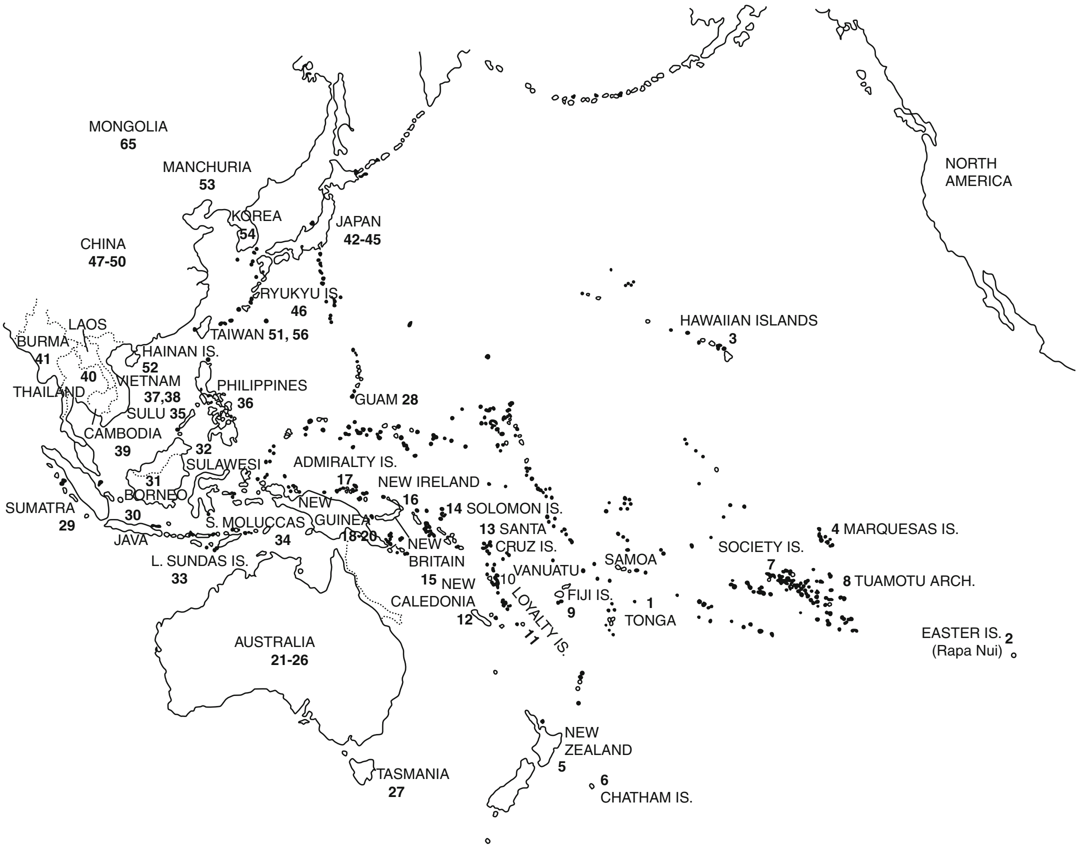
(*continued*)

Biological Distance in Bioarchaeology and Human Osteology, Table 1 (continued)

Series Name (abbrev.)[a]	No. of Crania	Location[b] and Number of Crania	Remarks
39. Cambodia & Laos (CML)	40	PAR-40	A combined sample of crania from various locations in Cambodia and Laos collected between 1877 and 1920. The exact dates of these specimens are not known.
40. Thailand (THI)	50	SIR-50	Most of the specimens represent dissecting room cases from Bangkok
41. Burma (BUR)	16	ZUR-16	The crania in Zürich are from a series (Cat. Nos. 93–125) of skulls collected in Mandalay, Myanmar (Burma), described in a catalogue dated c. 1900. The exact dates of these specimens are not known
East Asia: Japan			
42. Kanto (KAN)	50	CHB-50	A dissecting room population of modern Japanese from the Kanto District of eastern Honshu. The majority of the individuals were born during the Meiji period (1868–1911) and died well before 1940
43. Tohoku (TOH)	53	SEN-53	Dissecting room specimens of modern Japanese from the Tohoku District in northern Honshu Island
44. Kyushu (KYU)	51	KYU-51	Modern Japanese, which derive mostly from Fukuoka Prefecture in Kyushu Island. Other specimens are from Yamaguchi, Saga, Nagasaki and adjoining prefectures
45. Ainu (AIN)	50	SAP-18; TKM-5; TKO-27	Modern to near modern skeletons collected by Koganei in 1888–1889 from abandoned Ainu cemeteries in Hokkaido
46. Ryukyu Islands (RYU)	60	KYO-18; KAN-21; RYU-8; KYU-5; TKO-8	Eighteen near modern crania are from Tokunoshima Island of the Amami Islands located north of the Okinawa Group in the central Ryukyu Islands; 21 specimens are from two different locations on Kume Island, an island located west of Okinawa Island: Yattchi (17) and Hiyajo (4); 21 specimens are from five separate islands in the Sakishima Group of the southern Ryukyu Islands: Hateruma Island (2); Miyako (4); Iriomote Island (2); Ishigaki Island (1), and Yonaguni Island (12)
China and N.E. Asia			
47. Shanghai (SHA)	50	SHA-50	The specimens are mostly from post-Qing (post-1911) cemeteries in Shanghai
48. Nanjing (NAJ)	49	SHA-49	The series represents near modern crania exhumed from the modern city of Nanjing, Jiangsu Province, eastern China
49. Chengdu (CHD)	53	SHA-10; CHE-43	A majority of these specimens date to the Qing Dynasty (CE 1644–1911) and are from Chengdu, Sichuan Province in western China. Ten crania are from Leshan, Lizhong County, Sichuan Province
50. Hong Kong (HK)	50	HKU-50	Specimens represent individuals who died in Hong Kong between 1978 and 1979

51. Taiwan (TAI)	47	TPE-47	Modern Chinese living in Taiwan who trace their immediate origins to Fujian and Guangdong Provinces on the mainland of China
52. Hainan Island (HAI)	47	TPE-47	Near modern Chinese whose ancestors began migrating from the Canton region of China to Hainan Island around 200 BCE. This material was excavated by Takeo Kanaseki in Haikou City on Hainan Island
53. Manchuria (MAN)	50	TKO-50	Many of the specimens are from northeastern China or the region formerly referred to as "Manchuria," which today includes Heilongjiang and Jilin Provinces and adjacent northern Korea. A great many of these specimens are identified as soldiers, or cavalrymen, who died in battle in the late 19th century CE
54. Korea (KOR)	32	KYO-7; SEN-3, TKM-2; TKO-20	Specific locations in Korea are known for most of these near modern specimens
55. Mongolia (MOG)	50	SIM-50	The skulls are identified as coming from Ulaanbaatar (Urga), Mongolia and were purchased by A. Hrdlička in 1912
56. Atayal (ATY)	36	TPE-28; TKM-7; TKO-1	The Atayal are the second largest surviving Aboriginal tribe in Taiwan. The specimens are Atayal slain in the Wushe incident in 1930. The specimens were collected by Takeo Kanaseki in 1932

[a, b]AIM, Auckland Institute and Museum, Auckland, New Zealand; AIA, Australian Institute of Anatomy, Canberra, Australia; AMS, The Australian Museum, Sydney, Australia; AUK, University of Auckland, Auckland, New Zealand; BAC, Bachuc Village, Angiang Province, Vietnam; BAS, Naturhistorisches Museum, Basel, Switzerland; BER, Museum für Naturkunde, Berlin, Germany; BLU, Anatomisches Institut, Universität Göttingen, Göttingen, Germany; BPB, B. P. Bishop Museum, Honolulu, U.S.A.; BRE, Über-see Museum, Bremen, Germany; CAN, Canterbury Museum, Christchurch, New Zealand; CHA, Anatomisches Institut der Chairté, Humboldt Universität, Berlin, Germany; CHB, Chiba University School of Medicine, Chiba, Japan; CHE, Dept. of Anatomy, Chengdu College of Traditional Chinese Medicine, Chengdu, China; DAM, Dept. of Anatomy, University of Melbourne, Melbourne, Australia; DAS, Dept. of Anatomy, University of Sydney, Sydney, Australia; DUN, Dept. of Anatomy, University of Otago, Dunedin, New Zealand; DRE, Museum für Völkerkunde, Dresden, Germany; FRE, Institut für Humangenetik und Anthropologie, Universität Freiburg, Freiburg im Breisgau, Germany ; GOT, Institut für Anthropologie, Universität Göttingen, Göttingen, Germany; HCM, Faculty of Medicine, Ho Chi Minh City, Viet Nam; HON, Honokahua, Maui, Hawai'i, U.S.A.; HKU, University of Hong Kong, Hong Kong; KAN, Kanegusuku Storage Room, Board of Education Cultural Division, Kanegusuku, Okinawa, Japan; KYO, Physical Anthropology Laboratory, Faculty of Science, Kyoto University, Kyoto, Japan; KYU, Dept. of Anatomy, Faculty of Medicine, Kyushu University, Fukuoka, Japan; LEP, Anatomisches Institut, Karl Marx Universität, Leipzig, Germany; MMS, Macleay Museum, University of Sydney, Sydney, Australia; NMV, National Museum of Victoria, Melbourne, Australia; OTM, Otago Museum and Art Gallery, Otago, New Zealand; PAR, Musée de l'Homme, Paris, France; QMB, Queensland Museum, Brisbane, Australia; RYU, University of the Ryukyus, Naha, Okinawa Island, Japan; SAM, South Australian Museum, Adelaide, Australia; SAP, Dept. of Anatomy, Sapporo Medical College, Sapporo, Japan; SEN, Dept. of Anatomy, School of Medicine, Tohoku University, Sendai, Japan; SHA, Institute of Anthropology, College of Life Sciences, Fudan University, Shanghai, China; SIM, National Museum of Natural History, Smithsonian Institution, Washington, D.C., U.S.A.; SIR, Dept. of Anatomy, Siriraj Hospital, Bangkok, Thailand; THM, Tasmanian Museum and Art Gallery, Hobart, Australia; TKM, Medical Museum, University Museum, University of Tokyo, Tokyo, Japan; TKO, University Museum, University of Tokyo, Tokyo, Japan; TPE, Academia Sinica, Nankang, Taipei, Taiwan; TUB, Institut für Anthropologie u. Humangenetik, Universität Tübingen, Tübingen, Germany; WAM, Western Australian Museum, Perth, Australia; WEL, National Museum of New Zealand, Wellington, New Zealand; ZUR, Anthropologisches Institut, Universität Zürich, Zürich, Germany



Biological Distance in Bioarchaeology and Human Osteology, Fig. 1 Map showing the approximate locations of the 56 cranial samples used in the example (This figure, reproduced here courtesy of Etty Indriati, was originally published in Pietrusewsky (2008b))

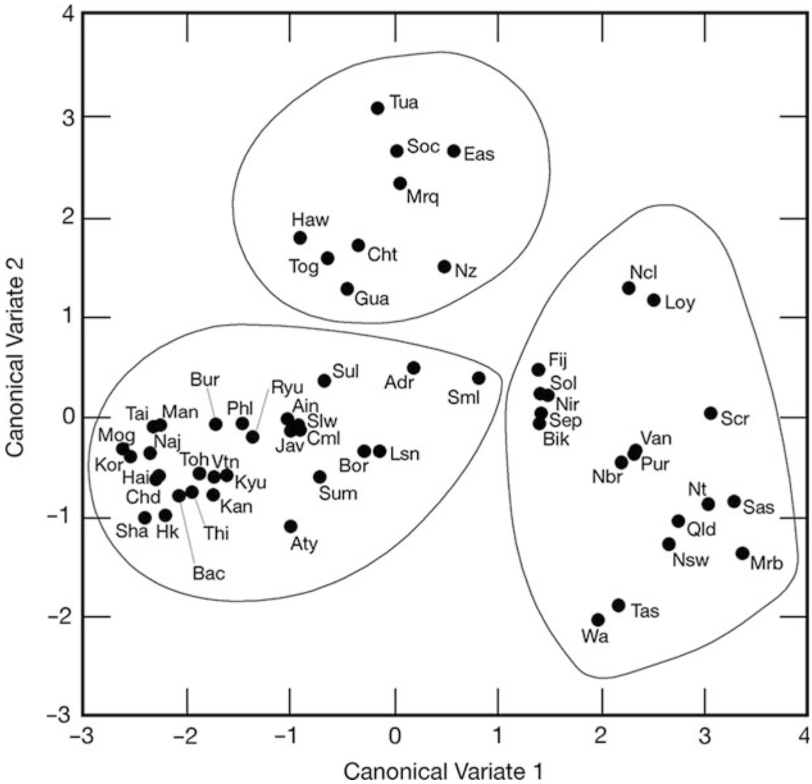
In addition to studies of skull form and teeth, the analysis of aDNA and other geochemical data will attract future research in biological distance. Combining data from multiple sources (e.g., Ricaut et al. 2010) will likewise provide new opportunities for reconstructing evolutionary and population history.

As never before, access to computers, imaging technology, user-friendly software for conducting biological distance studies, and sharing of data and quantitative methods will guide and encourage future studies.

Given the current repatriation claims and issues surrounding the accessibility of skeletal remains, the creation of data banks such as W.W. Howells' craniometric data bank, and the sharing of data worldwide will provide a wealth of information that is nonrenewal. Many of the skeletal series examined in biodistance studies just a few decades ago using traditional morphometrics (e.g., Polynesians and Australian Aboriginals) are no longer accessible to researchers.

Case Study 1: An Example of Biological Distance Analysis

In this example, two multivariate statistical procedures, stepwise discriminant function (canonical) analysis and Mahalanobis' distance, are applied to 27 landmark cranial measurements recorded in 56 modern and near modern male cranial samples for understanding the population history of the Asia-Pacific region (Table 1, Fig. 1) (Pietrusewsky 2008b). Discussion of these results is restricted to a canonical plot of group means and the dendrogram of Mahalanobis' distances, with detailed discussion provided in Pietrusewsky (2008a).



Biological Distance in Bioarchaeology and Human Osteology, Fig. 2 Plot of 56 group means on the first two canonical variates after applying stepwise discriminant function analysis to 27 cranial measurements. Abbreviations of the cranial samples are explained in Table 1 (This figure, reproduced here courtesy of Etty Indriati, was originally published in Pietrusewsky (2008b))

Stepwise Discriminant Function Analysis

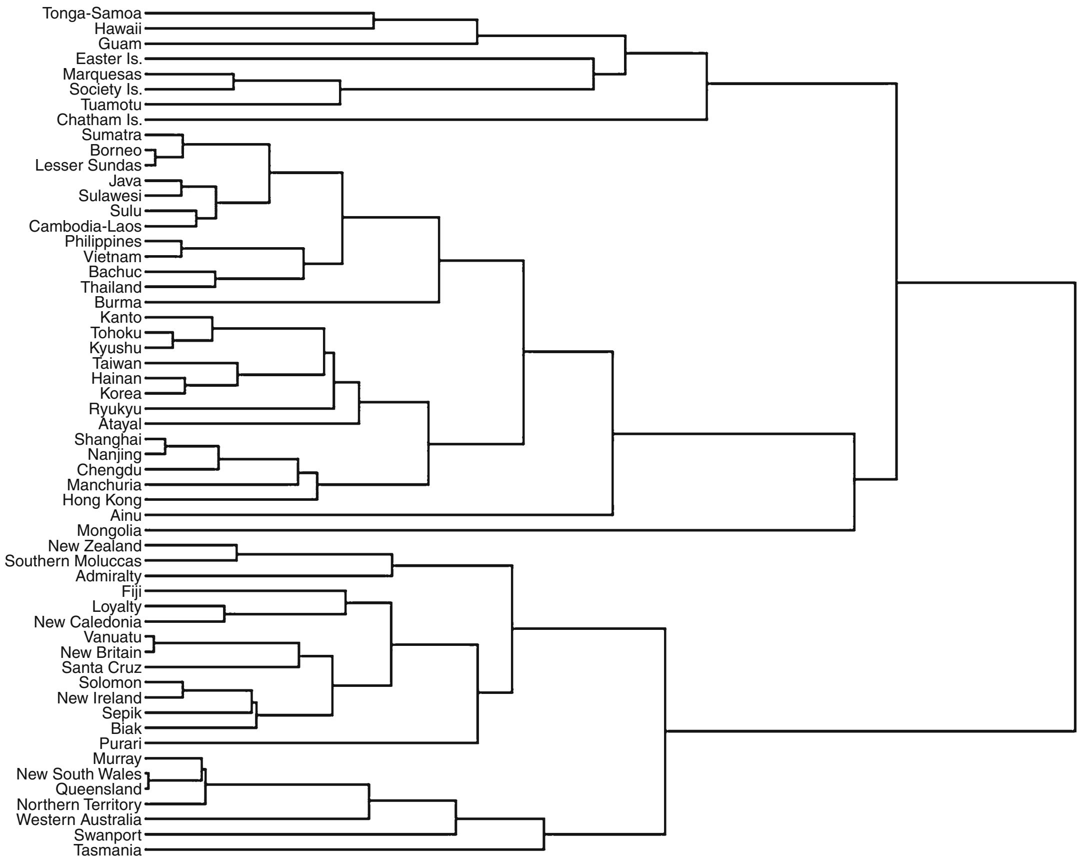
Three clusters emerge when the group means for the 56 group are plotted on the first two canonical variates (Fig. 2). One of these includes the cranial series from Australia, New Guinea, and geographical Melanesia. A second cluster includes the cranial series representing Polynesia and Guam. Cranial series from Mainland Southeast Asia and East Asia form a third major constellation. Of note, the cranial series from the Southern Moluccas, Admiralty Islands, and Lesser Sunda Islands occupy an intermediate position between the Polynesian and Australo-Melanesian cranial series.

Mahalanobis' Generalized Distance

Applying the UPGMA clustering algorithm to Mahalanobis' distances results in the dendrogram shown in Fig. 3. The primary division evident in this diagram places all the cranial series from Australia and Melanesia in one branch while the second includes the cranial series from Polynesia, Southeast Asia, and East Asia. Within these major divisions, there is internal differentiation that generally mirrors geography. It is also worth noting that New Zealand Maori (Polynesia), Southern Moluccas (Island Southeast Asia), and the Admiralty Islands (Melanesia) cranial series form a cluster that ultimately links with the Australian-Melanesian branch in this diagram.

Australia/Melanesia Versus Southeast/East Asia and Remote Oceania

The presence of two major divisions demonstrated in these results supports archaeological, linguistic, and genetic models that the indigenous inhabitants of Australia, Tasmania, and geographical Melanesia share a common origin that is unrelated to that for the modern inhabitants of Southeast Asia and East Asia. The sharp separation between Polynesian and Australian-Melanesians series further reinforces archaeological and linguistic models. These models hypothesize an earlier colonization of Australia,



Biological Distance in Bioarchaeology and Human Osteology, Fig. 3 Dendrogram (or diagram of relationship) that results from applying the UPGMA clustering algorithm to Mahalanobis' distances using 27 cranial measurements recorded in 56 male groups (This figure, reproduced here courtesy of Etty Indriati, was originally published as Fig. 4 in Pietrusewsky (2008b))

New Guinea, and neighboring regions of Near Oceania and a much later colonization that led to the peopling of previously uninhabited remote Oceania.

Southeast Asia and North/East Asia

These results further allow an examination of some of the current archaeological models advanced to explain the population history of East and Southeast Asia. The sharp contrast between East/North Asian and Southeast Asian cranial series does not support linguistic and archaeological models that argue that the indigenous inhabitants of Southeast Asia were replaced by immigrant groups of people of a more northern origin during Neolithic times.

Island Southeast Asia/Polynesian Homeland

Finally, these results also support an ancestral Polynesian homeland in East/Southeast Asia and not one within geographically adjacent Melanesia. The connection between New Zealand Maori (a Polynesian series) and the Southern Moluccas (Island Southeast Asia) cranial series supports a probable Island Southeast Asian origin of the Polynesians, an association also demonstrated in previous analyses of genetic data.

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Cross-References

- ▶ Ancestry Assessment
- ▶ Bioarchaeology, Human Osteology, and Forensic Anthropology: Definitions and Developments
- ▶ Demographic Transitions
- ▶ Dental Anthropology
- ▶ Forensic Anthropology: Definition
- ▶ Hokkaido Sequence and the Archaeology of the Ainu People
- ▶ Human Migration: Bioarchaeological Approaches
- ▶ Human Remains in Museums
- ▶ Hunter-Gatherer Subsistence Variation and Intensification
- ▶ Insular Southeast Asia at the Interface of Continent-Archipelago: Geography and Chronology
- ▶ Northern Asia: Origins and Development of Agriculture
- ▶ Skeletal Biology: Definition

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Biometry in Zooarchaeology

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Introduction

The measurement of bones is a routine aspect of zooarchaeological analysis. Requiring minimal equipment and relatively little experience, it nonetheless has the potential to contribute to many of the discipline's major recurring themes, including domestication, herd management, hunting strategies, and environmental change. Most analysts currently use the same standard set of measurements for mammals and birds – published by Angela von den Driesch in 1976 – allowing considerable scope for comparison between sites. A number of promising new statistical techniques such as mixture analysis have been applied to zooarchaeological biometry in recent years, but the development likely to have the biggest impact in the near future is the establishment of online repositories of measurement data, facilitating large-scale meta-analyses.

Definition

In the context of vertebrate zooarchaeology, biometry refers to the measurement of individual dimensions of hard tissues – primarily bone – and the calculation of simple indices. Common uses of measurements include species identification, sex determination, age estimation, assessment of domestication status, and tracing environmental changes.

Key Issues/Current Debates/Future Directions/Examples

Techniques and Standardization

For measurements to be useful, they must be repeatable and comparable. It is therefore necessary both to use equipment capable of producing reliable, accurate measurements and to ensure standardization between analysts in the exact dimensions to be measured.

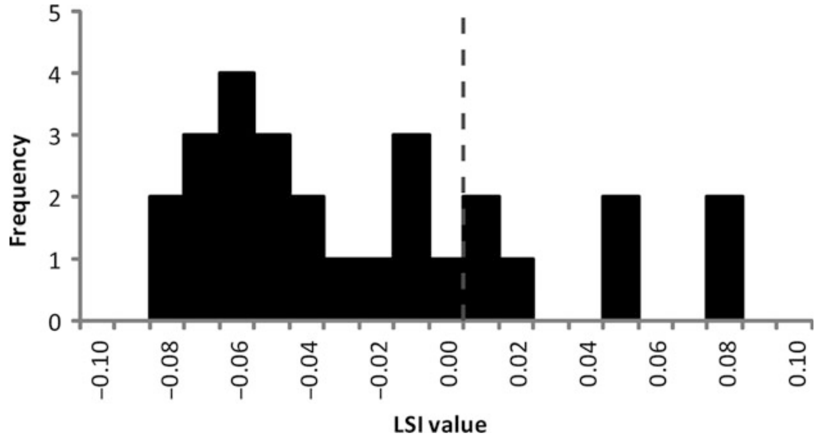
The most common tools for zooarchaeological biometry are simple sliding calipers – typically digital, although many analysts prefer to use purely mechanical vernier or dial versions (Fig. 1). These have a main pair of (typically) straight arms allowing accurate external measurements up to 150 or 200 mm on moderate-sized bones, and usually also a smaller secondary pair of arms for simple internal measurements of foramina, diastemata, etc. Technical precision is typically 0.01 mm, although this will rarely be achieved in practice due to observer error.

Biometry in Zooarchaeology, Fig. 1 Dial calipers being used to measure a cod vertebra (Photo by author)

Larger calipers are also available, as are specialized versions with longer, narrower, and/or angled arms to permit measurement of larger or more awkwardly shaped bones. More commonly, however, such measurements are taken using a measuring box. Various designs exist but all feature a horizontal surface marked with a scale and two vertical blocks perpendicular to this: the first fixed at the zero point and the second capable of sliding along the scale in order to take a measurement on a bone held against the first. Measuring boxes are particularly useful when more than two measurement (i.e., contact) points are required in order to ensure the correct orientation for the dimension to be measured.

For very small bones, measurements can be taken through a microscope using a scaled graticule, or alternatively using digital image analysis. Finally, curved measurements are occasionally taken using a simple tape measure, for example for the outer length of a horn core or the basal circumference of an antler.

Inter-analyst comparability can only be achieved through the use of standard measurement definitions and clear indication of the standards employed in each case. Fortunately, a near-universal standard for terrestrial mammals and birds exists in Angela von den Driesch's



Biometry in Zooarchaeology, Fig. 2 Distribution of LSI value for goats (*Capra hircus*) from Çatalhöyük, West Mound, by reference to Uerpmann's (1979) standard animal. The *dotted line* marks the position of the standard (Author's own data)

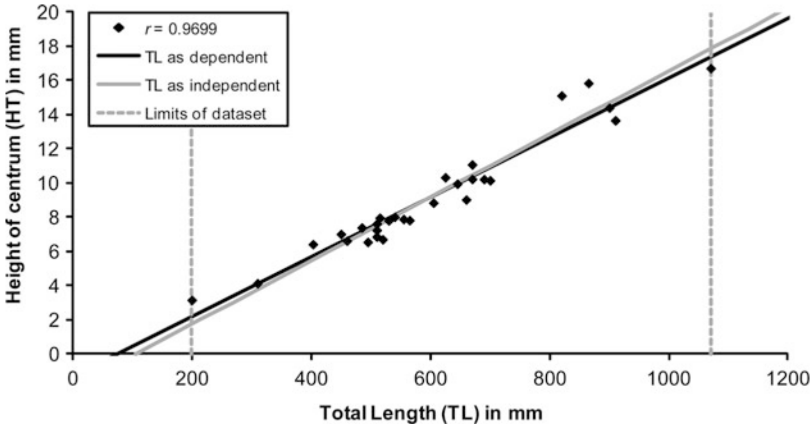
A Guide to the Measurement of Animal Bones from Archaeological Sites (1976) – a comprehensive and fully illustrated list of measurements designed for the major taxa encountered on Holocene sites in Europe, with abbreviations allowing easy reference to specific measurements (e.g., "Bd" = distal breadth). These can generally also be applied for related taxa found in other parts of the world, but run into trouble for species that differ substantially in morphology, such as beavers or primates. Other measurement lists do exist, but are typically specialized sets to be used as supplements rather than alternatives to von den Driesch (e.g., additional sheep metapodial measurements in Davis 1996). The degree of morphological variation in fish makes definition of standard measurements more difficult, although some of those set out by Morales and Rosenlund (1979) are widely used. The existence of widely accepted standards allows for inter-site comparison and compilation of measurement databases such as ABMAP, hosted by the UK's Archaeology Data Service.

Log-Ratio Techniques

Isolated measurements may be useful if they can be compared with published datasets, but for many purposes a large sample of measurements from the same assemblage is required. Even in a large collection of bones, the number of measurable specimens of any given element and portion (e.g., distal humerus) may be very small, however, and it is often impossible to draw meaningful interpretations from measurements of individual elements.

The log standard index (LSI) or "log-ratio method" can be used to circumvent this problem by combining measurements from multiple elements. Originally developed by paleontologists, it was introduced to archaeology by Hans-Peter Uerpmann (1979) and Richard Meadow (1981). Each measurement in the assemblage is converted into an index representing its magnitude relative to the equivalent measurement on a "standard animal" – either a modern specimen, average values from a modern population, or a more or less complete archaeological skeleton. This is done by dividing the observed measurement by the standard measurement and then taking the base-10 logarithm: a measurement identical to that on the standard will result in an LSI value of zero; a positive value indicates that the specimen is larger than the standard; and a negative value that it is smaller. The zero point is thus fairly arbitrary, but the LSI values can be used to assess the size distribution of specimens in an assemblage (Fig. 2).

One problem with this technique is that it assumes that *shape* does not vary systematically, that is, that the relative proportions of the standard animal are identical to those in the archaeological populations under study. Differences in relative proportions between the standard and the target population(s) have a blurring effect, increasing the dispersion of LSI values and making it harder to distinguish subgroups within the archaeological material. In theory this can be



Biometry in Zooarchaeology, Fig. 3 Linear least-squares regression of first vertebra centrum height and total length in cod (*Gadus morhua*). The exact line depends on which variable is treated as dependent, neither being strictly correct. Length estimation is only reliable within the limits of the original dataset (Author's own data)

minimized by choosing an appropriate standard – ideally from as close as possible to the target assemblage in both time and space – but there is often little choice: studies of prehistoric cattle, for example, almost always use the "Ullerslev cow," a Danish Neolithic aurochs (Degerbøl & Fredskild 1970). Equally problematically, there may be systematic differences in proportions between the subgroups that one is trying to distinguish, for example males and females or wild and domestic specimens.

Of course, LSI values also provide a means to investigate shape changes, which may be of considerable interest in their own right. Given a large enough sample, LSI values may be plotted by element, with variation in mean values revealing differences in anatomical proportions compared to the standard (e.g., Davis 1996). Shape variation between individuals within a single population is also an issue, and Davis notes that while measurements in the same axis – that is, lengths *or* breadths *or* depths – tend to be highly correlated throughout the body, correlations are typically weaker *between* these categories.

In addition, pooling measurements from multiple elements is likely to lead to sample inflation: the same individual may be represented multiple times, increasing apparent sample size, violating assumptions of independence, and making "significant" results more likely in statistical tests. The LSI approach can be very powerful despite these problems, but wherever possible it should be used to supplement rather than replace analysis of size on an element-by-element basis.

Estimating Body Size/Weight

Bone measurements and derived indices are both useful for assessing relative size, but neither represents data of interest in and of themselves. It is often useful to estimate a more intuitively meaningful dimension from the measurements: whether discussing domestication-linked size reduction in the Neolithic or livestock improvements in the postmedieval period, for example, most readers will get a better idea of the changes involved if they are expressed in terms of withers height (i.e., height at the shoulder) rather than, say, metacarpal distal breadth or an index of size relative to one specific Danish aurochs. In some cases the role of derived size estimates may go further. For fish, the distribution of estimated total lengths may help to infer capture technology, while length is also a proxy for age (see below).

Modern reference data have been used to calculate linear regression equations for deriving major dimensions of numerous species from common bone measurements (e.g., May 1985 for horse withers height, Jones 1991 for gadid fish total lengths). In most cases these are simple bivariate linear regressions (Fig. 3), although it is also possible to build several measurements into a multiple regression. Such regression equations should ideally only be used for archaeological specimens which fall within the range of the reference data used in their construction (interpolation); application to specimens outside this range (extrapolation) may not be reliable. They should also ideally be based upon measurements taken in approximately the same axis as the dimension to be estimated, but this is not always practical. For example, withers height in livestock can be most reliably estimated from long bone *lengths*, but since long bones are typically fragmented in zooarchaeological assemblages, it may be necessary to use breadth or depth measurements instead, accepting a weaker correlation and hence larger error term (see Davis 1996).

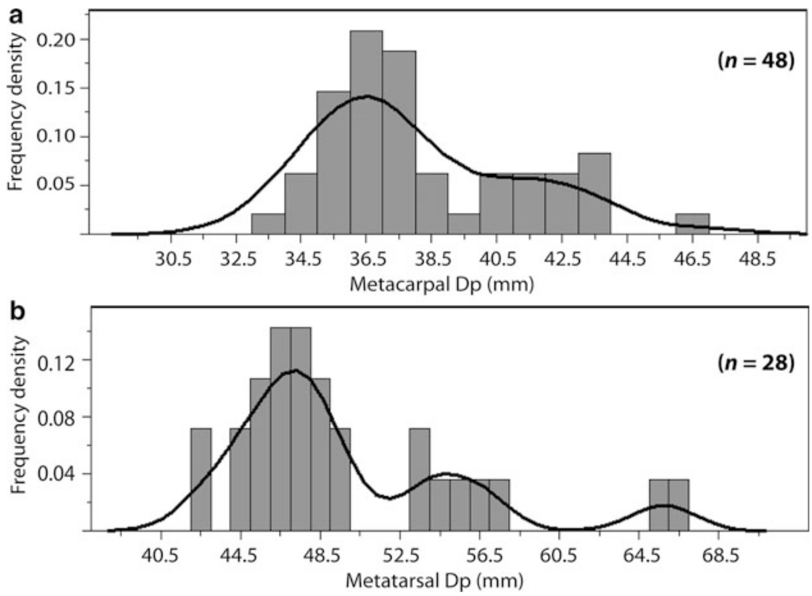
For other purposes it may be the weight of an animal (or at least the weight of meat and fat) that is of most interest to the zooarchaeologist, but predicting live weight is more complicated than estimating height or length. Since weight is correlated with volume – a three-dimensional property – it should increase in a cube ratio relative to any given dimension, resulting in a nonlinear regression curve. An additional complication is introduced by allometry: that is, size-correlated variation in anatomical proportions. In the context of zooarchaeology, the most important allometric effect is that between overall body size and the proportion of the body consisting of bone. Whereas weight depends on volume and hence increases in a cube ratio, the ability of bones to support this weight is (broadly speaking) a function of cross-sectional area – a two-dimensional property – and thus only increases in a square ratio. As animals get heavier, the size of their bones must therefore increase disproportionately in order to support their weight, further complicating the relationship between bone measurements and animal size.

Age and Sex Determination

Sex ratios may be of considerable interest to zooarchaeologists, shedding light on herd management or hunting techniques. Sex can most reliably be determined from qualitative differences such as pelvic or dental morphology, but many species also show marked quantitative sexual dimorphism, with males typically larger among mammals and the opposite occasionally true for birds. Unless dimorphism is extreme, however, distinguishing male and female specimens on the basis of measurements is necessarily a probabilistic rather than absolute process: while the very largest and smallest specimens may be attributable to sex groups with some confidence, there is typically considerable overlap between male and female ranges. Even where it is impossible to determine the sex of individual bones, however, it may nonetheless be possible to estimate sex ratios within the assemblage as a whole, based on the shape of the observed distribution.

Since size distribution depends on a range of genetic and environmental factors, it must be treated as population specific; that is, one cannot rely on size ranges observed in modern populations to assign archaeological bones to sex groups. Rather, the zooarchaeologist must plot the available measurements and look for clustering empirically. In exceptional cases discrete size groups may emerge, but the best one can normally hope for is a continuous but bimodal distribution, which may be easier to interpret following smoothing with the kernel density estimate technique (Fig. 4). The degree to which sex groups can be determined within a population depends not only on the degree of dimorphism and the variation within each group but also on their relative abundance: where a small number of (larger) males are present alongside a much greater number of (smaller) females – as is typical in domestic herds – the male peak size may be obscured by the upper tail of the female distribution, perhaps visible only as a small "shoulder" towards the upper end of the overall distribution. A size distribution exhibiting positive skew may well indicate a small number of male specimens (or perhaps the inclusion of a few wild individuals – see below). Without independent information on the degree of dimorphism, it is very difficult to estimate relative frequency, although mixture analysis may help by fitting two (or more) normal distributions to the data as closely as possible (Monchot et al. 2005).

Where two groups emerge, these *may* represent males and females, although other factors such as the presence of wild and domestic populations (see below) may be responsible.



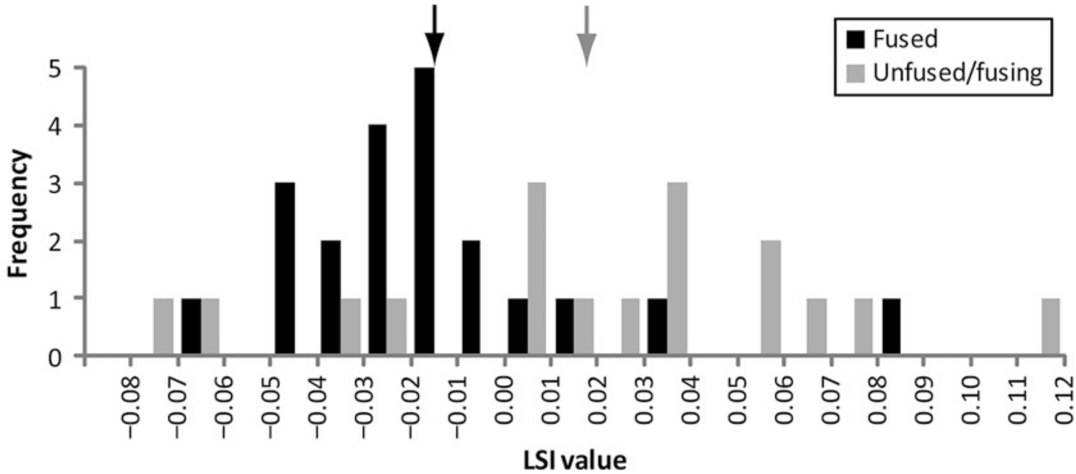
Biometry in Zooarchaeology, Fig. 4 Histograms of metacarpal (**a**) and metatarsal (**b**) proximal breadths for cattle (*Bos taurus*) from Neolithic Gomolava, Serbia, with overlaid kernel density estimates. The main groups *probably* represent domestic females and males, while the upper outliers may be wild specimens (After Orton 2008)

If a few specimens of known sex (based on nonmetric characters) are included in the dataset, then they can be used to help test the assumption that observed size clusters represent sex groups. An additional complication among domestic animals is the possibility of castration, effectively introducing a third sex group. The exact effect of castration varies depending on the technique and timing (Moran & O'Connor 1994), but as a rule-of-thumb castrates tend to have relatively long bones due to delayed epiphyseal fusion (Davis 2000, see also Popkin et al. 2012). This effect is visible for metacarpal length versus breadth in a study of known-sex Shetland sheep, but there is too much overlap between rams, ewes, and wethers (castrated males) for reliable application to archaeological specimens (Davis 2000).

Metric data are generally of more limited use for determining age at death, although taxa with continuous ("indeterminate") growth, notably fish, are an exception. On a fine scale, the size of young fish may even be used to make inferences regarding season of catch. In the case of mammals, however, growth more or less ceases in most elements by the point of epiphyseal fusion, and wide variation in growth rate (see e.g., Popkin et al. 2012) means that measurement of immature specimens is of little use for estimating age.

Metric data may nonetheless contribute to understanding of kill-off patterns of domestic stock at an assemblage level. For obvious reasons, size distributions are normally constructed only from mature specimens – indeed, many zooarchaeologists do not even measure immature bones – and hence represent only the (sub)adult fraction of a population. Since males are typically slaughtered younger than females in domestic herds, size distributions will be heavily biased towards female specimens. Where measurements are available for unfused or otherwise immature specimens, however, these are likely to be biased in the other direction – towards males. Counterintuitively, the unfused bones may thus actually be larger on average than their mature counterparts, especially for late-fusing elements. Comparing the size distributions of fused and unfused specimens element by element, from earlier to later fusing, can thus help to identify the timing of the main male cull (Fig. 5), although once again the presence of castrates would complicate matters.

Finally, the use of tooth measurements to estimate age at death should be mentioned. Since tooth crowns wear down over time, particularly among herbivores, the remaining height of the crown can theoretically be used to estimate the length of time for which the tooth has been in use and by extension the age of the animal



Biometry in Zooarchaeology, Fig. 5 Distribution of LSI values for distal metacarpals of sheep (*Ovis aries*) from Çatalhöyük West Mound, including both fused and unfused/fusing specimens. *Arrows* show mean values. The narrower range and smaller average size seen for mature specimens suggests that they are predominantly female and thus that most males were killed before fusion of the distal metacarpal (18–30 months according to Zeder 2006) (Author's own data)

(e.g., Klein & Cruz-Uribe 1983). Several variants on this "crown-height" approach have been developed, with a range of different measuring protocols and varying complexity in the formulae used to estimate age, but all suffer from several drawbacks – most notably inability to account for variation in the height of the unworn crown (see Twiss 2008).

Domestication

One of the most hotly debated applications of zooarchaeological biometry is to the detection of domestication and the distinction of wild and domestic specimens within an assemblage. Most species saw a rapid reduction in both size and dimorphism following domestication, thought to be due to the relaxation of certain selection pressures that applied within wild populations (Zohary et al. 1998). Biometry is thus one of the main lines of evidence that has been used to document the process of animal domestication, alongside changing age and sex structures, pathologies, and artifactual data.

Changes in morphology must necessarily have lagged behind the changes in human-animal interaction that represent domestication per se, but the speed with which size reduction manifested is hard to establish. Tracing size declines in a population over time will only ever provide a terminus ante quem for domestication in this sense, although the question of when domestication can be said to have occurred is in any case as much a theoretical as a practical one. Ideally, biometry should be complemented by assessment of changes in age and sex profiles, the latter being likely slightly to predate reduction in size.

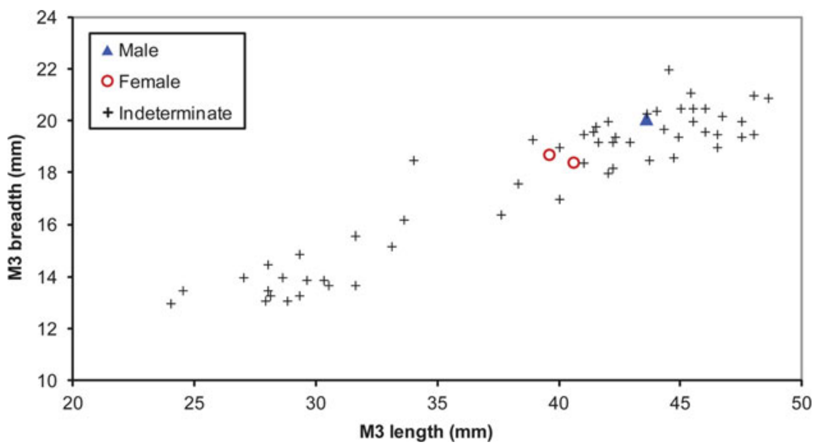
Of course, domestication is only one possible cause of size decline: intensive selective hunting can depress the size of available prey over time, for example, while environmental changes may result in shifts in size distribution among wild populations without any human intervention. A stronger case that size decline represents domestication can be made where other species with similar habitats can be shown not to have undergone the same changes over the same time span (e.g., Arbuckle & Makarewicz 2009).

Once a domestic population of a species has been established, hunting of wild individuals may nonetheless continue. Separating wild and domestic individuals within a zooarchaeological assemblage – or at least estimating their relative abundance – presents a challenge analogous to that of distinguishing sex groups, but with the added complication that both wild and domestic populations will include male and female groups.

		Group 1	Group 2	Group 3
Bimodal	*a*	dom. ♀	dom. ♂	
	b	wild ♀	wild ♂	
	c	dom. ♀, ♂	wild ♀, ♂	
	d	dom. ♀, ♂, wild ♀	wild ♂	
Trimodal	*e*	dom. ♀	dom. ♂, wild ♀	wild ♂
	f	dom. ♀, ♂	wild ♀	wild ♂

Smaller ◄——————► **Larger**

Biometry in Zooarchaeology, Fig. 6 Potential interpretations of observed bi- or trimodal size distributions for a dimorphic species with wild and domestic forms. Options *a* to *f* are not exhaustive but represent some of the more likely interpretations (excluding the possibly of castrates)



Biometry in Zooarchaeology, Fig. 7 Lower third molar measurements from pigs (*Sus scrofa*) at Neolithic Gomolava, Serbia, with sex highlighted where known (from canine morphology). The two clusters could represent either male and female or wild and domestic (options *a*/*b* or *c*, respectively, in Fig. 6), but the presence of both sexes in the upper cluster strongly supports the latter (after Orton 2008)

One cannot even assume that the offset between the sexes is the same in each population, since dimorphism is often much reduced in domestic herds (Zohary et al. 1998).

Where both wild and domestic populations of a dimorphic species are likely to be present in an assemblage, interpreting the size distribution can become quite complicated, with a trimodal distribution not uncommon (Figs. 4b; 6). Mixture analysis may again help to tease apart components within relatively large samples, but cannot entirely circumvent fundamental problems of equifinality: statistics may help to identify and quantify subgroups within a sample, but cannot reveal what they represent. Once again, the presence of a few known-sex specimens can help to choose between different interpretations of a bi- or trimodal size distribution (Fig. 7).

Cross-References

- ▶ Geometric Morphometrics and Environmental Archaeology
- ▶ Standardization, Storage, and Dissemination of Environmental Archaeological Data
- ▶ von den Driesch, Angela
- ▶ Zooarchaeology
- ▶ Zooarchaeology: Methods of Collecting Age and Sex Data

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Biomolecular Archaeology: Definition

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Brief Definition of the Topic

Biomolecular archaeology, a subfield of archaeometry, is the study of ancient molecules (especially nucleic acids, proteins, lipids, and carbohydrates) produced by past living organisms, most often applied to identifying organic residues from archaeological sites and objects, recovering DNA from human tissues and skeletal remains, and studying genetic parameters of plant and animal domestication. Research seeks to understand the processes that result in the preservation of biomolecules as well as the ways in which biomolecules can be used to reconstruct paleoenvironments and, more broadly, assess human biological and cultural evolution. Analytical techniques derive principally from chemistry (e.g., mass spectroscopy, isotope analysis), evolutionary biology (e.g., PCR), and proteomics (e.g., immunoassay, decoding genomes), among other sources. Recent texts by Gaines and colleagues (2008) and by Brown and Brown (2011) review the field and current applications.

Cross-References

► Archaeological Chemistry: Definition
► Archaeometry: Definition
► DNA and Skeletal Analysis in Bioarchaeology and Human Osteology
► DNA Interpretation Constraints in Archaeology
► Human Evolution: Molecular Timescale

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Bird, Junius

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Basic Biographical Information

Junius Bird was born in 1907 in Rye, New York, and from an early age was attracted to both archaeology and maritime adventures. As a young man, he participated in several expeditions to the Arctic Ocean, starting in 1927 when he joined Bartlett's Arctic expedition. He entered the field of archaeology without academic training, but his field knowledge and capacity led him to a post as a field assistant at the American Museum of Natural History in New York. From that base, he participated in numerous archaeological expeditions to different regions of the Americas, especially in Canada, the United States, and Central America, particularly in Panama, Peru, and Chile. In time, he became the museum's head curator of South American archaeology. In 1932, he visited Navarino Island, north of Cape Horn, where he spent several months surveying the entire north shore, excavating a shell midden at Puerto Pescado. It was there that he began the systematic application of stratigraphic principles to archaeological research, and he became convinced of the possibilities for archaeological discoveries in Patagonia and Tierra del Fuego.

In 1934, Bird and his wife, Peggy, departed to South Chile for a period of two and half years to survey its channels. There, they explored the maze of southwestern channels by sailing for six months in a 19-foot sailboat. This was a dangerous trip through a sparsely populated and almost unknown area characterized by heavy rainfall and continuous storms. The trip was successful due to the discovery of many sites, mostly shell middens, and opened up a whole new region for archaeological research (Martinic 1984). Following this trip, Bird began the archaeological exploration of the Patagonian steppes, discovering important sites in Cañadón Leona and Pali Aike.

Major Accomplishments

Bird was the definitive fieldman, with the capacity to produce good results with minimal equipment. He was famous for traveling the dirt roads of the Patagonian steppes in a Model T Ford. He constructed his own dump sifters, perfecting them over time. During his coastal trips, he discovered shell middens in many places, some of which he placed chronologically by making meticulous geological observations. It must also be noted that Bird made several relevant and astute taphonomic observations about the process of accumulation of bones in caves. He was a keen observer of what we now call formation processes.

As a result of these trips, particularly those to South Chile, Bird discovered some of the earliest evidence of the presence of humans in the Americas. He discovered in the Pali Aike Volcanic Field some of the sites that would become classic references when discussing human interaction with extinct Pleistocene fauna in the Americas. Both at Pali Aike and the Fell Caves, he was able to recover ground sloth (*Mylodon darwinii*) and horse (*Hippidion saldiasi*) bones as well as abundant camelid (*Lama* sp.) bones associated with hearths and lithic and bone artifacts. The lithics discovered include the world-famous "fishtail" projectile points, a marker of the earliest Americans.

Junius Bird's interest in Patagonia continued until the end of his life. He returned several times to collect samples for specific analyses. For example, he was among the first archaeologists to use Willard Libby's discovery of the radiocarbon dating technique to date human occupations, and using this technique, he was able to place human arrival in southern South America at around 11,000 years BP. This is more or less the oldest age that can be defended today, some sixty years later, for the first human peopling. He also returned to excavate new sites. His last field work in Patagonia took place in 1980, when he excavated the Tom Gould site, a rich open-air site in Pali Aike (Massone 1989-1990).

Bird's publications constitute classic references not only for the archaeology of the early peopling of America (i.e., Bird 1938, 1946, 1988) but also for the history of human occupation at different places along the Pacific coasts of South America.

One important result of Bird's studies is that he constructed a cultural and chronological scheme for Patagonia that is still in use today (Martin et al. 2011). However, it must be emphasized that he never restricted the scope of his interest to Patagonia, and his excavations in North Chile and North Peru rank among the most important archaeological antecedents for modern archaeology in South America.

After a long and productive life, Junius Bird died in New York in 1982. The people who knew him noted his enthusiasm and skills in the field, as well as the clarity of his research goals. Junius Bird's great contributions to our present understanding of Patagonian archaeology cannot be exaggerated.

Cross-References

- ▶ Glacial Landscapes: Environmental Archaeology
- ▶ Sea-Level Changes and Coastal Peopling in Southernmost Pacific South America: Marine Hunters from Patagonia

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Black, Davidson

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Basic Biographical Information

Davidson Black, FRS, was born on July 25, 1884, in Toronto, Ontario, Canada, and died on March 15, 1934, in Beijing, China. As a Canadian-trained anatomist and medical doctor, he was best known for his anatomical descriptions and naming of a new fossil human species, *Sinanthropus pekinensis*. Unlike most foreigners, Black got along extremely well with his Chinese colleagues as he treated them as equals and involved them in decision-making. He was known as 步達生 (pinyin: Bù Dáshēng) in China.

His father died when Dyo (as he was known by his family) was 2 years old and was brought up by his mother and uncles. Many summers were spent in the Kawartha Lakes region of southern Ontario, and when he was old enough for employment, he worked as a biological field assistant and a voyageur/fire ranger in forested regions of northern Ontario and later as a mining engineer for the Geological Survey of Canada on Vancouver Island. During these jobs, he got to know his First Nations' friends and was given the name "Mushkemush Kemit" (thought to be an Ojibwe phrase meaning "fast through the forest"). Like his father, he had a fragile heart, further weakened during a bout of rheumatic fever during his mid-teens. He eventually died at the height of his anthropological career at age 49 of congenital heart failure.

Starting in 1903 he studied at the University of Toronto, where he graduated with his Bachelor's degree in Medicine in 1906. He promptly returned to the University to complete his Arts degree, but with a delay in completing language requirements, he formally graduated in 1911. Before convocating, in 1909 he took a full-time teaching position in Anatomy at Western Reserve University in Cleveland, and during one of his visits to his Toronto home, he met Adena Nevitt, his future wife. Adena (second daughter of Richard Barrington Nevitt, a prominent Toronto physician who was a medical doctor for the Northwest Mounted Police) and Davidson married in December 1913. They had two children, a son Davidson (b. 1921) and daughter Nevitt (b. 1925). It was Black's close Anthropology colleague Wingate Todd who recommended that Black travel to England to work with well-respected neuroanatomist (Sir) Grafton Elliot Smith. Black followed Todd's advice during a sabbatical in 1914 when he visited Elliot Smith at his University of Manchester laboratory just as Elliot Smith was pondering the newly discovered Piltdown fossil puzzle. This visit was Davidson Black's first introduction to Anthropology, which fired his scientific imagination! Eventually returning to Cleveland (and with his new contacts in England including Woodward Smith and (Sir) Arthur Keith), Black set about to build anthropological teaching collections. Through this work, Black was introduced to American Henry Fairfield Osborn and the work of fellow Canadian William Diller Matthew, both of whom were intrigued by the potential of Asia as a fossil-hunting ground. Matthew's 1915 writings convinced Black that Asia was central to the search for primate ancestors.

In 1917 (after three attempts to join the war effort, because of his weak heart), Black joined the Canadian Medical Corps and was based at a military camp in southern England. During this overseas experience, unknown to Black, his medical passions were being discussed by members of the American Rockefeller Foundation, an agency that had initiated plans for a "Johns Hopkins" of the East. Black was being considered for the position of Neurology/Embryology professor at the newly conceived Peking Union Medical College, in Beijing, China. This invitation was Black's chance to now fully dedicate himself to the questions of Asian prehistory. In September 1919, Adena and Davidson Black arrived in China.

Major Accomplishments

Davidson Black is often identified as "discoverer" of Peking Man or *Homo erectus* from China. He did not discover these fossil human remains but instead initially recognized three teeth as belonging to a human ancestor that had not been identified previously. In 1927, Black published a monograph in which he named this species – *Sinanthropus pekinensis*.

Black was keen to search for human ancestors in Asia but had to concentrate on his professorial duties. Initially he published scientific analysis of human remains found by his Swedish colleague J.G. Andersson who worked for the Geological Survey of China. In 1926 Black learned of two fossil teeth found near Zhoukoudian (Dragon Bone Hill) village southwest of Beijing. He recognized these two teeth as human and arranged for Rockefeller Foundation funding for systematic excavations starting in 1927. Upon finding a third tooth, in situ, Black was confident in identifying the first-ever fossil human remains from China. By now the College recognized Black's dedication to Anthropology and also the key role that the PUMC along with the Geological Survey/Society of China might make to the human sciences, and Black was allowed to focus his energies on research. Black was central in the creation of a "union" between the GSC and PUMC that became a human origins facility known as the Cenozoic Research Laboratory. Annual excavations by teams of young men and boys resulted in the discovery of numerous teeth and jaw fragments and in 1929 the first evidence of a "complete" human cranium (Skull III) from the site by Pei Wenzhong. Black's responsibility was describing and analyzing these human finds; his papers were published by the GSC and in a journal called *Palaeontologia Sinica*. Davidson Black was the voice for *Sinanthropus* as he travelled to conferences in southern Asia, North America, and throughout Europe, illustrating replica examples and visual images (photographs and drawings) of these fossils to his scientific associates.

Black received numerous honors including:

- Grabau Medal, Geological Society of China in 1929
- Honorary D.Sc., University of Toronto in 1930
- King Gold Medal, Peking Society of Natural History
- Fellow of the Royal Society in 1932 for work on *Sinanthropus* (Croonian Lecture entitled *The Discovery of Sinanthropus*)
- Daniel Giraud Elliot Medal for work on Peking Man from US National Academy of Sciences awarded for 1931, conferred posthumously in 1934
- Recognition of his work in human origins with the species name *Gigantopithecus* "*blacki*"

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▶ Weidenreich, Franz
▶ Zhoukoudian, Archaeology of
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Blombos Cave: The Middle Stone Age Levels

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Introduction

Blombos Cave, an archaeological site situated on the southern Cape coastline, South Africa, contains Middle Stone Age (MSA) deposits dated at between c. 130 and 72 ka (ka = 1,000 years ago), possibly the most important period in the early development of modern human behavior. Since 1992 each excavation season at the site has yielded important new information on the behavioral evolution of *Homo sapiens*. This includes, at c. 75 ka, among the earliest known evidence for the manufacture of personal ornaments on shell beads, formal bone tool production, engraving of abstract designs on ochre and bone, the deliberate heating of silcrete, a lithic raw material, and the subsequent manufacture of bifacial stone points on this material using pressure flaking. In the 100 ka levels, a complex toolkit was uncovered that provides the oldest known evidence for the use of containers and for the production of an ochre-rich pigment or paint. These findings from Blombos Cave and subsequent reanalysis and excavation of other contemporary sites have resulted in a paradigm shift with regard to our understanding of the timing and location of the development of modern human behavior.

Definition

In tandem with the anatomical evolution of modern *H. sapiens* in Africa after 200 ka was the increasing capacity for symbolically driven behavior. Exactly when or how this capacity first translates into material culture that carried symbolic meaning is unclear. Innovative material culture recovered from Blombos Cave provides a clear signal that by 100 ka human behavior was mediated by symbols. This evidence is likely only one part of a behavioral mosaic, a “wind of change” throughout the African Middle Stone Age that culminated in the diasporas at c. 60–80 ka – a series of human expansions from Africa that first introduced fully symbolic *sapiens* behavior to Eurasia and the rest of the world.

Key Issues/Current Debates/Future Directions/Examples

A major research challenge in archaeology is identifying when and how symbols were used for the first time to mediate hominin behavior. Once in place this innovation provided an ability to share, store, and transmit coded information and played a crucial role in creating the social conventions and identities that now characterize human societies. Over the last decade, the Blombos Cave (BBC) results have challenged long-held beliefs that the origins of behavioral modernity and the first use of symbolic material culture lay in Europe and commenced about 40,000 years ago. The focus for modern human behavioral origins has since switched to Africa and now generates lively debate, worldwide. Further analyses of the BBC materials and ongoing excavations at the site continue to contribute to this debate. A new dimension, paleoclimatic reconstruction, has been added to this research paradigm and suggests that the variable climates that characterized the Late

Blombos Cave: The Middle Stone Age Levels, Fig. 1 Blombos Cave site entrance

Pleistocene had a major effect on the continuity of key cultural innovations. The adaptive responses of *Homo* to changing climates are however poorly understood; researching the role of climate in shaping the cognitive evolution of *H. sapiens* is therefore a priority. It is expected that existing and future results from BBC and other nearby sites will provide important information for understanding the development of human behavior within the context of climatic variability in the southern African Late Pleistocene.

Description of Blombos Cave

Blombos Cave lies 300 km east of Cape Town and is situated in a steep wave-cut calcrete cliff, 100 m from the Indian Ocean and 34.5 m above modern sea level (34°25′S, 21°13′E) (Figs. 1, and 2). It is set into the calcified sediments of the Tertiary Wankoe Formation, and the calcareous environment is at least partially responsible for the good preservation of the recovered deposits (Henshilwood et al. 2001b).

Stratigraphy and Ages

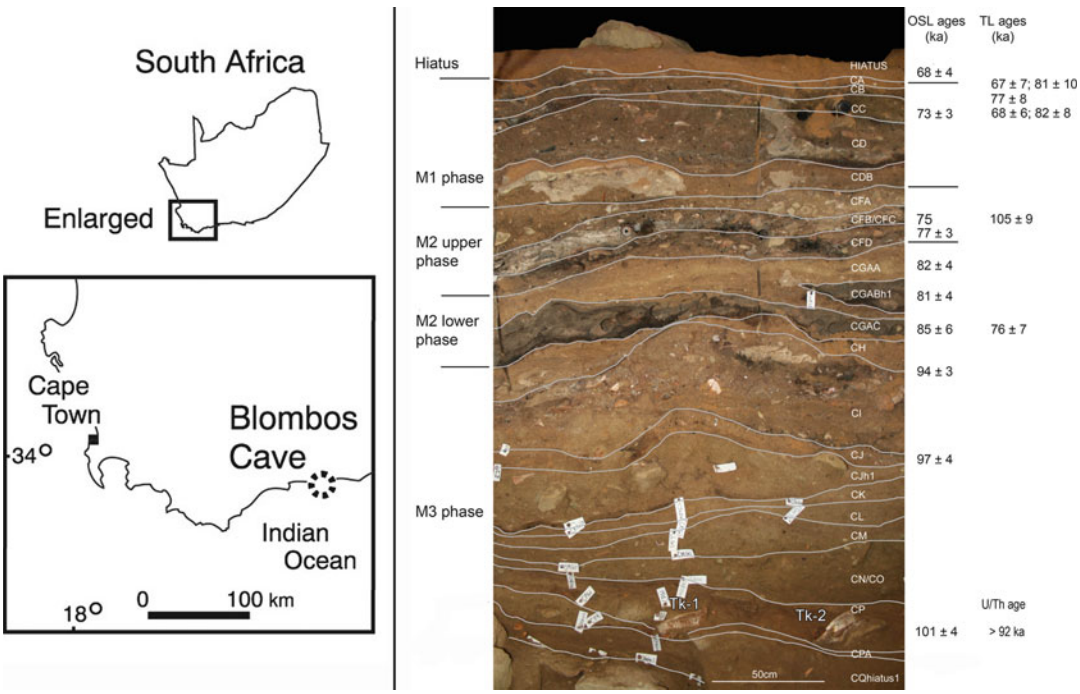
The earliest Later Stone Age (LSA) occupation is c. 2 ka. The MSA levels are divided into four phases comprising a number of discrete layers within each phase (Fig. 3). These phases are named M1, upper M2, lower M2, and M3.

A hiatus level composed of undisturbed aeolian sand above the M1 phase, DUN (Fig. 3), is dated to c. 70 ka. This layer of sand sealed the mouth of the cave and it reopened after the mid-Holocene high sea level stand at c. 4–3 ka. The upper part of the M1 phase dates to c. 73 ka and the upper M2 phase to c. 75 ka. The lower M2 phase layers date to c. 85 ka. The M3 phase dates to c. 100–94 ka and the ages of the lower levels, below level CQ hiatus, are currently being determined. The majority of dates were determined using optically stimulated luminescence (OSL) (Jacobs et al. 2006), but other methods, such as thermoluminescence (TL) (Tribolo et al. 2006) and uranium-thorium (U/Th) (Henshilwood et al. 2011), have also been employed.

Material Culture: M1 and Upper M2 Phases (Still Bay c. 75–72 ka)

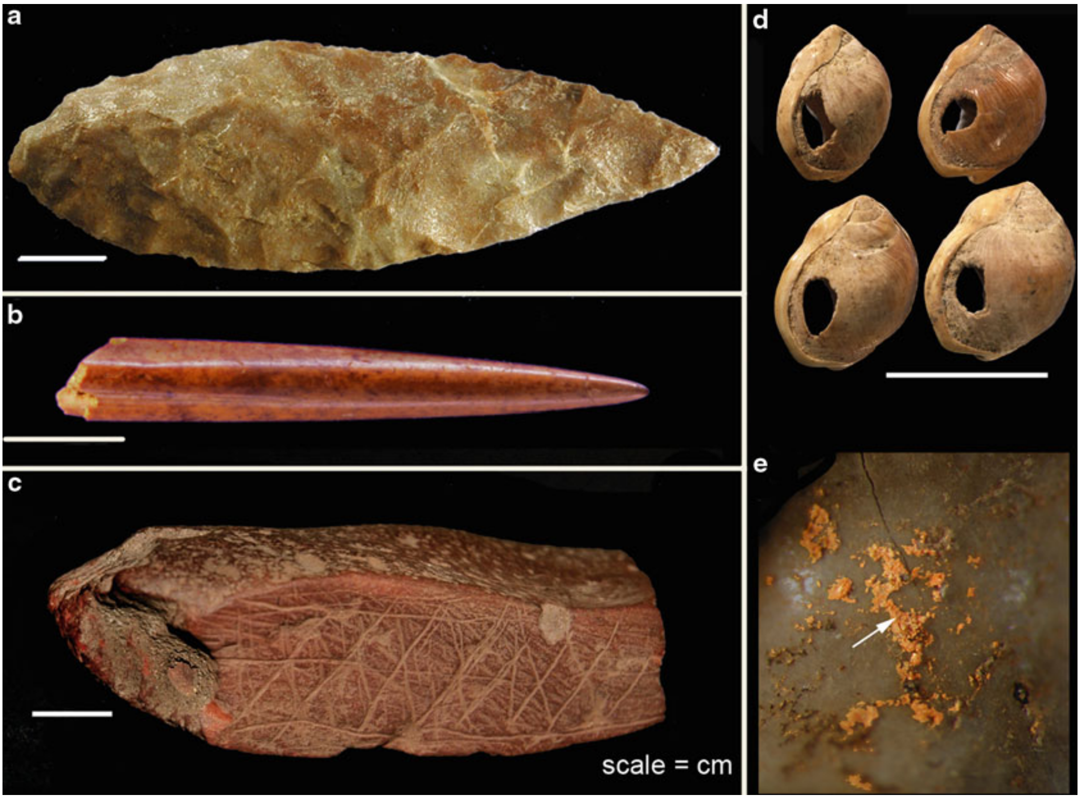
The M1 and upper M2 phases fall within the Still Bay complex. Artifacts from these phases include bifacial stone points, bone tools, marine shell beads, and engraved ochre (Fig. 4).

Blombos Cave: The Middle Stone Age Levels, Fig. 2 Interior of Blombos Cave (Image: Magnus Haaland)



Blombos Cave: The Middle Stone Age Levels, Fig. 3 Location of Blombos Cave showing west section of the excavation. M1, upper and lower M2, and M3 are occupation phases within the Middle Stone Age levels. The ages of each phase are shown at right (*OSL* optically stimulated luminescence, *TL* thermoluminescence, ka = 1,000 years, U/Th = uranium/thorium)

Bifacial Points (Fig. 4a): Still Bay points, or "leaf-shaped" points, are a distinct type restricted to the Still Bay techno-tradition of southern Africa. Henshilwood et al. (2001b: 429) state "We propose 'Still Bay sub-stage' as a regional, culture-stratigraphic term for assemblages with fully bifacially flaked, lanceolate shaped points." The bifacial points from BBC are made from



Blombos Cave: The Middle Stone Age Levels, Fig. 4 Artifacts from the Still Bay levels at Blombos Cave: (**a**) silcrete bifacial point, (**b**) formal bone tool, (**c**) engraved ochre SAM (AA-8938), (**d**) Nassarius kraussianus shell beads, and (**e**) ochre deposit on a shell bead (Images by C. Henshilwood & F. d'Errico)

silcrete, quartzite, and quartz. A macrofracture study of these points shows that some were used as spear points for hunting but that others probably served also as multifunctional tools (Lombard 2007). Approximately half of the silcrete points were heat treated and then finished using the pressure flaking technique (Mourre et al. 2010).

Bone Tools (Fig. 4b): Bone tools are an unexpected technological innovation in the Still Bay at BBC. Regarded as a distinctive marker in the Eurasian transition to modern cognitive behavior, they are rare at MSA sites. More than thirty formal bone artifacts have been recovered from the Still Bay levels at BBC (Henshilwood et al. 2001a; d'Errico & Henshilwood 2007). The majority are awls made on long-bone shaft fragments, further manufactured by scraping and then used to pierce soft material such as leather, or small shells to make beads (d'Errico et al. 2005). At least some bone tools that were carefully polished after being shaped by scraping are probably projectile points made for hafting. It is noteworthy that points are treated differently to awls. The high polish on these points has no apparent function that can be detected but seems rather a technique that gives a distinctive appearance – an "added value" – to these artifacts. These may have formed part of a material culture exchange system among groups to maintain or even enhance social relations. The BBC bone tools provide comprehensive evidence for systematic bone tool manufacture and use, but we cannot be certain if this was also the case at other Still Bay sites. A note of caution is that we are not certain that the production of worked bone gives a modern character to all MSA material culture since little is known about the evolutionary significance of bone shaping (Henshilwood & Marean 2003). Symbolic marking on bone is a likely feature that supports a symbolic interpretation. Microscopic analysis of a bone fragment marked with eight parallel lines from the Still Bay levels at BBC indicates they are the result of deliberate engraving and were possibly made with symbolic intent (d'Errico et al. 2001).

Engraved Ochres (Fig. 4c): Red ochre is a hydrated iron oxide with sufficient hematite (Fe^2O^3) content to be used as pigment. At BBC more than 2,000 pieces of ochre, many bearing signs of utilization, have been recovered from the Still Bay phases. During excavations in 1999 and 2000, two ochre pieces with deliberately engraved cross-hatched patterns AA-8937 (Fig. 4c) and AA-8938 were discovered from the M1 phase (Henshilwood et al. 2002). Two ground facets are present on specimen AA-8937, and on the larger of these, the cross-hatched design is engraved. It is clear that the design results from deliberate intent and it is arguably among the most complex and clearly formed of objects claimed to be early abstract representations (d'Errico et al. 2003). Six additional engraved ochre pieces from the Still Bay phases have subsequently been recovered (Henshilwood et al. 2009).

Marine Shell Beads (Fig. 4d, e): A strong argument for early behavioral modernity in the Upper Paleolithic is the presence of personal ornaments. The discovery of more than 65 *Nassarius kraussianus* ("tick shell") beads in the Still Bay phases at BBC has added a new dimension to the modern human behavior debates (Henshilwood et al. 2004; d'Errico et al. 2005). All the recovered "tick" shells were carefully pierced using a bone tool to create a keyhole perforation. These were then strung, perhaps on cord or sinew and worn as a personal ornament. Repeated rubbing of the beads against one another and against the cord resulted in discrete use-wear facets on each bead that are not observed on these shells in their natural environment. These use-wear patterns are the principal factor that defines the shells as beads. Microscopic residues of ochre occur inside some of the beads and result from deliberate coloring or by transfer when worn.

The wearing and display of personal ornaments during the Still Bay phase was not idiosyncratic. Discrete groups of beads with wear patterns and coloring specific to that group were recovered from various levels and squares within the site. This patterning suggests that at least a number of individuals may have worn beads, perhaps on their person or attached to clothing or other artifacts. The shell beads also provide insights into technological aspects of the Still Bay including the ability to drill, the use of cord or gut for threading, and the probable tying of knots to secure the beads. A comprehension of self-awareness or self-recognition is implied by the wearing of beads or other personal ornaments and was likely an important factor in cognitive evolution that was selected for long before the introduction of beads. Further, syntactical language would have been essential for the sharing and transmission of the symbolic meaning of personal ornaments within and between groups and also over generations, as is also suggested for the engraved ochre pieces.

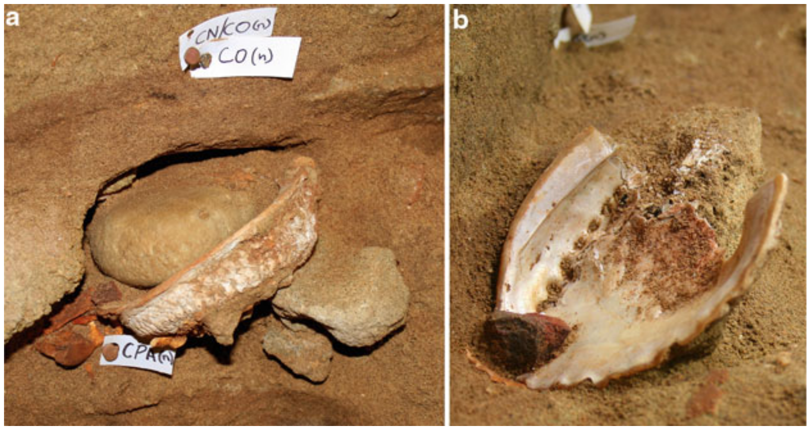
Material Culture: Lower M2 Phase (c. 85 ka)

Bone tools, bifacial points, and shell beads are absent from the lower M2 phase. The intensity of the cultural deposits is low in this phase but includes a few basin hearths; a very large hearth in layer CGAC; small quantities of blades, flakes, and cores in silcrete, quartz, and quartzite; and some small ochre pieces. Some of the ochre pieces are ground or scraped but none have deliberate engravings. A detailed analysis of these artifacts is currently underway and the overall impression is that human occupations in the M2 phase were of short duration and possibly that the size of the groups was also limited.

Material Culture: M3 Phase (c. 100–94 ka)

In this lower phase, lithics are abundant and silcrete is the dominant raw material. Retouch on the lithics is mostly informal and a higher incidence of ventral flaking and denticulate or notched edges distinguish them from those in the upper phases. The M3 lithics are currently under study. No bone tools have been recovered.

Modified ochre is common in this phase and eight slabs deliberately engraved with either



Blombos Cave: The Middle Stone Age Levels, Fig. 5 Ochre-processing toolkits in situ showing toolkit 1 (Tk1) (**a**) and toolkit 2 (Tk2) (**b**) (Images Grethe Moéll Pedersen)

cross-hatched, Y-shaped, or crenulated designs were recovered (Henshilwood et al. 2009). This indicates a tradition for the production of geometric engraved representation in the MSA at BBC with roots that go back in time to at least 100 ka and which includes the production of a number of different patterns.The findings support the view that the use of ochre during the MSA at BBC was not only functional but that it also served, perhaps primarily, in a symbolic role. In a wider context, this was also likely the case at other MSA sites in the southern Cape. Incised ochre pieces recovered from these latter sites also fall within the definition of engraved representations and demonstrate that there was a spatial and temporal continuity in the production and use of symbols in the region. The intra-site similarity of the abstract designs and methods used for the motifs at BBC and on regional intra-site level during the MSA is consistent with the continuity found in more recent symbolic systems that have been globally described for the Later Pleistocene and early Holocene.

Ochre-Processing Workshop, M3 phase (Fig. 5): In 2008 an ochre-processing workshop consisting of two toolkits was uncovered in the 100,000-year-old levels at Blombos Cave, South Africa. Analysis shows that a liquefied pigment-rich mixture was produced and stored in two *Haliotis midae* (abalone) shells and that ochre, bone, charcoal, grindstones, and hammerstones formed a composite part of the toolkits.

As both toolkits were left in situ and as there are few other archaeological remains in the same layer, it seems the site was used primarily as a workshop and was abandoned shortly after the compounds were made. Dune sand then blew into the cave from the outside, encapsulated the toolkits, and by happenstance ensured their preservation before the next occupants arrived, possibly several decades or centuries later.

Recent support for a southern African origin for *H. sapiens* comes from genomic and phenomic diversity studies. The recovery of these toolkits at Blombos Cave adds evidence for early technological and behavioral developments associated with *H. sapiens* to this scenario. It documents the first known instance for the deliberate planning, production, and curation of a pigmented compound and for the use of a container. Evidence for the complexity of the task includes procuring and combining raw materials from various sources (implying they had a mental template of the process they would follow), possibly using pyrotechnology to facilitate fat extraction from bone, using a probable recipe to produce the compound, and the use of shell containers for mixing and storage for later use. An elementary knowledge of chemistry and the ability for long-term planning suggest conceptual and cognitive abilities previously unknown for this time and serve as a benchmark during the early evolution of the technological and cognitive abilities of *H. sapiens* in southern Africa (Henshilwood et al. 2011).

Subsistence in the MSA Levels

The faunal collection from Blombos shows that MSA people practiced a subsistence strategy that included a very broad range of animals. This means they were able to hunt large animals, such as eland, but also gathered, collected, or trapped small animals such as tortoises, hyraxes, and dune mole rats. They also brought seal, dolphin, and probably whale meat back to the cave. The latter two were almost certainly scavenged from beach washups, but seals may have been speared or clubbed.

The shellfish provide early evidence for the use of seafoods. Shellfish were collected and brought back to the cave, and the M3 phase, with an age of c. 100 ka, is a particularly rich shell midden. Common species include the giant periwinkle (*Turbo sarmaticus*), limpets (Patella sp.), and brown mussels (*Perna perna*). Species variations may, with larger sample sizes, inform us of past changes in ocean paleotemperatures.

Fish remains are present, but not abundant, in all phases at BBC. Fish remains are more abundant in the LSA, but a wider range of species are present in the MSA. Chemical analysis of fish bone from the LSA and MSA levels using the carbon/nitrogen method confirms the antiquity of the MSA specimens. Most of the species present are not known to wash up after cold-water upwelling events; hence, scavenging of washups was not the primary source of fish. No artifacts that appear to be obvious fishing equipment have been found, but the range and sizes of species present indicate that a number of methods must have been employed. These include baited hooks, spearing, and tidal traps. Comparison of the elements from the same species that have survived in the MSA relative to the LSA at BBC has shown a large deficit in the MSA – in other words, age-related taphonomic processes have resulted in the loss of many fish bones, and there were likely many more fish deposited in the MSA than we can currently see. Fish are seldom reported from other southern African MSA sites, and by implication, it was thought that MSA people were incapable of exploiting coastal resources efficiently. The evidence for fishing at BBC and Klasies River contradicts this theory (Van Niekerk 2011).

The overall subsistence pattern at BBC signifies that no clear distinction can be made between Later Stone Age and Middle Stone Age subsistence behavior at the site (Henshilwood et al. 2001b; Henshilwood 2008). The implication is that during the MSA occupations, the subsistence mode was essentially modern.

Human Remains

The amount of human material recovered from the Blombos MSA is small – seven teeth (Grine et al. 2000; Grine & Henshilwood 2002). The crown diameters of at least some of these teeth suggest that the people at Blombos were probably anatomically modern. This conclusion is supported by similar evidence from a nearby archaeological site, Klasies River, that dates to a similar time period.

Summary

The origins of “modern” human behavior generate lively debate, worldwide, but an African evidence for its origins has long remained elusive. Published results from the Blombos Cave excavations complement recent and older findings from a number of African MSA sites that suggest some aspects of “modern behavior” evolved during the early Late Pleistocene in Africa. The discoveries at Blombos clearly reflects the acquisition of fully modern cognitive abilities by southern African populations by at least 100,000 years.

Cross-References

- ▶ Cognitive Evolution and Origins of Language and Speech
- ▶ Fossil Records of Early Modern Humans
- ▶ Hominids, Earliest African
- ▶ Out-of-Africa Origins
- ▶ Pinnacle Point: Excavation and Survey Methods

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Blue Shield

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Introduction

The last quarter century has been a particularly traumatic period for cultural heritage exposed to damage by armed conflicts and natural disasters. Armed conflicts can be international or internal in nature, often causing humanitarian casualties as well as damage to cultural heritage. The damage is often deliberate, as in looting of sites and collections or the destruction of cultural heritage as a part of ethnic strife. Bosnia, Kosovo, Afghanistan, Iraq, Georgia, Egypt – these are just a few of the countries which have seen damage done to their heritage in recent years. Natural disasters were even more numerous in this period and were often more deadly and destructive than armed conflicts.

Since 2005, the International Council of Museums Disaster Relief Task Force (ICOM DRTF) has monitored at least 27 natural disasters affecting cultural property (taken from unpublished email correspondence between ICOM-DRTF members.) These include the Indian Ocean tsunami, the Haiti earthquake, and the Japan earthquake/tsunami/Fukushima nuclear meltdown, among many others. Natural disasters and armed conflicts are obviously here to stay and, in fact, may increase with global climate change and political instability. The Blue Shield may offer some hope to prevent or mitigate damage to cultural property in future disasters through networking, monitoring, and emergency planning and response.

Definition

The Blue Shield is an overarching term describing a group of organizations whose goal is to promote the protection of cultural property in the event of armed conflict and natural disasters. These are divided into the International Committee of the Blue Shield (ICBS) and its member organizations, the Blue Shield National Committees (BSNCs) and their individual and organizational members, and the Association of National Committees of the Blue Shield (ANCBS). The Blue Shield organizational structure is loosely based on the Red Cross model, which includes the International Committee of the Red Cross (ICRC), the various Red Cross committees in each individual country (such as the American Red Cross), and the International Federation of the Red Cross (IFRC), which helps coordinate the activities of the national committees. The Blue Shield is sometimes referred to as "the Red Cross for culture."

Historical Background

A follow-up to the 1899 and 1907 Hague Conventions (both setting forth rules of war), the 1954 Hague Convention for the Protection of Cultural Property in the Event of Armed Conflict is the first international treaty dealing exclusively with cultural heritage during war. Drafted in response to the damage and looting of cultural heritage during World War II, the 1954 Hague Convention deals primarily with conflicts between nations and describes each nation's responsibilities toward cultural heritage (1954 Hague Convention, Chapter 1). Basically, these include planning during peacetime for the protection of each nation's domestic cultural property should an armed conflict occur and to safeguard and respect the cultural property of other States Parties with whom they are in armed conflict. The treaty also describes the protective symbol of the Blue Shield and the terms of its use to designate protected cultural property and personnel (Fig. 1).

The 1954 Hague Convention was violated repeatedly during the Bosnian conflict (1992–1996), with evidence that some military forces deliberately destroyed cultural sites bearing the blue shield, the international symbol for the protection of cultural property during armed conflict. This included the destruction of multiple mosques, minarets, churches, and other religious institutions, along with the infamous shelling of the historic city of Dubrovnik and the Stari Most Bridge. Several individuals have been charged with war crimes under the United National International Criminal Tribunal for the former Yugoslavia.

The situation in Bosnia initiated a discussion within the international cultural property community about how to better support the 1954 Hague Convention. The International Committee of the

Blue Shield, Fig. 1 Blue Shield symbol used to mark the archaeological site at Tikal in Guatemala. Photo courtesy David Mitchell

Blue Shield was founded in 1996 and is headquartered in Paris, also the home of UNESCO, which administers the Hague Convention treaty. In addition, a Second Protocol to the Hague Convention was drafted in April 1999 and came into force in 2004. Its purpose is to strengthen the main convention by including more specific language about punishing violations.

Key Issues/Current Debates

International Committee of the Blue Shield (ICBS)

ICBS consists of the International Council on Archives, the International Council of Museums (ICOM), the International Council on Monuments and Sites (ICOMOS), the International Federation of Library Associations (IFLA), and the Coordinating Council of Audiovisual Archives Associations (CCAAA). Its board is made up of the five directors general of these organizations with a rotating presidency. While ICBS does not have a permanent office or staff, the staffs of these individual organizations coordinate and carry out the daily activities of the ICBS.

The mission of ICBS is to "work for the protection of the world cultural heritage by coordinating preparations to meet and respond to emergency situations as well as post-crisis support" (http://icom.museum/what-we-do/programmes/museums-emergency-programme/international-committee-of-the-blue-shield.html). The Second Protocol to the 1954 Hague Convention mentions ICBS and recognizes its role as an advisory body to international organizations such to the intergovernmental Committee for the Protection of Cultural Property in the Event of Armed Conflict at UNESCO and the International Criminal Court.

National Committees of the Blue Shield

Blue Shield national committees (BSNCs) strive to mirror the structure of the ICBS as closely as possible by including the national equivalent cultural organizations. For example, the International Council of Museums–USA is a founding member of the US Committee of the Blue Shield and represents the interests of museum professionals interested in implementing the 1954 Hague Convention here in the USA.

Each BSNC must apply for and receive official recognition from the ICBS; however, there is a great deal of flexibility from country to country. In some countries, the BSNC is a function of the Ministry of Culture or some other government body; in others it may be formed by other NGOs or organizational members, and in still others, such as the US, it may be a nonprofit organization with both individual and institutional members.

There are now more than 20 BSNCs, with many more under construction. Their primary mission is to promote implementation of the 1954 Hague Convention in their individual countries. The treaty is essentially a legal agreement between nations, and the BSNC members, as citizens of their respective nations, can influence political leaders, coordinate and train their militaries, and generally raise public awareness. In addition, BSNCs have a responsibility to raise awareness about the importance of domestic emergency preparedness and response for culture, both within their own countries as well as to help colleagues abroad. This may take place either as part of their own national humanitarian response or as part of the Blue Shield network. (see www.uscbs.org for an example of a BSNC).

An emerging function of BSNCs may be an active role in raising military awareness about protecting sites during armed conflict. Prior to the 2011 NATO "No-Fly Zone" in Libya, the US Committee of the Blue Shield worked with archaeologists and other NGOs within the Blue Shield network such as ICOM, ICOMOS, and the Archaeological Institute of America, to produce a list of coordinates of important Libyan cultural sites. USCBS then shared this information with the US Department of Defense prior to the initiation of the no-fly zone, resulting in minimal damage to cultural sites during the NATO bombing.

Association of National Committees of the Blue Shield (ANCBS)

ANCBS was formed by a group of BSNCs and the ICBS by the 2008 Hague Accord to better coordinate the efforts of BSNCs, particularly with regard to emergency response (www.ancbs.org). The founding of ANCBS came in part from the feeling among cultural heritage professionals that there was not a timely or effective international response to the looting of the Iraq National Museum in 2003 and that BSNCs could better coordinate an emergency response in such situations. It also seemed natural that the National Committees have their own organizational structure for mutual coordination.

The ANCBS board consists of members (mostly the presidents or chairs) of various BSNCs and is based in The Hague, which in addition to being the home of the 1954 Hague Convention is also deemed the "international city of peace and justice" because it is home to the International Criminal Court. The board meets regularly in The Hague and in other cities around the world, as well as with the ICBS board in Paris.

Current Debates

One roadblock to the success of the Blue Shield is the perception that it is wrong to worry about saving culture during natural disasters and armed conflicts. While humanitarian assistance must always come first, a response for cultural property often comes too late or does not come at all. Up until recently, it has also been left out of emergency planning and response. This is changing slowly and is an area where BSNCs can make a real difference by raising awareness in their respective countries. One recent example is the US Committee of the Blue Shield's organizing a partnership with a number of US NGOs and government organizations after the 2010 Haitian earthquake. As a result, a very small percentage of the total US government humanitarian aid package for Haiti was set aside for culture, resulting in the Smithsonian Haiti Cultural Recovery project (www.haiti.si.edu).

Future Directions

As more BSNCs develop and ICBS becomes better staffed and funded, Blue Shield will become a more effective advocate for implementation of the 1954 Hague Convention and for emergency response for cultural heritage. Better preparedness and increased awareness among the population, governments, and military leaders will hopefully lead to a decrease in the loss to our shared cultural heritage worldwide.

Cross-References

- International Council on Monuments and Sites (ICOMOS): Scientific Committees and Relationship to UNESCO
- International Council of Museums (ICOM)
- International Council of Museums (ICOM): Code of Ethics
- International Council on Monuments and Sites (ICOMOS) (Ethics)
- International Council on Monuments and Sites (ICOMOS) (Museums)

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Bobrinsky, Alexander A.

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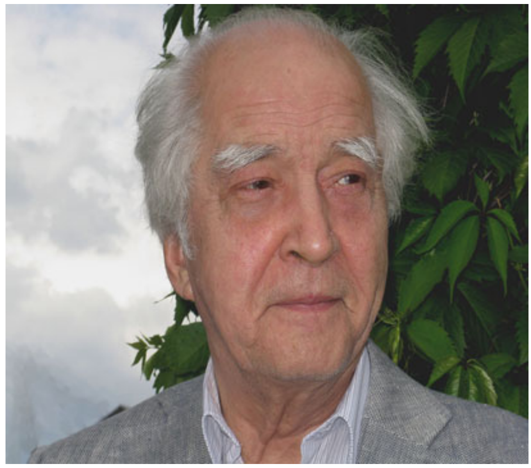

Bobrinsky, Alexander A., Fig. 1 Alexander Afanasievich Bobrinsky

Basic Biographical Information

Alexander Afanasievich Bobrinsky (1930–2010) (Fig. 1) was an outstanding Soviet and Russian researcher of ceramics and ancient pottery production. From 1952 until 1956, Bobrinsky was a student of the History Department at the Lenin Moscow State Pedagogical Institute, and during 1959–1962, he was a postgraduate in archaeology in Lomonosov Moscow State University under the scientific leadership of corresponding member of Russian Academy of Sciences, Artemiy V. Artsihovsky. In 1962, Bobrinsky successfully finished a thesis titled *Pottery Wheels of Eastern Europe in 9-13th Centuries AD*, and in 1979, he completed his doctor of history thesis, *Pottery Production in Eastern Europe. Sources and Methods of Study*. From 1963 until 2010, he worked as a leader of the History and Ceramics Laboratory at the Institute of Archaeology Russian Academy of Sciences.

As early as 1959, Bobrinsky began to collect a database of ethnographic information on the rural pottery production of various peoples from Eastern Europe, the Caucasus, and Central Asia. That work included, on the one hand, mass and systematic fill-in-the-blank requests of the population of these regions, and, on the other hand, many years of studying at recent rural pottery production centers. This work produced a tremendous resource of ethnographic data from about 1,000 pottery centers of European Russia, Baltic countries, the Ukraine, Belarus, Moldova, Caucasus, and Central Asia. This compendium became the basis for deeper understanding of important regularities in the history of ancient pottery production.

Major Accomplishments

A.A. Bobrinsky is a creator of the new "Historical-and-Cultural Approach" for analysis of ancient pottery production. The core of this approach consists of the reconstruction of concrete potters' skills and cultural traditions in pottery technology, vessels' shapes, and pottery decoration through archaeological ceramics. In this field, A.A. Bobrinsky elaborated a general system of pottery technology investigation (1978, 1999), and new methods to study the shape of vessels (1987, 1988, 1991). Furthermore, his research revealed the main historical regularities in the development of special constructions for firing of vessels – bonfires, ovens, stoves, and kilns (1991, 1993). Moreover, Bobrinsky proposed well-proven new theories of the emergence, initial development and evolution of pottery wheels (1993, 1996), pottery kilns (1991), and ancient pottery production as well (1993, 1997, 1999, 2006). In recent years, he has focused a lot of attention on methods for studying the sex and age of ancient potters, ascertained through the nail prints on ceramics (2008).

All the new methods elaborated by Bobrinsky aimed to solve a core scientific goal – ceramics as a valuable source of historical information on ancient populations. A.A. Bobrinsky always tried to impart his knowledge to young scholars and that is why a strong scientific school in the study of ancient ceramics and pottery production now exists in Russia and in the countries of the former USSR.

Cross-References

▶ Ceramics: Scientific Analysis
▶ Ethnoarchaeology
▶ Ethnoarchaeology: Approaches to Fieldwork
▶ Human Skeletal Remains: Identification of Individuals
▶ Indigenous Knowledge and Traditional Knowledge
▶ Interpretation in Archaeological Theory
▶ Modern Material Culture Studies
▶ Medieval Pottery Research Group (MPRG)
▶ Medieval Russia (Rus'), Archaeology of
▶ Technological Studies in Archaeological Science

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Bonavia, Duccio

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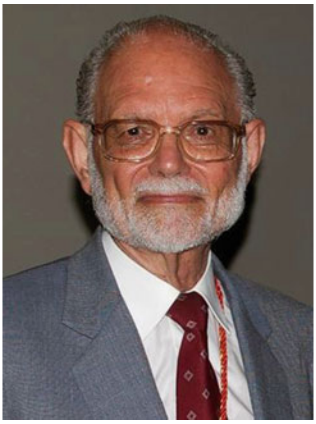
Basic Biographical Information

Duccio Bonavia, born in Spalato (Dalmatia) on March 27, 1935, was the son of Aurelio and Neda Bonavia, both native Italians. After the Second World War, when Duccio was 14 years old, his family moved to Peru in July 1949 and settled in Lima. In 1965, Duccio received his Peruvian citizenship while still retaining his Italian citizenship (Fig. 1).

Duccio received his primary education from a school in Spalato (1940–1944) and his secondary education in Bassano del Grappa, Possagno, and Treviso (1945–1947). He finished his high school studies at Colegio Italiano Antonio Raimondi in Lima (1950–1951). He then enrolled in the National Engineering School, today known



Bonavia, Duccio, Fig. 1 Duccio Bonavia

as the National University of Engineering, where he intended to study architecture (1952–1954). Duccio, however, did not enjoy his engineering courses and soon switched to the University of San Marcos (1955–1960) where he studied archaeology and anthropology.

Duccio married Ana Mori Tomatis from Lima though of Italian descent on June 15, 1962. They had two children, Bruna and Aurelio. Both children went on to earn their Ph.D., Bruna in biology and Aurelio in microbiology. Anita was the great love of Duccio's life, both at home and in their travels together. Duccio dedicated several of his publications to Anita.

After the death of his wife in 2004, Duccio was practically alone in Lima. He decided to move to Saskatchewan in Canada to be with his daughter, Bruna, and her husband, Thomas Fisher, and their sons, Lucas and Stephen. Duccio's son, Aurelio, lives in Seattle. Duccio left Lima in the spring of 2010 and lived in Canada for a year. Duccio died at the age of 77 on Saturday, August 4, 2012, in Magdalena de Cao, Ascope in Peru. He died during the last phase of his fieldwork at Huaca Prieta, Magdalena de Cao on the north coast of Peru. Duccio and Tom Dillehay were codirectors of the research project.

Just a few days before Duccio left for his last trip to Peru, he finished editing the English translation of his book on corn (Cambridge University Press). His research on the subject was kept in characteristically good order and is ready for another scholar to continue. In Peru, he donated his archaeology library to the University of Trujillo as well as his collection of plant and small animal samples, which were left to the archaeobiology lab at the university. The remainders of his things including his extensive library on Peruvian archaeology were sent to his most recent residence in Saskatchewan. It was Duccio's wish that after his passing, his library would be donated as well.

Major Accomplishments

Duccio's career in archaeology began when he studied under Dr. Raúl Porras Barrenechea, a professor of history at the University of San Marcos. His teachers at the university also included Jorge C. Muelle, an art historian; Luis E. Valcáreal, an Andean ethnohistorian; Ella Dunbar Temple, a specialist in colonial institutions; Mons. Pedro Villar Córdova and Edward P. Lanning, both archaeologists; and, lastly, José María Arguedas, an anthropologist with a great passion for indigenous cultures. For Duccio, archaeology was not only a scientific discipline but a great passion for the living cultures of the past.

While he was still a student, he participated in the *First Roundtable for Anthropological Sciences*, organized by the University of San Marcos in 1958, and, with Lumbreras and Caycho, presented his archaeological study of Aya Orjo (1958). The same year, at the Second National Congress of Peruvian History, Duccio presented another paper dedicated to the analysis of ceramics from Puerto Viejo, Chilca (1959).

Duccio obtained his Bachelor's degree in 1960 with a thesis called *On the Teatino Style*. A year later, he received his Doctor of Letters with his thesis *Six Occupation Sites from the Bottom of the Lurin River Valley*. Both of Duccio's theses were in the field of ethno-archaeology and were completed at the University of San Marcos in Lima.

Immediately after obtaining his academic degrees, Duccio embarked upon a number of archaeological explorations, including excavations in the Huarmey Valley on behalf of the Botanical Museum at Harvard University (1960). He explored the northern Peruvian valleys with Donald Thompson (1961) and organized the Italo-Peruvian expedition in northern Peru (1961). He explored the Casma Valley with Donald Collier in 1962, and from 1962 to 1963, he took over the Catastro project dedicated to the pre-Hispanic monuments in the Lima Valley. This last project was commissioned by the Metropolitan Deliberations Board and included participation from Ramiro Matos and Félix Caycho. The report was published in five volumes, which are currently in the archaeological monuments inventory in Lima. From the 1960s through today, more than 70 % of the registered archaeological sites in the Lima Metropolitan area were destroyed.

In 1965, Duccio traveled to Rome to represent the National Culture Commission of Peru and participated in postgraduate courses on new techniques in archaeological exploration, which was sponsored by the Lerici Foundation (1965). From 1967 to 1968, he obtained a scholarship from the French government to further his studies in the Quaternary Geology Laboratory at the University of Bordeaux in France under the guidance of Professor François Bordes.

Duccio was a consistent participant in conferences and academic events dedicated to Andean archaeology, such as the XXXVII International Congress of Americanists in 1966 (La Plata, Argentina), the XXXVII International Congress of Americanists in 1968 (Stuttgart, Germany), and the International Congress of Americanists in 1970 and the XLI International Congress of Americanists in 1974 (Mexico). He also participated in the International Symposium "Criticism and Perspectives of Andean Archaeology" organized by the National Institute of Culture of Peru, UNDP, and UNESCO (Paracas, 1980) as well as the World Archaeological Congress in Southampton, UK, in September of the same year. He was a speaker at the Symposium "Recent Advances in the Understanding of Plant Domestication and Early Agriculture" in 1986. He also organized the international meeting on the "State of Peruvian Archaeology" with Ramiro Matos (Lima, 1988) and the Symposium on "French Research in Peru" with the French Embassy, IFEA, and ORSTOM (Lima, 1988).

Duccio Bonavia taught at several Peruvian and foreign universities such as the National University of San Cristóbal de Huamanga in Ayacucho (1963–1964), the University of San Marcos (1964–1970), and the Peruvian University of Science and Technology (1968). He was a professor in the Biology Department at the University Peruana Cayetano Heredia de Lima (1971–2005). He was also twice a professor at the Friedrich Wilhelms University in Bonn, Germany, and participated in a seminar on anthropology under Max Uhle (1981 and 1983–1984).

His academic merits earned him several positions such as Honorary Professor at the National University of Trujillo (1994), Extraordinary Investigative Professor at the Peruana Cayetano Heredia University (2002), Honorary Professor at Ricardo Palma University in Lima (2005), and Doctor Honoris Causa at the National University of Trujillo (2006). Duccio also spoke several languages including Italian, French, Spanish, Serbo-Croatian, and English, following in the footsteps of his mentor Dr. Jorge C. Spring (Jorge C Muelle). Dr. Spring and Duccio were good friends and hosted several visitors to the National Museum of Anthropology.

Duccio was a member of the Society for American Archaeology, the Société des Americanistes de Paris, Société des Americanistes (Switzerland), Société Préhistorique Française, and the Institute of Andean Studies. He was an honorary member of the Permanent Council of the International Union for Prehistoric and Protohistoric Sciences (USA). He also served as a representative of Peru at the Peruvian Historical Society and the National Academy of History. He was also a corresponding member of the Royal Academy of Spanish History and the National Academy of Argentinian History and a member of the Sciences Academy of Latin America and a life member of the College of Peruvian Archaeologists and also of the Società Dalmata di Storia Patria.

Duccio traveled extensively throughout Peru, mainly in the coastal valleys as well as several places in the sierra and the jungle. With a team from the Biophysics Laboratory from the University Peruana Cayetano Heredia, he climbed the Pariacaca Mountain in 1985 to study the Inka sanctuary of the same name.

Among his major studies in the field of archaeology was a study of a Mochica mural painting in the Valley of Nepeña (1958), an exploration of the north coast with Ernesto Tabío and Donald Thompson (1959), a stratigraphic excavation at Ancon (1960), and an excavation at Huarmey commissioned by the Harvard Botanical Museum (1960). He organized the scientific expedition to the jungles of Ayacucho sponsored by the National University of San Cristóbal de Huamanga (1963). He also organized the excavations at the ruins of Yaro (Pajaten, 1966) and in the Chancay River basin (Lambayeque) under the auspices of the Royal Ontario Museum (1971), among others.

Duccio has contributed to the creation and the strengthening of several institutions devoted to Peruvian archaeology. He was the Chief of Investigations at the Archaeological Museum at the University of San Marcos (1956–1961). He was the head of the technical team of the Metropolitan Deliberations Board in their studies of historic and archaeological sites (1963), head of the Explorations Department of the National Museum of Anthropology and Archaeology in Lima (1964), then assistant director (1968–1979), and an archaeologist affiliated with the National Archaeological Board in Lima (1963). He was a member of the Committee of Monuments as part of the Peruvian Commission of UNESCO (1967), a consultant to the Ford Lima Foundation (1975–1980), founder of the Laboratory of Prehistory in the Department of Biology at the University Peruana Cayetano Heredia (1978), a member of the Commission for the technical rating of archaeological projects at the National Institute of Culture (1979–1985), and a founding member and director of the Peruvian Association for the promotion of the social sciences (FOMCIENCIAS 1980).

Duccio received several fellowships throughout his life, including one from the Harvard Botanical Museum for his excavations in Huarmey (1960) and from the Ministry of Foreign Affairs of France for his studies at the University of Bordeaux with professor François Bordes (1967–1968), from the Royal Ontario Museum (Canada), from the Ford Foundation to excavate in Huarmey (1974), from the John Simon Guggenheim Memorial Foundation (New York, USA), and from the Harvard Botanical Museum (1976–1977), to investigate preceramic corn in Huarmey. He also received fellowships from CONCYTEC to draw a map of mural paintings in Peru (1983) and from the Ford Foundation to analyze the conditions of university teaching in archaeology in Peru along with Ramiro Matos (1989–1990). Their report was subsequently published.

He received funding from the French Institute of Andean Studies in 1993 to write a book on Andean camelids and to translate into English the Fish and Wildlife Service (1999). To write his last book on corn, he received funding from the University San Martín de Porres (2006).

Duccio's academic bibliography is incredibly varied and comparable to the classics in American anthropology. He dabbled in art, pre-Colombian urbanism, botany, zoology, ecology, paleopathology, the indigenous diet, parasitology, physiology of height, and some aspects of medicine. The following bibliography includes 14 books, seven monographs, 44 inserts as chapter books, 139 specialized articles in magazines, 39 articles, and 20 reviews and comments devoted to the publications of his colleagues. He has been a big supporter of the theory of the second center of domestication of corn in the Andes.

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▶ Andes: Prehistoric Period

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Bone Chemistry and Ancient Diet

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Introduction

Dietary practices are a fundamental aspect of human life, from the basic caloric necessities to the socioeconomic variables which affect food production, acquisition, preparation, and consumption. Archaeologists have used many different data sources to study ancient dietary practices, including direct evidence from animal bones, macrobotanical plant remains, pollen and phytoliths in the soil, organic residues in pottery, and coprolites, as well as indirect evidence from skeletal pathology, dental wear patterns, ethnographic observations, writings, and artistic depictions. Nevertheless, for most such studies, the results are just the determination of the main menu, with animal foods the only source of semiquantitative dietary estimates.

It was only in the late 1970s that a new area of research developed – bone chemistry – which has expanded considerably our understanding of human dietary practices (Vogel & van der Merwe 1977). Biochemically, you are what you eat, and bones, teeth, and other tissues preserved in the archaeological record may be analyzed and provide direct information about the diet of individuals. This has led to research on how diets may vary based on age, sex, and socioeconomic status, as well as between different sites and time periods (here are some of the recent synthetic publications about stable isotope analyses and human diet: Tykot 2004, 2010; Pollard & Heron 2008; Lee-Thorp 2008; Price & Burton 2011).

Specifically, the combination of stable carbon and nitrogen isotopes in bone collagen and other tissues, and carbon and oxygen isotopes in bone apatite or tooth enamel, may be used to reconstruct prehistoric diet because of differential isotope fractionation between certain plant groups of atmospheric carbon dioxide during photosynthesis and trophic level increases in nitrogen isotopes. This allows us to distinguish between plants that follow different photosynthetic pathways; those which are nitrogen fixing versus absorption; and consumption of foods from different trophic levels, especially aquatic fish and mammals versus terrestrial plants and animals, but also between hunter-gatherers and agriculturalists, and even address short-term dietary change through microsampling of tooth roots and hair. Trace elements such as barium and strontium provide additional information about food sources and diet, while oxygen isotope analysis is used to study potential seasonality of shellfish gathering, and along with strontium and lead isotope analysis the mobility of the consumers.

Reliable isotope results have been obtained from samples of our early human ancestors, while the use of modern instruments which require only tiny samples and have a low per-sample cost has led to hundreds of archaeological bone chemistry studies around the world, with frequent publications in the *Journal of*

Archaeological Science, the *American Journal of Physical Anthropology*, *Archaeological and Anthropological Sciences*, and the *International Journal of Osteoarchaeology*.

Key Issues

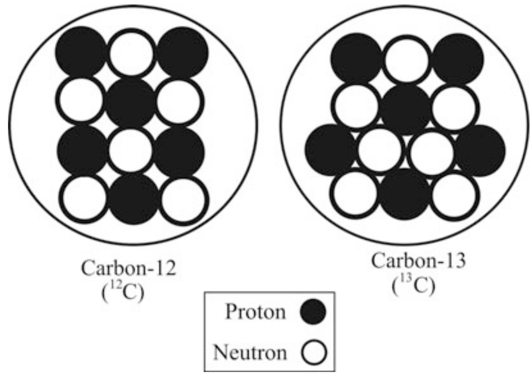
Principles of Stable Isotope Analysis

There are two stable isotopes each for carbon (^{12}C, ^{13}C) and nitrogen (^{14}N, ^{15}N), and three for oxygen (^{16}O, ^{17}O, ^{18}O) (Fig. 1). The lightest isotopes for each are the most abundant in nature (c. 99 % for each), while the small but measurable amount of variation in the heavier isotopes is measured in parts per thousand or per mil (‰). High-precision stable isotope measurements using stable isotope ratio mass spectrometers are reported using the delta notation ($\delta^{13}C$, $\delta^{15}N$, $\delta^{18}O$) relative to internationally recognized standards:

$$\delta^{13}\mathrm{C}\,(\text{in ‰ or per mil}) = [\{(\text{sample }^{13}\mathrm{C}/^{12}\mathrm{C})/(\text{standard }^{13}\mathrm{C}/^{12}\mathrm{C})\} - 1] \times 1000$$

For carbon and oxygen, the standard is *Belemnitella americana* from the Pee Dee limestone formation in South Carolina, while for nitrogen, it is AIR.

While all terrestrial plants photosynthesize CO_2 from the atmosphere and turn it into complex carbon-based molecules, there are three different photosynthetic pathways for plants which result in differences in their carbon isotope ratios which are then passed on to their consumers (Fig. 2). Trees, shrubs, and grasses from temperate regions follow the C_3 (Calvin-Benson) pathway, and have $\delta^{13}C$ values averaging about −26.5 ‰, while grasses native to hot, arid environments follow the C_4 (Hatch-Slack) pathway and have $\delta^{13}C$ values averaging about −12.5 ‰ (although maize is more positive, c. −10 ‰). There are also some differences between particular species of plants and for the same plant grown at different latitudes (Fig. 3). Succulent plants like cactus utilize the CAM (crassulacean acid metabolism) photosynthetic



Bone Chemistry and Ancient Diet, Fig. 1 Stable isotopes with different numbers of neutrons in the nucleus

pathway, with carbon isotope ratios often similar to those of C_4 plants but much more variable due to local ecological settings. In heavily forested areas, a canopy effect occurs due to incomplete atmospheric mixing and results in even more negative carbon isotope ratios. Atmospheric carbon isotope ratios have become depleted by about 1.5 ‰ since the industrial revolution, so values obtained on modern terrestrial plants and animals must be adjusted accordingly for comparison with most archaeological studies.

Wheat, barley, and rice are the most widely used domesticated C_3 cereal crops, while maize (corn), millet, and sorghum are the main C_4 domesticates. Stable carbon isotope analysis therefore has been widely used to address the importance of maize in the Americas and millet in Europe, Africa, and Asia.

For isotopic analysis of human remains to study diet, different tissues may be tested. Bone is made of a complex organic material called collagen (mostly a combination of essential and nonessential amino acids) and the bone mineral known as apatite (calcium hydroxyphosphate carbonate). Tooth enamel has a similar structure to bone apatite, while tooth roots have both collagen and apatite. Hair is made of keratin, a proteinaceous compound like collagen.

Empirical carbon isotope data for large mammals, along with data for laboratory-raised

Bone Chemistry and Ancient Diet,
Fig. 2 General pattern of photosynthesis showing carbon isotope fractionation

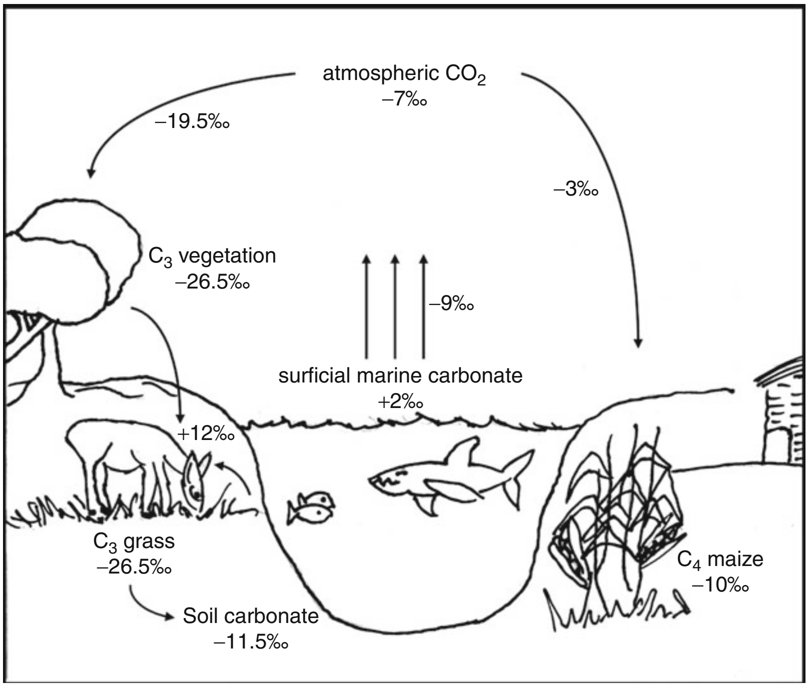


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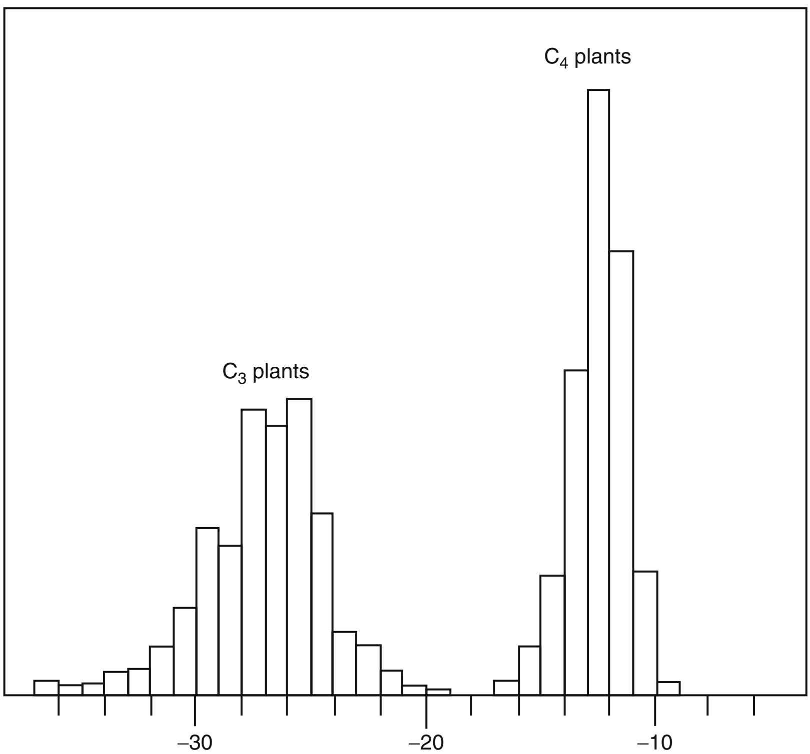
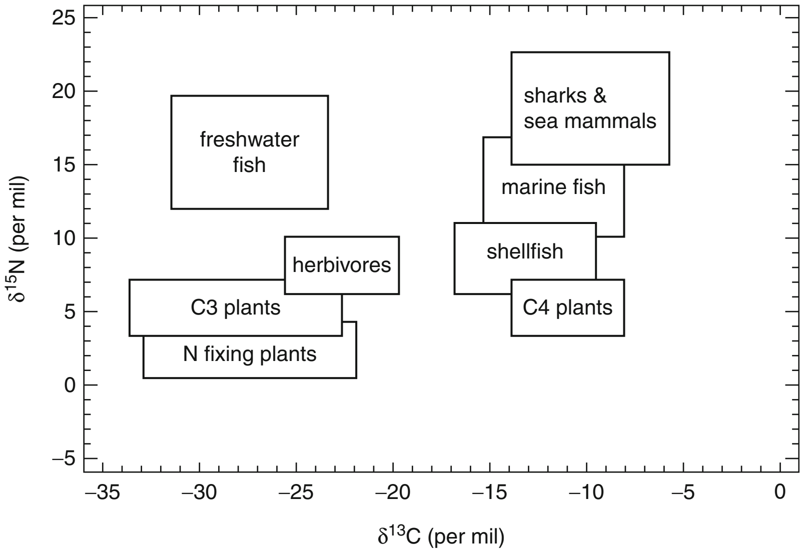
Fig. 3 Carbon isotope ratios for modern C_3 and C_4 plants





Bone Chemistry and Ancient Diet, Fig. 4 Carbon versus nitrogen isotope ratios for a typical food web. Isotope ranges may vary by region

rats and mice, indicate that bone collagen $\delta^{13}C$ is metabolically enriched about +5 ‰ relative to diet, although this value is affected by the proportion of protein in the total diet and any differences in $\delta^{13}C$ values between protein and energy sources. Studies have shown that bone collagen is disproportionately produced from the protein portion of the diet, while bone apatite and tooth enamel are produced from a mixture of dietary protein, carbohydrates, and fats (lipids). Experimental data on rats shows that bone apatite is enriched about +9.5 ‰ relative to the whole diet, regardless of the variety or isotopic composition of the foods consumed (Ambrose & Norr 1993; Tieszen & Fagre 1993), while data for larger herbivores and humans suggest that the diet-apatite spacing is about +12 ‰ (Tykot et al. 2009). Stable carbon isotope analysis of both bone collagen and apatite thus permits quantitative estimates of several dietary patterns.

Carbon isotope ratios for freshwater and marine foods are more variable than terrestrial plants and animals, due to differences in carbonate values in the water and trophic status, with marine (saltwater) fish having positive $\delta^{13}C$ values similar to that of maize. Fish and sea mammals, however, typically have much higher nitrogen isotope values, and their high protein content contributes much more carbon to bone collagen than does maize (c. 10 % protein) or other plants. In contrast, carbon isotope ratios for bone apatite, which equally represent dietary carbohydrates, fats, and proteins, allow for the identification of just a few percent of C_4 plants in an otherwise C_3-based diet.

Nitrogen isotope ratios for plants depend primarily on whether they obtain their nitrogen by symbiotic bacterial fixation or directly from soil nitrates, but also vary according to rainfall, altitude, and other factors. Plant values also may be elevated due to human-led fertilization practices. From their local baseline values, nitrogen isotope ratios increase about 3 ‰ for each trophic level due to metabolism, with lots of variation among marine organisms. Humans dependent on terrestrial plants and animals usually have $\delta^{15}N$ values in bone collagen of about 6–10 ‰, whereas consumers of freshwater or marine fish and sea mammals may have $\delta^{15}N$ values of 15–20 ‰. The most accurate interpretations may be made when there are isotopic data available for the animal and plant foods likely to have been consumed by a specific population, so testing is often done not just on human remains but also faunal and floral samples found at archaeological sites (Fig. 4).

Oxygen isotope analyses are also used to study ancient diet. Oxygen isotope values relate directly to local climate, temperature, and humidity and are used for determining the seasonality of shells, climate studies, mobility, and their impacts on dietary patterns. Analyses have been done on oxygen in both the carbonate and phosphate components of bone apatite and tooth enamel. Strontium isotope ratios directly represent the geographic area of food production/acquisition and thus the mobility of dietary resources and/or their consumers. Strontium isotope analysis has been used for migration studies in many parts of the world (see Meiggs & Freiwald's entry on ▶ Human Migration: Bioarchaeological Approaches in this encyclopedia).

Bone collagen and bone apatite have resorption/replenishment rates estimated at 7–10 years or more, so that isotopic analysis of bones of adults provides the average diet for many years prior to death. Tooth tissues, however, do not turn over, so their isotope values represent diet from the time of formation, regardless of age at death. Tooth formation begins in utero for deciduous teeth and ranges from 0 to 18+ years of age for permanent teeth. The analysis of multiple teeth from the same adult individual may reveal the age of weaning (first the introduction of solid foods and later the cessation of breast feeding) since a nursing infant is effectively a carnivore and will have much higher $\delta^{15}N$. Differences between juvenile teeth and adult bone values may reflect changes in diet due to geographic movement (e.g., for marital reasons) or change in status.

Stable isotope analysis of multiple human tissues can provide a science-based dietary life history of an individual. Although collagen is rarely preserved in bones predating the Upper Paleolithic and even for recent time periods is often badly degraded in hot and moist environments, bone apatite has provided reliable results throughout the Holocene and tooth enamel for early hominins back into the Miocene. Microanalysis of tooth segments (or hair or fingernails, when preserved) may be done to address short-term isotopic dietary variability, perhaps due to seasonal mobility or harvesting practices.

Sample Preparation and Stable Isotope Analysis

For isotope analysis of archaeological bone, the first step is to remove any potential contamination, either from the soil or from added preservatives, for a sample weighing about 1 g. It is then necessary to separate the specific tissues to be analyzed. For collagen, this involves demineralization of the bone using acid and separation from any residual lipids. The procedures used in the Laboratory for Archaeological Science at the University of South Florida involve demineralization in 2 % hydrochloric acid (72 h), removal of base-soluble contaminants using 0.1 M sodium hydroxide (24 h before and after demineralization), and dissolution of residual lipids in a 2:1:0.8 mixture of methanol, chloroform, and deionized water (24 h) (Fig. 5).

Bone collagen is often not well preserved, and a yield of less than 1 % is considered unreliable for isotope analysis (bone originally has more than 20 % collagen). The main issue for low yields is that degradation may have resulted in unequal breakdown and loss of the different amino acids, which individually have different isotope values because of the different chemical reactions involved in their initial production. The amount of carbon and nitrogen measured by the mass spectrometer, relative to the size of the sample put in for analysis, and the C to N ratio of the gases produced (which should be the same as in living organisms) are additional tests of reliability. Duplicate 1 mg samples of collagen pseudomorphs are placed in tin capsules and analyzed for $\delta^{13}C$ and $\delta^{15}N$ in continuous flow mode using a Carlo-Erba NA2500-II EA with a Costech Zero-Bank autosampler, coupled with a Thermo Delta + XL stable isotope ratio mass spectrometer in the Paleolab at USF (Fig. 6a).

Bone apatite and tooth enamel carbonate are prepared using procedures designed to remove non-biogenic carbon without altering the biogenic carbon isotope values (see Tykot 2004). About 10 mg of powdered sample is immersed in 2 % sodium hypochlorite to dissolve organic components (24 h for enamel, 72 h for bone

Bone Chemistry and Ancient Diet, Fig. 5 Chemical extraction of bone collagen for isotope analysis

apatite), followed by the removal of non-biogenic carbonates using 1.0 M buffered acetic acid for 24 h. The integrity of apatite and enamel samples is assessed through yields obtained in each stage of the pretreatment process and the CO_2 yield during the mass spectrometry analysis. More complex tests of sample reliability have been used in some laboratories, however, including Fourier transform infrared spectroscopy (FTIR). Apatite and enamel samples weighing 1 mg are isotopically analyzed on a second Thermo Delta + XL mass spectrometer equipped with a Kiel III individual acid bath carbonate system (Fig. 6b). It is a scientifically sound idea to perform repeat isotope analyses for outliers when testing a group of individuals thought to have had similar isotope values.

For both bone collagen and apatite/enamel carbonate analysis, reference gases and solid standard samples are analyzed to ensure reliability of the isotope results. The analytical precision for stable isotope ratio mass spectrometers is typically 0.1 ‰ or less for ^{13}C and ^{8}O and 0.2 ‰ for ^{15}N.

Estimating the percentage of C_4 plants in human diet is fairly straightforward for herbivores and human agriculturalists, if seafood was not available and animals were not consuming wild C_4 grasses, by simple interpolation between the endpoints of bone apatite for a pure C_3-based diet versus a pure C_4-based diet. Rather than using the average endpoints of −26.5 and −12.5 ‰, the specific carbon isotope values for the C_3 plants most likely consumed should be used, since they do vary between grasses (e.g., wheat, barley, rice) and legumes, etc., in order to set an accurate baseline. For a C_4 endpoint based on maize, the value would be about −10 ‰. So if the range was from −24 ‰ to −10 ‰ (14 ‰), then each per mil more positive than −24 ‰ would represent about 7 % maize in the overall diet.

When animal or aquatic foods are a significant part of the diet, the bone collagen carbon and nitrogen isotope data are necessary to include in the percentage calculations. Mathematical models have been developed to combine collagen and apatite isotope data for distinguishing between plant and animal food sources with similar isotopic signatures, most recently by using multivariate statistics (Froehle et al. 2012).

Trace Element Analysis

A number of studies have been done measuring and interpreting trace elements in bone mineral, including Sr, Ba, Fe, Cu, Mg, Mn, Zn, and Pb. Lead is a toxic element known to accumulate in bone due to the usage of lead-based drinking, cooking, and eating materials, as well as toy soldiers, paint chips, and other items children have ingested. Strontium and barium however are structural substitutes for calcium in bone apatite and tooth enamel and show significant trophic level variation in their concentrations. Both Sr and Ba are acquired by plants through the soil and are then passed on to their consumers, with a decrease in concentrations for each trophic level. This fractionation is even greater for Ba than Sr due to its chemical structure as barite ($BaSO_4$) in the soil. There is, however, considerable geological variability in the soils, so that archaeologists must be extremely careful in making interpretations about the relative importance of plants versus meat in the diet. Testing of herbivorous and carnivorous animals, and plant foods if available, from the same area is highly recommended. In addition, care is needed in taking samples from bone with minimal contamination or diagenesis (Burton & Price 2000). Most elemental analyses of bone have been done by ashing the sample, dissolution, and using an ICP spectrometer; some more recent

Bone Chemistry and Ancient Diet, Fig. 6 Stable isotope mass spectrometers in the Paleolab at the University of South Florida connected (**a**) to a CHN analyzer for collagen and other organic samples; (**b**) to a Kiel III acid bath for bone apatite, enamel, and other carbonate materials

studies where sample removal was not allowed have been done nondestructively using an X-ray fluorescence spectrometer (Fig. 7).

Trace element measurements of bone are reported relative to calcium, e.g., Sr/Ca and Ba/Ca, or logarithmically, e.g., log (Ba/Sr). Much greater differences in the Sr and Ba concentrations and in the Ba/Sr ratios have been observed for marine versus terrestrial diets.

Recent Applications

Stable isotope analysis of human remains to study ancient diets has expanded considerably in the last decade, with several dozen or more publications just in the last few years. The main issues being addressed include:

- Early hominin dietary practices
- Seafood consumption by near-coastal populations

Bone Chemistry and Ancient Diet, Fig. 7 Nondestructive trace element analysis of bone using a portable X-ray fluorescence spectrometer

- Dietary contribution of freshwater resources from lakes and rivers
- Mesolithic-Neolithic dietary changes
- Importance of millet in east Asia, Africa, and Europe
- The spread of maize in the New World
- Dietary differences based on sex and/or status
- Weaning practices
- Mobility and migration

Following is an overview of two areas of my own research, specifically the importance of maize and seafood in different areas of peninsular Florida and the dietary practices of coastal and island inhabitants in the Mediterranean.

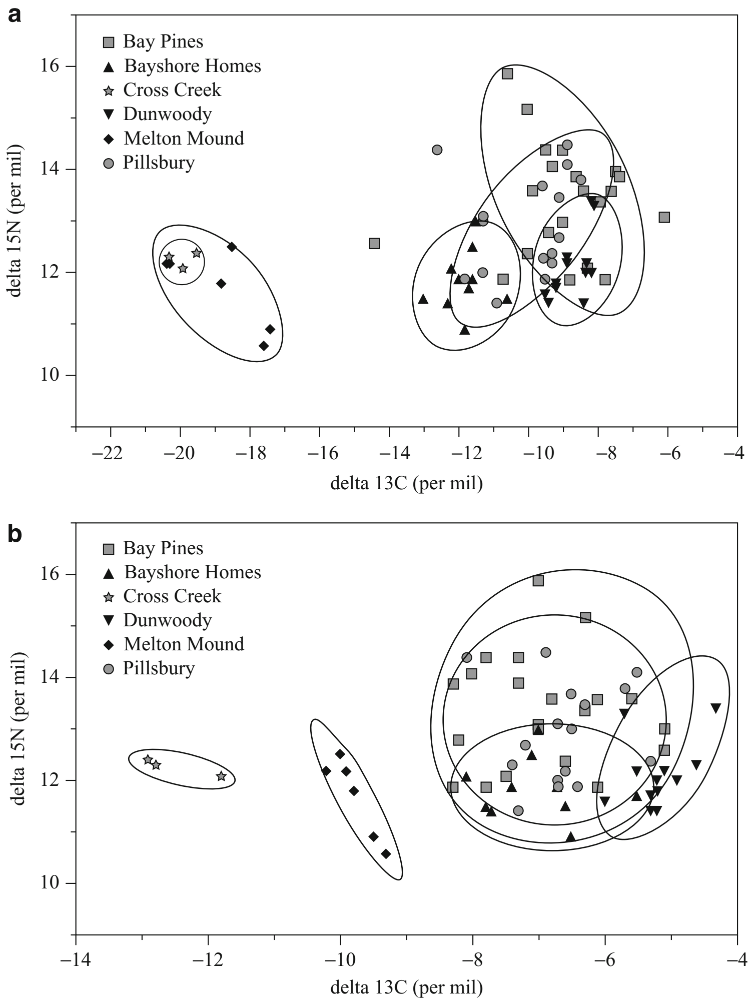
Florida

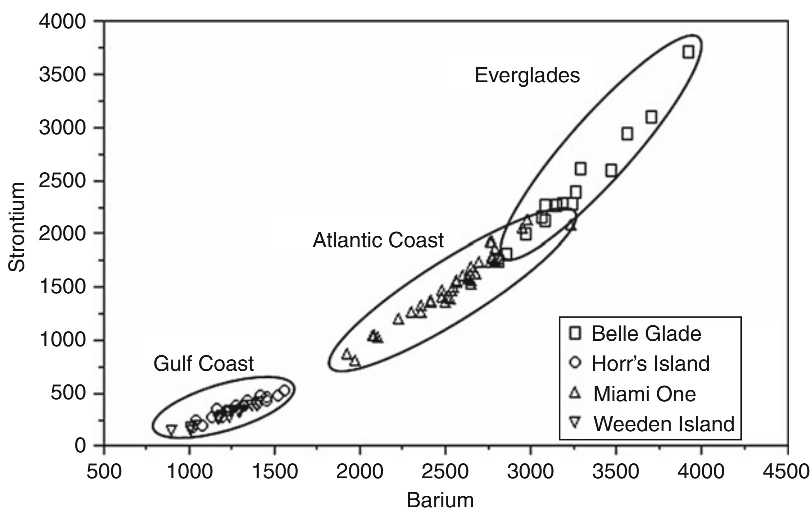
Bone collagen and apatite for more than 100 human individuals from 7 sites in peninsular Florida were analyzed by stable isotope mass spectrometry to test for the presence and increasing importance of maize in the southeastern United States (Tykot et al. 2005; Kelly et al. 2006). Previous studies, mostly on bone collagen, had clearly indicated maize was a dietary staple for the Mississippian culture by about 1000 CE, but it had been thought that maize may never even have reached southern Florida. At the inland site of Melton Mound, however, positive carbon isotope ratios especially for bone apatite and tooth enamel fully support that C_4 plants such as maize were a small but noticeable part of the diet by 600–800 CE. Four sites near the Gulf Coast were tested, with individuals from Bayshore Homes (Safety Harbor period) and Dunwoody (Late Caloosahatchee) averaging much lower $\delta^{15}N$ in bone collagen and more positive $\delta^{13}C$ for bone apatite, relative to the earlier Bay Pines (Weeden Island I) and Pillsbury (Manasota) sites, while the $\delta^{13}C$ results for bone collagen were similar for all four (Fig. 8). This strongly supports that it was a plant such as maize (with much less protein than fish but having an equal impact on apatite $\delta^{13}C$ values) did become a dietary staple in this region by the early 2nd millennium CE. For all sites, however, there was also a large range of variation among individuals, and at least at one site, it seems that males had higher nitrogen isotope values than females, perhaps due to greater fish consumption. This is being investigated further through elemental analysis of Ba and Sr, which in a separate study has shown a much greater importance of seafood at sites on the Gulf Coast when compared with those near Miami on the Atlantic side of Florida (Fig. 9).

The Mediterranean Region

In the Mediterranean world, while seafood is a regular part of many modern people's diet, there is little in the way of shell mounds or other archaeological evidence that it was a staple in ancient times, even prior to the Neolithic. However, for Mesolithic sites on the Atlantic coast, including Portugal and Spain, isotope studies have shown that seafood was a major part of the diet (e.g., Richards & Hedges 1999). In contrast, an early study using both stable isotope and elemental analysis on Mesolithic coastal sites of Arene Candide in Liguria and Grotta dell'Uzzo in Sicily (Francalacci 1989; Mannino et al. 2011) suggested that seafood was

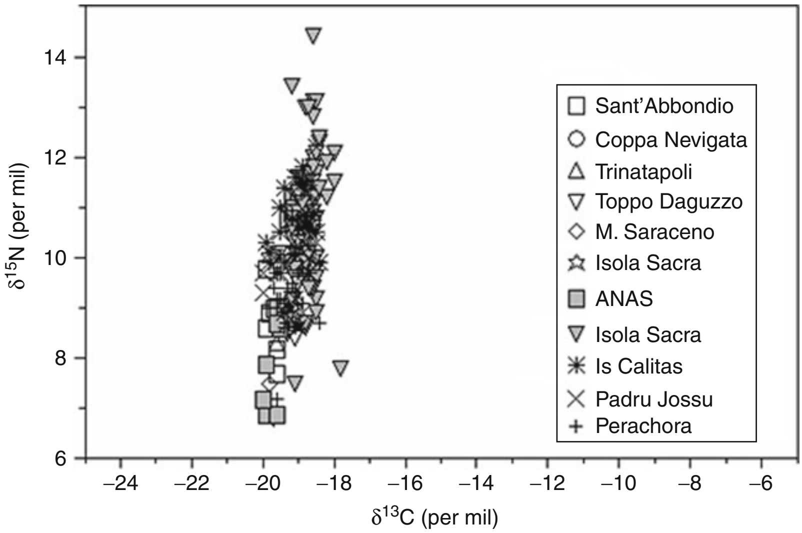
Bone Chemistry and Ancient Diet,
Fig. 8 Stable isotope data for selected precontact archaeological sites in Florida. (**a**) $\delta^{15}N$ versus collagen $\delta^{13}C$; (**b**) $\delta^{15}N$ versus apatite $\delta^{13}C$





Bone Chemistry and Ancient Diet,
Fig. 9 Barium versus strontium trace element data for selected Florida sites showing differences based on geographic regions

Bone Chemistry and Ancient Diet, Fig. 10 Human bone collagen $\delta^{13}C$ versus $\delta^{15}N$ for selected Bronze-Iron Age sites in the central Mediterranean



not a staple in the Mediterranean, and beginning in the Neolithic when there were domesticated sheep, goat, cattle, pig, wheat, barley, and other crops, studies by many scholars have shown it was negligible at sites in Italy, Croatia, Greece, Tunisia, and even on the islands of Sardinia (Lai et al. 2007), Malta, the Balearics, and Crete. There are some modest isotopic differences in diet based on status in the Late Bronze Age, e.g., at Mycenae (Richards & Hedges 2008), while freshwater fish become important at some sites, but even in Roman times when there was regular, large-scale maritime seafaring, it appears there was little seafood consumption even at the port site of Isola Sacra near Rome (Prowse et al. 2004; Killgrove & Tykot 2013) (Fig. 10). It is important, however, to have isotope data for fish and shellfish in the specific region of study since there are cases where their isotope values are rather negative and thus overlapping with terrestrial plant and animal values. African millet, a C_4 plant, was apparently present in Europe in the Neolithic, but not isotopically noticeable until the Bronze Age in northern Italy (Tafuri et al. 2009) and Iron Age at sites in Greece and Slovenia (Murray & Schoeninger 1988).

Future Directions

The analytical methods and examples presented above for human bone and other tissues do not include all of the scientific ways to study ancient diets. Stable isotope analyses have been done on individual amino acids in bone collagen, on cholesterol preserved in bones and teeth, on dental calculus, on carbonates and humic matter in soils, and organic residues (lipids) absorbed in pottery. Still being developed are other ways to study diet, including isotopic analyses of calcium, sulfur, and hydrogen, and decreasing even further the size sample necessary for analysis.

Acknowledgments I especially thank Nikolaas J. van der Merwe for getting me involved in isotope analyses more than 20 years ago, the dozens of colleagues I have worked with on six continents, and the many undergraduate and graduate students who have worked in my lab. For more than 10 years, most of my isotope samples have been analyzed in the Paleolab, managed by Ethan Goddard.

Cross-References

- ▶ Bioarchaeology in the Roman Empire
- ▶ Bioarchaeology, Human Osteology, and Forensic Anthropology: Definitions and Developments
- ▶ Bone: Chemical Analysis
- ▶ Isotope Geochemistry in Archaeology
- ▶ Isotopic Studies of Foragers' Diet: Environmental Archaeological Approaches
- ▶ Isotopic Studies of Husbandry Practices
- ▶ Maize: Origins and Development

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Bone Density Studies in Environmental Archaeology

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Introduction

Archaeologists and paleontologists have long recognized that the ability of bones to survive in the fossil record varies as a function of their intrinsic physical characteristics. Of these characteristics, bone density has become the most commonly used proxy measure of the potential of a specific skeletal element to survive site formation processes. In the analysis of archaeological faunal assemblages, bone density data have provided a framework for the assessment of preservational bias. Density-mediated destruction of faunal remains may result in a *sample assemblage* that is not representative of the *deposited assemblage* (terminology after Klein & Cruz-Uribe 1984), and this bias may affect the interpretation of important lines of faunal evidence such as skeletal element abundance, age/mortality profiles, and species representation. Studies have documented a wide range of bone density across the various elements within a skeleton, demonstrating the importance of basing counts of elements (MNE) and individuals (MNI) in archaeological assemblages on skeletal portions of high density.

The primary challenges in bone density research have been the derivation of accurate density measurements and the establishment of methodological standards. Over the past three decades, density data sets have been published for numerous species of mammals, birds, and fish. However, researchers have employed different methods in measuring and calculating "bone density" values. As a result, published bone density data sets vary significantly in their accuracy and are typically not suitable for comparison with one another. Most studies have been based on very small samples; those that have involved large samples have documented significant intraspecific variation in bone density.

Definition

Bone is made up of an organic matrix, a mineral component, and water. The organic matrix is primarily collagen, with a small proportion of noncollagenous proteins. The mineral component consists almost exclusively of hydroxyapatite, a calcium phosphate (Martin et al. 1998). The (dry) mass of a bone divided by its volume is known as its *apparent density* or *structural density*. Lyman (1984) emphasized a further distinction between *true density* (mass divided by volume exclusive of pore space) and *bulk density* (mass divided by volume inclusive of pore space); "pore space" includes any medullary cavity. Many studies have employed techniques that measure exclusively the mineral component of bone samples, producing data on *bone mineral density*.

The "bone density" data sets published in archaeological literature differ in terms of which property ("true density" or "bulk density") they attempt to represent and how accurately these properties have been measured. This variability reflects the diversity of methodologies used by researchers and has resulted in a current state of uncertainty in which "bone density" may refer to a certain property in one study but a different property in another. Consequently, the bone density data set from any given study is typically unsuitable for comparison with those from others. This observation may even apply to studies conducted by the same research group; in a number of cases, researchers have altered their methodology for calculating bone density over time, with the result that the data produced in their more recent studies are not appropriate for comparison with those of their earlier studies. In numerous cases, methodological shortcomings have resulted in published bone density data that are inaccurate and of limited use in archaeological analyses (Lam & Pearson 2005).

The methodology for any study must be examined carefully in order to determine the actual property to which "bone density" refers.

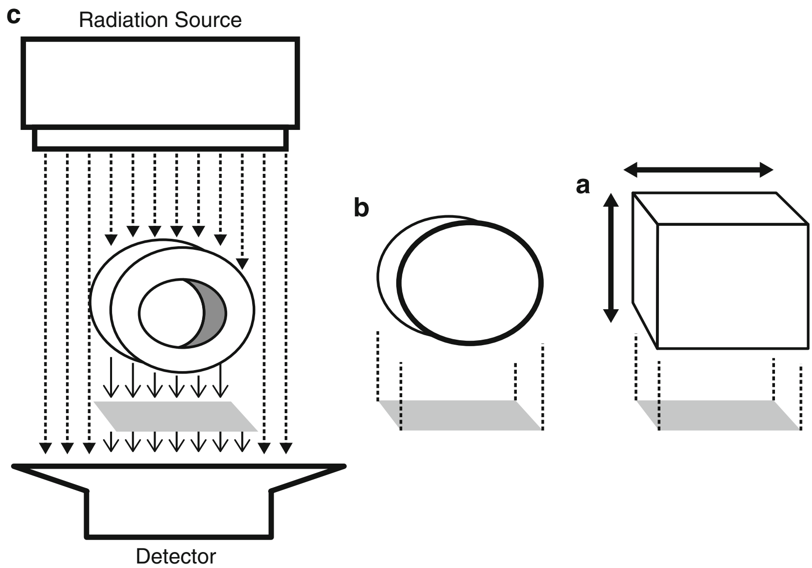
Key Issues/Current Debates/Future Directions/Examples

Archaeological studies of bone density were first conducted by some of the pioneers of taphonomic research (Brain 1969; Behrensmeyer 1975; Binford & Bertram 1977), who were interested primarily in applying these data to interpretations of the Plio-Pleistocene archaeological record. Perhaps the most well-known application of bone density studies was that of Brain (1969), in his assessment of Dart's proposal of an osteodontokeratic culture among australopithecines. Brain observed that the faunal preservation at the early South African cave sites more likely reflected patterns of bone density than selection, use, and manufacture by early hominins.

These early studies of bone density used water displacement to measure a range of artiodactyl skeletal elements, but differences in methodology resulted in inconsistencies between the density data produced by each study. Subsequently, most studies of bone density have been conducted using photon densitometry, a technique introduced to zooarchaeological research by Lyman (1984). Photon densitometry provided the advantages of being nondestructive and able to measure elements at very specific locations – known as "scan sites" or "regions of interest" (ROIs). While the earlier water displacement studies had measured the density of entire elements (providing a single value for each element) or, in the case of long bones, proximal and distal halves, Lyman's use of scan sites took into account the heterogeneous composition of most skeletal elements by defining multiple points of measurements for each. The scan sites defined by Lyman have become accepted as standard locations of density measurement by subsequent researchers, with modifications made to account for morphological variations among different taxa.

Despite Lyman's attempt to provide standardized parameters for bone density studies, the adoption of photon densitometry ironically resulted in greater incompatibility among the bone density data sets produced in the past two decades. Photon densitometers measure bone mineral *content* across a scan site (Fig. 1). In order to transform this measure of bone mineral content into a (bone mineral) *density* value, researchers must independently determine the volume of the scan site – the cross-sectional area of the site multiplied by its thickness, which is typically set by the machine (e.g., 1 mm). Despite having in common their use of photon densitometry, Lyman and other researchers employed different methods to estimate this cross-sectional area, affecting the accuracy and comparability of their density data sets. The end result has been that the practical definition of "bone density" varies from study to study. In some studies, the cross-sectional areas of all scan sites have been assumed to be a rectangle or a circle. Other studies have devoted greater effort to produce more precise measurements of the shape of the bone cross section. However, photon densitometry cannot determine the volume or shape of internal cavities; at best, it can measure *bulk density*, but not *true density*. With a few exceptions, researchers who employed photon densitometry did not take the additional steps to exclude internal cavities in their calculations of "density"; the failure to account for such cavities results in artificially low density values at the scan sites where they occur.

In order to address this shortcoming of photon densitometry, computed tomography (CT) has been used to measure bone mineral density for several species of mammal (Lam et al. 1999). The use of CT enabled precise assessment of the cross-sectional shape, including that of internal cavities, of each scan site and resulted in the most accurate bone mineral density measurements to that point. CT analysis of several ungulate taxa documented the highest bone density to be, among cranial elements, in the teeth and the petrous and, among postcranial elements, in the middle shaft portions of long bones (Lam et al. 1999).



Bone Density Studies in Environmental Archaeology, Fig. 1 A schematic representation of photon densitometry, after Kreutzer (1992). The detector cannot determine the shape of the bone; it measures bone mineral *content*. The accuracy of the density value derived for each scan site (in this illustration, the middle shaft portion of a long bone) directly reflects the accuracy of the determination of the cross-sectional area. In "A," the cross section of the scan site is estimated to be a *rectangle* of maximum width and height. Such data underestimate the density of all scan sites and are categorized here as Class A. In "B," the external outline of the cross section is measured, but the internal cavity is not. Data produced in this manner are categorized as Class C and represent *bulk density*. They underestimate *true density* wherever an internal cavity occurs. Data that account for both external and internal shape ("C") are categorized as Class D and represent *true density*. The assessment of internal shape must be conducted independently of photon densitometry

Despite the advantages of CT, the use of photon densitometry has remained common in bone density studies. Recently, another nondestructive technology – digital photodensitometry – has been introduced to archaeological research into bone density. This technology allows the examination of large samples at low cost but, like photon densitometry, cannot measure internal cavities (Symmons 2004). In order to produce accurate density measurements, these technologies must be supplemented with the use of an independent method, such as water displacement or CT, that can determine the size of internal cavities.

The problematic effects of multiple methodologies of variable accuracy and precision can be seen in the divergent density values that have been produced for a single taxon (Fig. 2). Lam and Pearson (2005) conducted a review of bone density studies in archaeology, categorizing published density data sets for mammalian taxa into one of four classes: A–D, from least accurate to most accurate. Class A studies calculated density as if the cross section of the bone was a rectangle, with sides of maximum width and height (Fig. 1A). This invariably represents an overestimation of the cross-sectional area, resulting in an underestimation of bone density. The degree of inaccuracy varies with scan site, depending on how closely the cross section of that site corresponds to a rectangular shape.

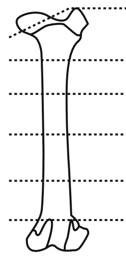
Studies categorized as Class B and Class C accounted for the external shape of the cross section, with Class B studies using a rough, geometric estimate (e.g., circle, triangle, polygon) and Class C studies deriving an actual measurement of the external outline of the scan site; however, neither accounted for the presence and size of the medullary cavity. The accuracy of Class B data varies according to how closely the geometric estimate matches the shape of the cross section. Class C data should be accurate for scan sites that have no internal cavity (Fig. 1B). Only Class D data demonstrate accuracy across all scan sites, accounting for both the shape of the external contour and any internal cavities, but data sets in this class remain few. Some studies have derived density values in more than one class for comparative purposes. Class C density values have been found to be up to 1,000 % higher than Class A values and Class D values up to 120 % higher than Class C values for the same scan site (Lam & Pearson 2004).

The publication date of a bone density study does not inform as to the accuracy of the data it presents. In the past decade, some studies have continued the publication of Class A data, while others have presented methodological advances such as the combination of photon densitometry (to measure bone mineral content) and CT (to determine cross-sectional area) in the same study (Novecosky & Popkin 2005).

Class D data have proven significant in documenting the large difference in density between the epiphyses and shafts of long bones, a difference obscured by the inclusion in Class A–C data of the marrow cavity in the density calculations (Fig. 2). This observation has illustrated the importance of incorporating shaft fragments into the quantification of long bone abundance. Such fragments are more likely to survive in the archaeological record than those of epiphyses. Quantification based primarily on epiphyses will underestimate the overall abundance of long bones for situations in which density-mediated destruction has occurred; in addition, it may result in a bias for metapodials, which have relatively dense epiphyses and represent low-utility elements, over high-utility long bones such as femora, whose epiphyses are less dense. At Paleolithic sites, the failure to count shaft fragments may lead to a biased overrepresentation of low-utility elements, potentially resulting in the erroneous interpretation that the assemblage was accumulated through scavenging behavior (Marean & Kim 1998).

Lyman's (1984) bone density data set for deer was used widely by researchers, even in cases in which the species of interest was not deer. In the past twenty years, efforts have been made to collect density data for other species – primarily mammals (including humans [Galloway et al. 1997]), but also several species of fish (e.g., Butler & Chatters 1994) and bird (e.g., Cruz & Elkin 2003). Some studies of mammal species have observed significant intertaxonomic differences in bone density patterns; however, it remains unclear the extent to which they reflect differences in research methodology rather than actual differences in density. Lam et al. (1999) derived bone mineral density values for a small sample of bovid, cervid, and equid species, finding that overall patterns of bone density were extremely consistent among the three groups. Other studies (e.g., Gutiérrez et al. 2010) have found, for individual scan sites, a high degree of variation in bone density among individuals within the same taxon. While some of this variation may be attributable to differences in age, with the bones of juveniles being less dense than those of adults, the effects of other variables such as sex, diet, health, and activity levels on bone density require further investigation. A thorough documentation of the range of intrataxonomic variability is a prerequisite to any assessment of differences in bone density between species.

Additional challenges to be addressed include the use of bone density data in quantitative



	I	II	III	IV	V
FE 1	0.28	0.34	0.57	1.03	0.60
FE 2	0.16	0.40	0.38	0.75	0.61
FE 3	0.20	0.39	0.46	0.76	0.66
FE 4	0.36	0.51	0.69	1.01	1.33
FE 5	0.24	0.41	0.54	0.81	0.56
FE 6	0.22	0.23	0.35	0.85	0.50

bone mineral density (g/ml)

Bone Density Studies in Environmental Archaeology, Fig. 2 Published bone density values for different scan sites of a sheep or goat femur, taken from five different studies. Columns I, II, and III represent Class A data; column IV represents Class C data (bulk density); column V represents Class D data (true density) (see Lam & Pearson (2005) for sources) analyses. The standard use of correlation/regression analysis in many studies to examine the relationship between bone density and bone survivorship requires the condition that each individual identified in a faunal assemblage was originally represented by an entire skeleton. It also requires the condition that all the preserved remains of that skeleton were recovered and identified. As neither condition is likely to hold for most archaeological fauna assemblages, researchers must modify their quantitative analyses as appropriate (Lam & Pearson 2004; Novecosky & Popkin 2005). Continued research is required to produce accurate density values for larger samples, to assess the range of intrataxonomic and intertaxonomic variability in bone density, and to provide effective methods for incorporating bone density data into archaeological analyses.

Cross-References

- ▶ Binford, Lewis R. (Theory)
- ▶ Dart, Raymond Arthur
- ▶ Human Remains Recovery: Archaeological and Forensic Perspectives
- ▶ Middle-Range Theory in Archaeology
- ▶ Taphonomy in Bioarchaeology and Human Osteology
- ▶ Taphonomy in Human Evolution
- ▶ Vertebrate Taphonomy in Archaeological Research
- ▶ Zooarchaeology
- ▶ Zooarchaeology: Methods of Collecting Age and Sex Data

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Bone Differentiation (Human and Nonhuman) in Archaeological and Forensic Contexts

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Introduction

Differentiating human and nonhuman bone has important applications in both archaeological and forensic contexts and can be particularly challenging when skeletal remains are fragmentary. Archaeologists often make initial determinations about whether skeletal remains are human or not in the field, although more detailed analyses often take place in the laboratory, particularly for bulk bone recovered during excavation. In cases where skeletal remains are found unexpectedly, one of the first questions in establishing whether the remains have forensic significance involves determining whether they are of human or nonhuman origin. Differentiating human and nonhuman bone can be achieved through a variety of methods, including gross, histological, and molecular analyses. More detailed reviews of these methods can be found in Hillier & Bell (2007), Mulhern (2009), and Mulhern & Ubelaker (2012).

Definition

Human bone is most likely to be confused with mammalian bone, particularly mammals that are about the same size. However, the human skeleton is adapted for bipedal locomotion, resulting in many easily distinguishable skeletal features throughout the skeleton, particularly related to the morphology of joints and muscle attachment sites. The human skull is also readily identifiable, with the combination of a very large brain case and flat face. In general, human bones show less pronounced muscle markings and flatter, less sculpted joint surfaces than nonhuman mammalian bones. For a photographic reference for distinguishing human and nonhuman mammalian bone, see France (2009).

A large cranial vault and thinner cranial bones distinguish the human skull from other mammals of comparable size. Also, the opening to the brainstem (foramen magnum) is located directly underneath the skull in humans and toward the back of the skull in quadrupedal animals. The human face shows no projection of the nasal area or the jaws, unlike other mammals.

In humans, the spine exhibits a characteristic “S” shape when fully articulated to accommodate upright posture. In addition, the size of the vertebrae becomes dramatically larger toward the lumbar spine because of the need to support body weight. In quadrupeds, the articulated spine has more of a “C” shape with vertebrae that are more uniform in size throughout the spine.

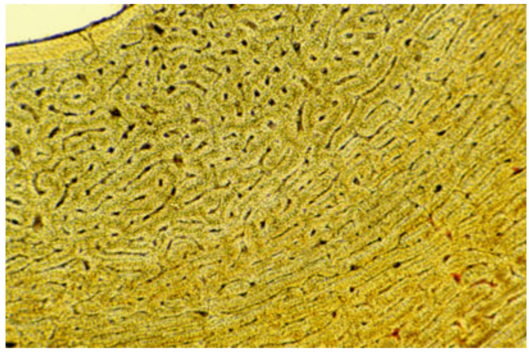
The human thorax is most similar to an ape, with a broad, shallow rib cage resulting in ribs that have a more pronounced c-shaped curve than seen in a typical quadruped. Humans have a long clavicle and very mobile shoulder, elbow, and wrist joints. Also seen in apes, this combination of features is not characteristic of other mammals of similar size. Most mammals have greatly reduced or absent clavicles as well as more stable, restricted shoulder girdles and elbow and wrist joints. Specific skeletal features to look for in humans included a rounded humeral head, reduced olecranon process of the ulna, and broad contact between the capitulum of the humerus and the radial head.

The human pelvis is unique among mammals, with a bowl shape capable of supporting internal organs with an upright posture. The broad iliac blades accommodate the repositioning of gluteal muscles needed to offset torque forces caused by supporting the body weight on alternating limbs during bipedal striding.

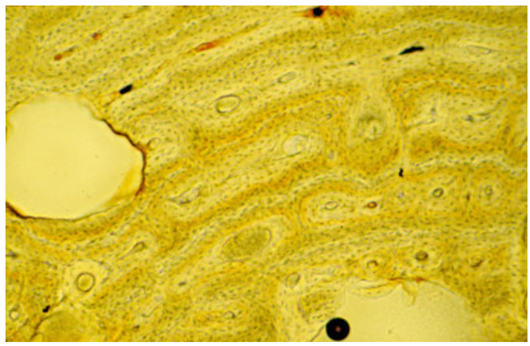
The lower limbs in humans show many adaptations to bipedal locomotion. The thighs are angled from hip to knee to position the limbs directly underneath the body. This can be seen in the medial angle of the femur. The hip, knee, and ankle joints in humans are robust to accommodate body weight. The human tarsals are also very robust compared to other mammals. Humans have five digits in the foot; the first (medial) digit is the most robust. Many mammals have a reduced number of digits. Due to similarities in size and overall morphology, bear paws are commonly mistaken for human feet (and hands) in North America, particularly when partially fleshed with the claws missing. Anatomical differences between a human foot and bear foot include the relative length of the digits; humans have longer medial digits, and bears have longer lateral digits. Also, the tarsal bones of a bear are not as robust as their human counterparts, and the metatarsal heads of bears each have two associated sesamoid bones, whereas only the first metatarsal head in humans exhibits sesamoids. Specific features of the lower limbs characteristic of humans include a femoral greater trochanter that is shorter than the femoral head, a lateral lip on the anterior aspect of the distal femur that helps to hold the patella in place, and a platform-like talus.

In cases where it is not possible to confirm or exclude human origin based on gross analysis, histological methods may be useful (Mulhern & Ubelaker 2012). Histological analysis is necessarily destructive and requires specialized equipment and training. Preparation of histological specimens typically involves removing a cross section of a bone and grinding it down to a thin wafer that can be mounted on a microscope slide for viewing under a light microscope. The overall organization of histological structures, as well as the size and shape of structures may provide important clues regarding the bone's origin.

Mammals that grow quickly in size such as cows, deer, and sheep typically have bone that exhibits a plexiform structure, with a rectangular organization (Fig. 1). This type of pattern is not found in human bone and, if observed, can be used to rule out bone of human origin (Mulhern 2009). A pattern of linear bands of primary and/or secondary osteons is also consistent with nonhuman bone (Fig. 2) and rarely seen in human bone. Human bone is characterized by



Bone Differentiation (Human and Nonhuman) in Archaeological and Forensic Contexts, Fig. 1 Plexiform bone in a sheep femur

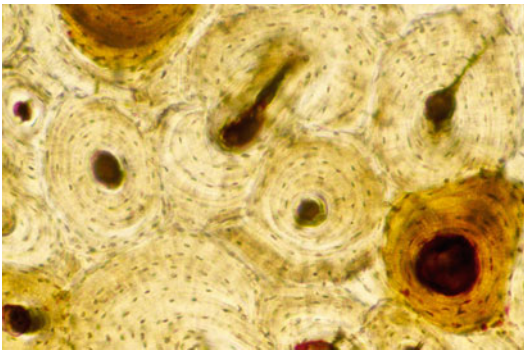


Bone Differentiation (Human and Nonhuman) in Archaeological and Forensic Contexts, Fig. 2 Osteon banding in a miniature swine femur

haphazardly distributed secondary osteons, or Haversian systems embedded within lamellar bone (Fig. 3), but is not unique in this respect, as many other mammals (including those with plexiform bone) also have bone with this type of pattern. In particular, large carnivores exhibit Haversian bone-like humans. This is potentially problematic in a forensic context, since size of the bones could be similar.

Key Issues/Current Debates

Attempts have been made to apply metric analysis of histological structures (such as osteon size or Haversian canal size) to identify



Bone Differentiation (Human and Nonhuman) in Archaeological and Forensic Contexts, Fig. 3 Haversian bone in a human femur

differences among species, but the accuracy of many of these studies is questionable because they are based on small sample sizes (Mulhern & Ubelaker 2012).

Overall, studies show that humans have larger Haversian canals than most mammals; however, most studies are based on relatively small sample sizes, so the extent of variability is not well understood. Osteon sizes in humans overlap those of other mammals, particularly those with medium or large body sizes. Several studies have also attempted to develop discriminant function equations that can be used for distinguishing human and nonhuman bone based on histomorphometric variables such as osteon and Haversian canal size. A new area of research involves an investigation of the circularity of osteons, which suggests that osteons in nonhuman bone are more circular than those found in human bone. A complete review of these methods can be found in Mulhern and Ubelaker (2012).

Biomolecular methods including radioimmunoassay and mitochondrial DNA analysis have also been used for species identification, which is particularly important in wildlife forensics; applications of these studies are summarized in Mulhern (2009). The cost of such methods makes gross analysis and histological methods preferable when possible.

Future Directions

Future directions for distinguishing human and nonhuman bone include an expansion of our understanding of the variability of bone histology among species as well as among and within bones of individuals. As more studies involving larger sample sizes provide additional data, the accuracy of methods used to distinguish human and nonhuman bone based on histological structures will likely improve.

Cross-References

▶ Bioarchaeology: Definition
▶ Bone, Trauma in
▶ Bone: Chemical Analysis
▶ Bone: Histological Analysis
▶ Commingled Remains: Field Recovery and Laboratory Analysis
▶ DNA and Skeletal Analysis in Bioarchaeology and Human Osteology
▶ Forensic and Archaeological Analyses: Similarities and Differences
▶ Osteology: Definition
▶ Skeletal Biology: Definition
▶ Taphonomy in Bioarchaeology and Human Osteology

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Bone Tools, Paleolithic

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Introduction

"Bone tool" is a generic term used to identify implements made of various animal tissues that include bone, tooth, antler, and ivory. During the Paleolithic (2.6 Ma to ~10,000 BP), these tools took different forms and have been studied by archaeologists to address a variety of questions. Researchers have investigated early purported bone tools in an attempt to identify firm criteria to distinguish between marginally modified or used tools and bones altered by natural causes. Bones interpreted as genuine tools have been investigated to gain a better understanding of early hominin adaptation, technology, and cultural traditions. Different research questions have concerned the emergence and diversification of formal bone tools, defined as functional artifacts shaped with techniques specifically conceived for bony tissue, such as scraping, grinding, grooving, and polishing. For much of the twentieth century, formal bone tools were seen as a technological innovation directly stemming from the spread of anatomically modern humans across Europe at the beginning of the Upper Paleolithic and strictly associated with a suite of critical inventions that followed this peopling event (cave and mobiliary art, personal ornaments, blade technology, complex funerary practices, musical instruments, etc.). Upper Paleolithic bone industries were used in this framework to support the scenario of a cognitive revolution occurring in Europe at c. 40,000 years ago. The discovery of bone awls and projectile points at a number of Still Bay (d'Errico & Henshilwood 2007) and Howiesons Poort (Backwell et al. 2008) sites from southern Africa, securely dated to between 75 and 60 ka, has challenged this view, but not the significance attributed by many archaeologists to this category of material culture. The early appearance of bone tools in the African Middle Stone Age, together with pigments and personal ornaments, has been used to support the so-called Out-of-Africa scenario for the origin of behavioral modernity, linking the origin of our species in Africa around 200,000 years ago with the gradual emergence of modern culture on that continent. In this context, bone tools are interpreted as a significant behavioral corollary of the emergence of anatomically modern humans in Africa. However, some authors have cautioned that Middle Stone Age sites with advanced bone tools are rare and that the cognitive implications of formal bone tool manufacture are uncertain (Backwell et al. 2008). In addition, bone industries that show a level of technological complexity, equivalent to that normally associated with Upper Paleolithic cultures produced in Europe by modern humans, are associated with transitional technocomplexes such as the Châtelperronian in France and Spain and the Uluzzian in Italy and Greece. The former technocomplex is now firmly attributed to Neanderthals, but the authorship of the latter is uncertain due to the scarcity and ambivalent features of the human remains associated with those layers. This implies that the ability to produce formal bone tools may not be the preserve of modern humans. In parallel with these studies, the complexity of Upper Paleolithic bone tools has stimulated research seeking to document the technological, typological, and functional changes that characterized bone tool industries in Eurasia between 40 and 10 ka. In this review we will focus on these different topics and summarize recent advances in the field.

Definition

A bone tool is taken here to be an implement that can be used to achieve a task or modify or produce an item. This definition does not include categories of bone artifacts used in nonfunctional activities, such as musical instruments, notations, and ornaments. This entry focuses on Paleolithic bone tools from Africa and Europe.

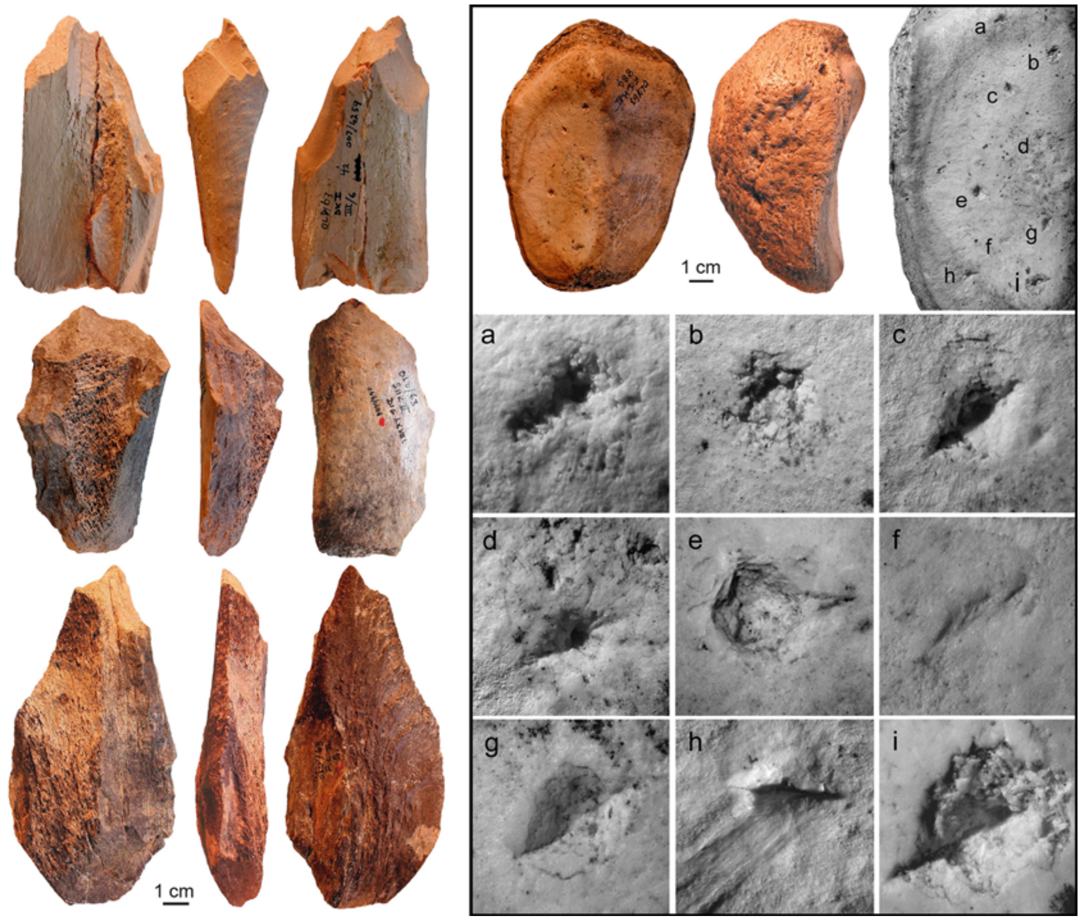
Historical Background

Earlier Stone Age of Africa

Ever since Dart interpreted bones from Makapansgat as tools, an interpretation largely rejected, research interest has focused on whether some bone objects from early hominin sites should be interpreted as artifacts or the result of nonhuman taphonomic processes, which are known to produce pseudo-bone tools morphologically similar to human modified or used artifacts. Criteria for characterizing the patterns produced by specific agents are not always clearly defined, and the issue of equifinality compounds the problem. In light of this, it has become widely accepted that in order to distinguish between pseudo-tools and true tools, it is necessary to adopt an interdisciplinary approach, combining the analysis of a wide range of bones modified by known agents, taphonomic analysis of the fossil assemblages from which the purported bone tools derive, microscopic studies of possible traces of manufacture and use, experimental replication of the purported tools, and the quantification of the wear pattern. In 1959 Robinson proposed that a metapodial shaft fragment with a smoothed and pointed end from Sterkfontein Member 5 West (~1.7–1.4 Ma) was a tool. Thirty years later Brain described 68 similarly modified bones and horn cores from Members 1–3 at Swartkrans, dated ~1.8–1 Ma. Comparative scanning electron microscope inspection of replicas of the worn area on archaeological specimens, and experimental shaft fragments used to extract tubers from the ground and work skins, suggested to Brain and Shipman that the wear patterns on the smoothed tips of the Swartkrans specimens matched those produced experimentally. The anthropogenic nature of the material was later confirmed by Backwell and d'Errico (2001), based on comparison with a large reference collection comprising fauna modified by ten nonhuman agents, morphometric and fracture analysis of bone flakes from Swartkrans Member 1–3, experimental use of shaft fragments in a variety of tasks, microscopic analysis of natural, experimental, and archaeological wear patterns, and quantification of striation width and orientation on archaeological and experimental specimens. The breakage patterns and size of the bone tools, compared with the remainder of the faunal remains, indicated that early hominins selected heavily weathered, elongated and robust bone fragments for use as tools (Fig. 1). The wear pattern on the Swartkrans tools fitted most closely that created when excavating termite mounds in the Sterkfontein Valley. Evidence of shaping by means of grinding on some of the more robust horn cores suggests that the users had the cognitive ability to modify bone intentionally for optimal efficiency in the task for which they were used. These authors described 16 new bone tools from Swartkrans and used the enlarged collection to search for patterns of variation between members. No significant differences were observed between Members 1 to 3 in the type and size of the bone fragments used as tools, as well as in the length and type of the wear pattern, demonstrating that no major changes occurred through time in the bone type favored and the motion in which the tools were used. A functional study of the Sterkfontein and Swartkrans bone tools was also conducted by Van Ryneveld, who experimentally used bone tools in a number of tasks and compared the resulting patterns with that present on the Swartkrans specimens using scanning electron microscopy. She concluded, based on visual comparison between wear patterns and the productivity of the various activities involved, an anthropogenic origin for the wear and that archaeological tools were used to excavate subterranean plant foods in dolomitic ground, debark softwood trees, process hides, and extract termites from their mounds. More recently, Backwell and d'Errico (2008) recognized 14 bone pieces from the nearby site of Drimolen as digging tools (Fig. 1), indicating that the use of these tools was widespread at sites in the Sterkfontein Valley. In an attempt to refine the

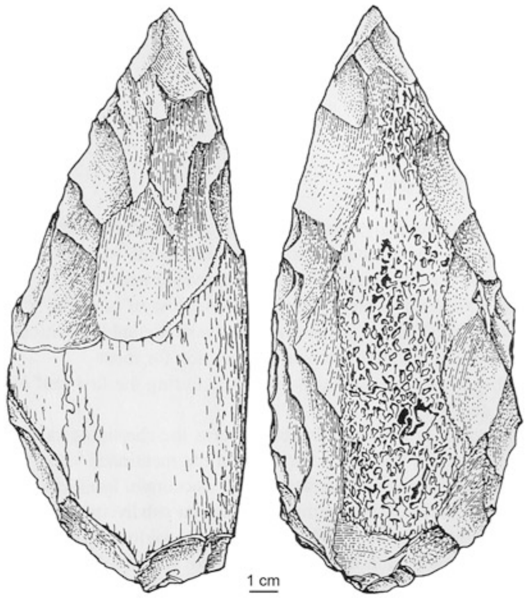
Bone Tools, Paleolithic, Fig. 1 Selection of bone tools from the South African early hominin sites of Swartkrans (*top*) and Drimolen (*bottom*) (Images: Backwell & d'Errico)

functional interpretation of the bone tools from Swartkrans and Drimolen, they conducted a statistical analysis of 2D and 3D roughness variables obtained from a representative sample of archaeological, ethnographic, and experimental bone tools (d'Errico & Backwell 2009). Results show that the wear pattern on the early hominin bone tools from Drimolen is incompatible with that of tuber digging and very similar to termite foraging and fruit processing. Members 1–3 at Swartkrans contain the remains of the robust australopithecine *Paranthropus robustus*, while Members 1 and 2 have additionally yielded the remains of *Homo erectus*. The absence of this taxon in Member 3, from where most of the bone tools derive, suggests, but does not prove, that these implements were used by *Paranthropus robustus*. The association of a high number of *Paranthropus* remains with bone tools and the virtual absence of stone tools at Drimolen reinforces the hypothesis that *Paranthropus robustus* was the user of the South African bone tools. A different bone tool tradition is observed in East Africa, where Mary Leakey reported 125 artificially modified bones and teeth from Olduvai Beds I and II bearing evidence of intentional flaking, battering, and abrasion. These specimens derive from massive elephant, giraffe, and *Libytherium* limb bones, and to a lesser extent from equids and bovids, as well as from hippopotamus and suid canines. Shipman analyzed the collection microscopically and concluded that 41 of the bone pieces were modified by hominins and the remainder bore ambiguous



Bone Tools, Paleolithic, Fig. 2 Selection of bone tools from Olduvai Gorge showing intentional shaping through knapping (*left*), and an elephant patella (*right*), with impact marks (details) resulting from repeated striking against a pointed stone (Images: Backwell & d'Errico)

traces, or evidence of abrasion by sediment. A patella, astragalus, femoral condyle, and magnum bearing puncture marks were interpreted as anvils, and 35 implements were described as bones shaped by flaking prior to use. Twenty-six were interpreted as light-duty implements used on soft substances (hide-working), and the remaining 11 described as heavy-duty tools utilized on mixed substances, perhaps in butchering or digging activities. Backwell and d'Errico (2004) reanalyzed the collection, focusing on fracture patterns and flake removals. Comparative microscopic analysis of different areas of the purported Olduvai tools, and of the edges of bone pieces from the rest of the faunal assemblage, suggested to these authors that the surfaces of all of the purported bone tools are affected by postdepositional abrasion, rendering impossible the interpretation of the function of the tools based on the wear pattern alone. However, analysis of breakage patterns and removals identified a reduced number of pieces that are likely candidates for having been intentionally knapped. These comprise fresh bone shaft fragments and epiphyseal pieces bearing five or more flake scars, some of which are contiguous, with one or more anomalously invasive primary removals (Fig. 2). Most of them reveal a particularly high proportion of bifacially arranged removals, and they are virtually unaffected by carnivore damage. They proposed that some bones functioned as handheld hammers (Fig. 2). An interesting aspect of their results lies in the stratigraphic occurrence of the bone tools. While Leakey and Shipman identified bone tools in all the beds, they identify, with one possible exception, bone tools only in Bed II. This suggests modification of bone fragments by knapping is not a behavior associated with the Oldowan, but with the more developed phases of this technological tradition (Developed Oldowan B) and/or the Early Acheulean. Knapped bone tools appear more systematically, according to their results, in coincidence with the appearance of remains of *Homo erectus* in middle and upper Bed II. The presence in a Bed II site of an intentionally knapped bone hand axe constitutes supplementary evidence that *Homo erectus* was responsible for the production of at least some of these bone tools. Similarly flaked bones are reported from other Acheulean sites, namely, Ternifine in Algeria, the Grotte des Ours in Morocco, and Gesher Benot Ya'aqov in Israel. Bones bearing traces interpreted as resulting from use are also reported at Melka-Konturé, Ethiopia, in layers dated to 1.7 Ma.



Bone Tools, Paleolithic, Fig. 3 Lower Paleolithic bone hand axe made of *Elephas antiquus* limb bone from Castel di Guido, Italy (Drawing: F. d'Errico)

Lower Paleolithic of Europe

Intentionally flaked tools are reported from 12 Lower Paleolithic sites in Europe, eight of which are in Italy. Acheulean-type bifaces, made by flaking elephant long bones, are known from three Middle Pleistocene sites in Italy: Castel di Guido, Fontana Ranuccio, and Malagrotta (Costa 2010). The Castel di Guido and Fontana Ranuccio specimens, in particular, show multiple scars on both faces with clear negative bulbs of percussion (Fig. 3). The use of long bone shaft fragments and an equid phalanx used to retouch stone artifacts is documented at the Middle Pleistocene site of Boxgrove in England. Putative bone and ivory points have been reported from at least six Lower Paleolithic sites in Europe, namely, Mesvin in Belgium, Bilzingsleben in Germany, Lunel Viel in France, Castel di Guido in Italy, and Torralba and Ambrona in Spain. Shaped bone and ivory points from the sites of Torralba and Ambrona were thought to have been used as awls or with wooden hafts, with the use of hafted bone and ivory points implying the employment of a spear armature technology. However, a reappraisal of the ivory points from Torralba, Ambrona, and Castel di Guido concluded that these pieces are natural, resulting from the accidental breakage of the tusks during the life of the animal (Villa & d'Errico 2001).

Middle Paleolithic of Europe

The use of bone or antler bases to retouch stone artifacts is documented at many Mousterian sites from Europe including Combe Grenal, Artenac, and La Quina in France, Riparo di Fumane and Riparo Tagliente in Italy, and on the Crimean peninsula (Patou-Mathis 2002). Recently, a human skull fragment from the Mousterian site of La Quina has been shown to be the oldest evidence of a human bone used as a tool in the form of a retoucher (Verna & d'Errico 2011). Bone and antler points are reported from at least 12 Middle Paleolithic sites: Butesti and Budzujeni in Moldavia, Prolom II in Crimea, Salzgitter-Lebenstedt in Germany, the Broion cave in Italy, Castillo in Spain, and several French sites such as Combe Grenal, Vaufrey, La Quina, la Grotte de l'Hermitage, Pech de l'Azé 1, and Camiac. Some of the pieces were interpreted as points hafted on throwing or thrusting spears, while others were described as awls and borers. A collection of mammoth ribs and fibulae from Salzgitter-Lebenstedt in Germany is said to have been intentionally pointed and/or flattened, but these objects require reappraisal before they can be accepted as genuine artifacts because similar objects have been shown to be the result of natural processes. Bone described as intentionally flaked or retouched has been reported from a number of Mousterian sites (e.g., Cueva Morin and La Quina), but the possibility that flaking may have resulted from fracture for marrow extraction by humans or carnivores has been excluded in only a few cases. Firm evidence of worked, and in some cases decorated, bone awls comes from Châtelperronian and Uluzzian sites in France and Italy (d'Errico et al. 2011). Findings at Arcy-sur-Cure and Quincay in France (Fig. 4), dated to between 40 and 38 ka BP, have yielded good evidence of complex bone technology in the form of shaped and decorated awls. The late Mousterian levels at Buran Kaya III in Crimea have yielded one bone haft made of a horse metapodial and several bone tubes made on wolf and hare long bones, dated to between 36 and 32 ka BP.

African Middle Stone Age

An increasing number of bone tools are reported from Middle Stone Age (MSA) sites in Africa. These include bone objects from Broken Hill (Kabwe), Zambia, attributed to the early MSA and thought to be associated with *Homo heidelbergensis* (elsewhere named *Homo rhodesiensis*) and interpreted as two gouges and a point. A point from Mumbwa Cave is considered doubtful. Other evidence for bone working in the MSA is provided by barbed and unbarbed bone points from the Katanda sites (Fig. 5) in the Semliki Valley, Democratic Republic of the Congo, dated ~90–60 ka (Yellen et al. 1995). A point tip, a mesial fragment, an almost complete spear point, a tanged bone point, and 26 awls are reported from M1 and M2 layers at Blombos Cave, with ages ~84–72 ka (Fig. 6). A single massive point, different from those found in the MSA and LSA layers at Blombos Cave, was recovered in the dune sand layer, with an age of ~70 ka (d'Errico & Henshilwood 2007). An awl and a possible flaked shaft fragment come from the Blombos M3 phase, with an age of 98.9 ± 4.5 ka. The morphological variability in the bone points from Blombos Cave, and the size and weight of the one complete specimen, suggests that they are more likely spear points than arrow points. The interpretation of the Blombos bone artifacts as spear points is consistent with ethnographic and recent archaeological stone point dimensions, which show spear tips to be five times larger than arrow heads. A bone point from Peers (Skildergatkop) Cave was retrieved from either the Howiesons Poort (HP) or Still Bay layers at the site. A recent study of carbon-nitrogen ratios in the Peers point, and a sample of Later Stone Age (LSA) and MSA faunal remains from this site, confirms that the point originates from MSA layers (d'Errico & Henshilwood 2007). A single bone point was discovered at Klasies River in layer 19 of Shelter 1a at the base of the HP. A date of approximately 80–60 ka, centered on 70 ka, was suggested for the HP at Klasies River. The only other pointed bone implements known from the MSA come from Sibudu Cave. These items include a polished bone pin attributed to the late MSA, from layer Co with an age of ~35 ka, a second bone pin, from layer PGS, and a large bone point from layer GS. These two items occur in the HP sequence with age estimates >61 ka. In addition to a small spatula-shaped tool, the discovery of a collection of worked bone at Sibudu Cave (Backwell et al. 2008) confirms a bone tool industry for the Howiesons Poort technocomplex. Comparative microscopic and morphometric analysis of the large bone point from Sibudu with bone tools from southern African Middle and Later Stone Age deposits, an Iron Age occupation, nineteenth-century San hunter-gatherer toolkits, and bone tools used experimentally in a variety of tasks revealed that it is most similar to arrow points from LSA, Iron Age, and historical

Bone Tools, Paleolithic, Fig. 4 Selection of Châtelperronian bone tools from Grotte du Renne at Arcy-sur-Cure, France (*left*), and Uluzzian sites from Italy (Images: d'Errico/Vanhaeren/Borgia)

San sites. This is interpreted, together with the extreme symmetry recorded in the tip of the Sibudu point, as a shift from the use of hand-delivered bone spearheads in the Still Bay (at Blombos) to bow and arrow technology in the HP. If confirmed, the bone point from Sibudu Cave pushes back the origin of bow and bone arrow technology by at least 20,000 years, substantiating arguments in favor of the hypothesis that crucial innovations took place during the MSA in Africa. The Sibudu bone point also falls within the morphological variability of a type of unpoisoned fixed bone arrow point used by Bushmen for hunting small game and birds, which is in accordance with the associated fossil fauna, represented mostly by small forest antelope.

African Later Stone Age

Projectile bone points and awls are associated with the Border Cave Early LSA assemblage, with an age of ~36 ka BP, and bone points similar to those known ethnographically occur at many

Bone Tools, Paleolithic, Fig. 5 Selection of barbed bone points from Katanda, Democratic Republic of the Congo, interpreted as harpoons used for fishing (Images: F. d'Errico)

LSA sites in southern Africa, including Rose Cottage, Oakhurst, and Nelson Bay caves, as well as Jubilee, Bushman Rock, and Giant's Castle Rockshelters (Deacon & Deacon 1999). Unlike MSA points, which were typically modified through scraping, LSA points evidence shaping through scraping and grinding. Later Stone Age bone tool categories include finely worked arrowheads, linkshafts, spatulas, polished needles, awls, fish hooks, gorges, and pegs, many of which are incised and decorated. The production of a range of tools from different raw materials is thought to imply increased technological and social complexity and the possible emergence of craft specialization. Later Stone Age bone tools are frequently associated with a suite of other innovations that include microlithic stone tool industries, rock art, and decorative items like beads and shell pendants. Formal bone tools, as with many of the innovations that became common in the LSA, were already present, although rare, in the MSA. Grinding to shape formal tools is the only shaping technique that is virtually absent before the Later Stone Age.

Upper Paleolithic of Europe

This period is characterized by previously unseen complexity in the techniques used to manufacture bone artifacts, greater diversity in the raw materials used, and a proliferation of bone tool types and patterns used to decorate them (Camps-Fabrer 1988; Knecht 1993). During this period we also observe for the first time clear consistencies in the geographic distribution and association of bone tools, with some types widespread over large regions and others characterizing an area or a specific cultural facies. The Upper Paleolithic can be seen in this respect as a time in which all the bone/organic tools specific to hunter gatherers of high latitude appear and become established. Projectile point types, size,

Bone Tools, Paleolithic, Fig. 6 Bone tools from the Middle Stone Age deposits at Blombos Cave (Images: d'Errico/Henshilwood)

and the way in which they are prepared for hafting reveal a previously undocumented variability and complexity, suggesting the emergence of prey-specific and perhaps season-specific hunting equipment (Fig. 7). Evidence for the use of complex foreshaft and detachable projectile points appears at the beginning of the Upper Paleolithic and becomes more elaborate at the end of this period. Among the new tools that appear for the first time in this period, we find the boomerang – a specimen in mammoth ivory was discovered at Oblazowa, Poland, in levels dated to 23 ka BP (Valde-Nowak et al. 1987) – bone needles, spear throwers, and perforated batons at French sites dated to ~20 ka BP (Fig. 8). Harpoons made of reindeer and red deer antler become common in the Magdalenian ~13 ka BP (Julien 1982). Bone and antler tools

Bone Tools, Paleolithic, Fig. 7 (**a**) Aurignacian split base point from Spy, Belgium; (**b**) Early Gravettian spear point from Mazière, Belgium; (**c**) fragment of a spear point with bladelet inserts, and spear point (**d**) from the Upper Magdalenian levels of Pincevent, France (Images: courtesy M. Vanhaeren)

used as soft hammers, pressure flakers, and punches used for intermediate percussion flaking also become common during this period. A number of tools used in hunting and domestic activities, typologically labelled as perforated batons, spatulas, pegs, and knives, still need to be investigated to elucidate their most likely functions.

Key Issues/Current Debates

A review of the literature shows that research interest in prehistoric bone tools has focused mainly on three areas. The first concerns verifying the existence, deciphering the functions of early hominin bone tools dated to between 1 and 2 Ma, and identifying who used them. The second area of interest concerns formal bone tools from MSA deposits in Africa, and whether they may be taken as reliable proxies for the emergence of modern humans and so-called modern behavior. The third relates to Upper Paleolithic bone industries and the reasons for the high degree of technical and symbolic investment in their production. The manufacture of bone and ivory implements using techniques specifically conceived for these materials, such as scraping, grinding, grooving, and polishing, is generally considered to be associated with

Bone Tools, Paleolithic, Fig. 8 Harpoon (**a**) and *baton percée* (**b**) from the Late Magdalenian levels of the La Madeleine shelter, Tursac, France; (**c**) spear thrower decorated with a female ibex interpreted as giving birth (**a** and **c**, courtesy of Musée National de Préhistoire, Les Eyzies-de-Tayac; **b**, photo Descouens, courtesy National History Museum of Toulouse)

modern human behavior and advanced cognition. A reason for this view is that the final shape of a bone tool manufactured with these techniques can be accomplished with a high degree of accuracy, which makes "formal" bone tools especially appropriate for inferring the degree of standardization and complexity of a technical system. Another reason is that the production of tools from a range of raw materials is thought to imply a diversified strategy of raw material acquisition and the possible emergence of craft specialization and increased complexity in social roles. A third reason for linking social and cognitive complexity with the presence of bone tools is the view that elaborated bone tools are a technological innovation associated with the spread of anatomically modern humans across Europe at the beginning of the Upper Paleolithic, forming part of the suite of critical inventions that followed this peopling event. As such, Upper Paleolithic bone tool industries have been used to support the scenario of a cognitive revolution occurring in Europe at ~40 ka, but the discovery of bone awls and probable projectile points at a number of securely dated MSA sites in South Africa challenges this view.

International Perspectives

The emergence of bone technologies has traditionally been considered as coeval with the arrival of modern humans in Europe. Recent discoveries and reappraisal of old evidence reveal a more complex pattern, with two traditions of bone modification and utilization in South and East Africa during the Early Stone Age, convincing instances of bone shaping through percussion at a number of Acheulean and Mousterian sites from Europe, and the systematic use of bones as retouchers in the Lower and particularly Middle Paleolithic of Eurasia. Clear evidence of complex bone technologies is found at Middle Stone Age sites in sub-Saharan Africa, at late Neanderthal sites from France and Italy, and at early Upper Paleolithic sites from Europe, Siberia, and the Near East. Abundant and diverse evidence for the use of bone as a raw material is associated with most Upper Paleolithic cultures, starting with the Ancient Aurignacian at ~40 ka. The broad implications of this emerging pattern for the cultural evolution of our lineage have not been explored in detail, mostly because researchers focus their attention on a single topic, site, or time period. Outdated paradigms regarding the evolution of stone and bone tool technology appear to have become established in the literature and thus in the minds of many scholars. It is widely accepted, for example, that the development of technology was a gradual process that proceeded in parallel with biological evolution and that the early use of bone tools was essentially immediate, involving only a short series of single-stage operations, and thus a low degree of conceptualization. It is also thought that bone tools shaped by knapping simply reflect the transfer of the percussion flaking technique from stone to bone and that early humans were incapable of developing sophisticated techniques specifically conceived for bone. Multidisciplinary research in the fields of archaeology, primatology, paleoanthropology, ethnography, genetics, and radiometric dating indicates a different scenario. The Paleolithic record of bone and stone tools shows that hominin technological evolution advanced in a nonlinear manner and that from the outset bone tools exhibit signs of innovation, manifest as implements intentionally modified through knapping and grinding. Current findings are at odds with the idea that hominins of the genus *Homo* were the only modifiers of early bone tools and do not support the hypothesis that the manufacture of formal bone tools is the exclusive domain of behaviorally modern humans. The identification of a discontinuous pattern, with innovations appearing and disappearing, or being associated in a way that does not match the expected trend, supports the view that bone and complex lithic technology do not necessarily represent reliable hallmarks of "modern behavior" and cannot be attributed an unequivocal evolutionary significance. A paucity of sites that have been excavated or dated using modern standards makes it difficult to establish whether the apparent disappearance of cultural innovations, particularly when these are embodied in small, fragile items, is due to sampling, excavation methods, destructive taphonomic processes, variability in subsistence strategies, or a loss of previously acquired cultural traits. In order to explain the discontinuous pattern in hominin technological evolution and the trans-species phenomenon of bone tool utilization in prehistory, we need to evoke social, demographic, and climatic factors, and their potential impact on similar innovations among geographically dispersed populations in Africa and Eurasia.

Future Directions

There is a cogent need to promote collaborative interdisciplinary research, bringing together specialists from different research traditions to analyze material and find the most suitable ways forward. We need to combine technological and morphometric attributes of bone tools to evaluate differences between sites and periods and identify regional clines and diachronic evolutionary trends. Finally, a georeference database of bone tool distribution across regions in which there are abundant sites with bone tool industries would assist in addressing the link between cultural and environmental change.

Cross-References

▶ African Stone Age
▶ Archaic *Homo sapiens*
▶ Australopithecines
▶ Blombos Cave: The Middle Stone Age Levels
▶ Dart, Raymond Arthur

- ▶ Europe: Middle to Upper Paleolithic Transition
- ▶ Handaxes and Biface Technology
- ▶ *Homo habilis*
- ▶ *Homo heidelbergensis*
- ▶ *Homo neanderthalensis*
- ▶ Hunter-Gatherers, Archaeology of
- ▶ Neanderthals and their Contemporaries
- ▶ Oldowan Industrial Complex
- ▶ Olduvai Gorge Archaeological Site
- ▶ *Paranthropus*
- ▶ Southern and East African Middle Stone Age: Geography and Culture

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Bone, Trauma in

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Introduction

Forensic anthropology is playing an ever increasing role in medicolegal death investigations. Beyond osteological analysis in a laboratory setting, forensic anthropologists work with law enforcement agencies to search for clandestine graves, assist at crime scenes in the recovery of human remains and associated evidence, assist medical examiners with trauma analysis in relatively recent cases, and conduct research, casework, and educational programs through academic settings. At the core of medicolegal death investigations are questions about cause and manner of death which may determine whether or not a crime was committed. Bioarchaeologists may apply a similar protocol of osteological methods to historic and archaeological populations for individual or population level trauma analysis. For forensic anthropologists who apply these methods to homicide investigations, the role is increasingly demanding as they are called to testify in court about human identification, interpretations about inflicted trauma, and the time since death.

Deaths resulting from traumatic injuries are better contextualized through the study of skeletal trauma. On an individual level, ante- and perimortem injuries provide details about a person's life and death, and healed trauma reflects injuries or events that occurred throughout a person's life while those occurring in association with the death event may indicate the manner of death. Across a population, the prevalence of trauma provides information about activities, mobility, warfare, and the general health of a population. Several comprehensive literature reviews and original studies are included in Grauer (1995), Larson (1997), Roberts and Manchester (2005), and Buikstra and Beck (2006).

The population approach has been more widely used in bioarchaeological research involving analysis of historic or archaeological populations. However, a population approach to documenting trauma is critical to war crime and genocide investigations in which establishing the scale and widespread pattern of injuries prove the occurrence of unlawful mass atrocities (Kimmerle & Baraybar 2008). Consequently, the analysis of trauma in bone has many applications for anthropological research today.

Historical Background

Skeletal trauma has been used to document injuries that occurred during a person's life (antemortem trauma) as it may be useful in human identification when antemortem records are available for comparison or show patterns of activity (Fig. 1). In traditional approaches, the process of documenting skeletal trauma has been largely descriptive and focused on fracture classification (Ortner & Putschar 1981; Mann & Murphy 1990; Buikstra & Ubelaker 1994; Galloway 1999). Increasingly, contextual information is incorporated into an interpretation of which injuries occurred and to some extent, the circumstances surrounding the event. Contextual

Bone, Trauma in, Fig. 1 Close-up view of left face showing healed, antemortem fractures to the nasal bones and maxilla

information may include burial factors at the crime scene, clothing, associated artifacts, radiography and other scanning technologies, bone density, and histology (Brogdon et al. 2003; Kimmerle & Baraybar 2008; Komar & Buikstra 2008).

Key Issues

Terms and Concepts

Skeletal trauma is typically described by the mechanism of force: sharp, blunt, sharp-blunt, or projectile trauma (Table 1). Injuries resulting from gunfire (GSW) are categorically placed with blunt trauma as they produce a crushing force to the bone. However, for practical purposes, GSW injuries are often uniquely categorized. Likewise, projectile trauma may include gunfire or explosives. Injuries resulting from explosive or blasting forces result from blunt trauma, projectile trauma, pressure changes, and burning. Increasingly, modern investigations into crimes occurring during conflicts include many examples of explosive injuries such as those resulting from the shelling of civilian populations, mortars, grenades, or other acts involving explosive devices. Since these types of injuries result from

Bone, Trauma in, Table 1 Mechanisms of skeletal trauma

Category	Mechanism of force	Examples
Blunt trauma	Crushing, bending, twisting	Hammer, bat, club, crowbar, fist or foot (stomping)
Sharp trauma	Cutting, stabbing, puncturing	Knife or blade, saw
Blunt-sharp trauma	Crushing, cutting, hacking	Machete, axe, hatchet
Blasting trauma	Crushing, projectile, burning	Explosive ordinances, mortars, grenades, pipe bombs
Gunfire trauma	Crushing, projectile	Handgun, rifle, shotgun, submachine or machine gun

several mechanisms (i.e., projectile and blunt trauma), they are also often described in a unique category.

The timing of fractures or injuries is critical to correctly interpreting the circumstances surrounding the incident (Table 2). Trauma occurring at the time of death and in association with the death event is called perimortem trauma. Differentiating perimortem "injuries," "fractures," "defects," or "trauma" from postmortem "damage," "breakage," or "scavenging" is often highly scrutinized in court when one party wants to cast doubt on the timing of the injuries or the opinionated cause of death (Fig. 2).

The use of the terms "ante-" and "perimortem" trauma can also be confusing at times, since the pathologists occasionally combine "ante- and perimortem trauma" into one category of "antemortem." The difference is the presence of tissue reaction to the injured area, be it inflammation or repair, which does not have time to develop in the perimortem period. Usually, such determination can be based on microscopic rather than gross examination. An anthropologist, relying on skeletal evidence, also attempts to differentiate trauma that occurred while a person was living (antemortem) from that which is associated with the death event (perimortem). This can be based on evidence of healing or patterns of the injury and its survivability. However, the window of

Bone, Trauma in, Table 2 Timing of fractures

Category	Morphological characteristics of fractures and/or defects
Antemortem (injury occurred prior to death and is NOT associated with the death event)	Fractures show signs of healing, i.e., porosity, new bone growth, callus formation, or infectious lesions
Perimortem (injury occurred at or around the time of death and IS associated with the death event)	Fractured margins are sharp and even. Bone may bend inward or away from direction of force. Radiating fractures from point of impact may be present
Postmortem	Damage to bone may include breakage, weathering, and erosion due to soils and water, or animal scavenging. Damaged margins tend to be uneven and rough in texture without evidence of radiating fractures. Bone elasticity is diminished and fractures are not consistent with "bending" quality of living tissue

Bone, Trauma in, Fig. 2 Postmortem breakage – an artifact of taphonomic processes, not inflicted trauma (Modified from Kimmerle & Baraybar 2008)

timing would be typically wider than the one based on microscopic evaluation of inflammatory reaction, which has sequential pattern. Examination of skeletal remains usually would not inform directly about the mechanism of death, for example, hypovolemic/hemorrhagic shock and suffocation; however, it may be often reasonably inferred, and on occasion, microscopic findings at the injury site may be helpful.

In the course of homicide investigations, differentiating perimortem trauma from postmortem artifacts is important for determining the cause of death and other mitigating factors such as the intent to kill vs. wound or the atrociousness of the crime. In human rights investigations, such as those associated with modern conflicts, patterns of injuries may be indicative of specific crimes that are committed and differences are often observed among civilian causalities vs. genocide victims (Meddings 1997; Coupland & Meddings 1999; Michael et al. 1999). Due to protective clothing and the nature of modern combat, fewer casualties sustain gunfire injuries to the thorax. However, a group of casualties exhibiting multiple gunfire injuries to the thorax, shot back to front, are more likely civilians or executed soldiers rather than soldiers who were lawfully killed on the battlefield.

The protocol and methods used to identify, document, analyze, and present trauma are applied to both past (i.e., bioarchaeological) and current populations (i.e., forensic cases or war crime investigations) (see Table 3). However, the context, location, culture, and timing of the incident must be taken into account when approximating a specific weapon or the general circumstances around the mechanism of the injury. For example, a semi-patterned defect on a skull may be the result of blunt trauma. Determining the specific weapon used and context of events that occurred will depend on whether the skull relates to a recent homicide victim or, for example, a Roman soldier from the third century. Understanding the context and accounting for a number of variables about the individual and population are important for creating the most accurate and comprehensive interpretation of events. Therefore, part of the protocol for interpreting skeletal trauma should include a range of factors as discussed in Table 4.

Bone, Trauma in, Table 3 Protocol for trauma analysis

Specific anatomical location
• Describe the bone, side, and aspect of each area affected
• Where necessary and/or possible, reconstruct bony fragments. Establish the number of injuries which may consist of one or more bone fractures/defects
Type of fracture and/or defect
• Simple or comminuted/complex
• Complete, incomplete, partial
• Linear, radiating, concentric
• Fracture line or defect: describe morphology, size, and location
• Mechanism of force such as crushing, compression, or twisting/spiral
Number of injuries
• This may be fewer than the number of fractures if one injury caused multiple bones to fracture
Sequence of multiple injuries
• To sequence multiple bone injuries, assess where the factures or evidence of injuries overlap one another
Direction and speed or “velocity” of force
• Use only very general or broad descriptions and avoid commenting on “velocity” in cases of GSW. The range of ammunition and types of weapons do not conform to allow a standard use of these terms
• Location of injuries should include bone, side, region, and aspect
• Direction of force should be broadly descriptive, i.e., “left to right” or “up to down”
Timing of injury
• Morphological characteristics of fracture margins (ante- or perimortem)
• Histological analysis of fracture margins for timing of injury
• Report any postmortem damage if present and differentiate from traumatic injuries
Documentation methods
• Draw, sketch, and photograph bones
• Document injuries both prior to and following cleaning, washing, or processing
• Radiograph bones and clothing
• 3D imaging through laser or CT scanning
• Microscopy of fractured edges, particularly useful for cut marks and sharp trauma
• Histology of fractured edges may assist with timing of injury (i.e., ante- vs. perimortem)

Interpreting skeletal trauma by direct examination of the skeletal remains reveals evidence that soft tissues or radiographs alone cannot always demonstrate. In some cases, the number of skeletal fractures is greater than the number of soft tissue injuries evidenced by an external examination of the body. In contrast, inflicted trauma resulting in death may consist of soft

Bone, Trauma in, Table 4 Epidemiological approach to interpreting skeletal trauma

Demography (i.e., age, sex, ancestry of decedent)
Context (i.e., facts about the scene, modes of deposition, witness statements, crime scene forensic evidence such as blood patterns)
Location of death (i.e., public place or private residence)
Burial factors (i.e., primary or secondary crime scene/ burial location, buried or surface remains, use of containers for concealment)
Intent
Scientific protocols
Methods for differential diagnosis
Weaponry and ballistics science
Cause, manner, and mechanisms of death

tissue injuries without the presence of skeletal fractures or defects. There is a misperception that without soft tissues, investigators are limited in their ability to reach definitive conclusions about the cause or manner of death. Even in cases where the specific cause of death is unknown (whether due to decomposition, the mechanism of injury or incomplete recovery), the manner of death may be homicide as evidenced by the circumstances of the death. In such cases, the context and other investigative facts combined with skeletal trauma enable a ruling such as "*homicide due to unspecified traumatic causes, homicidal violence*, or *battered baby/child syndrome*."

The morphology of skeletal trauma is shaped by internal (i.e., the particular area of bone affected), extrinsic (i.e., the type of weapon), and other factors (i.e., whether or not it resulted from act of volition). By reconstructing the bony fragments, information may be gained about the type of weapon, the number, and in some cases, the sequence of injuries. The critical first step is to differentiate perimortem trauma from postmortem or taphonomic artifacts. In other words, fractures that result at the time of death and may have contributed to the death have to be differentiated from animal scavenging, warping due to ground pressure for buried remains, surface weathering, or excavation damage (Fig. 2).

Documentation of Skeletal Trauma

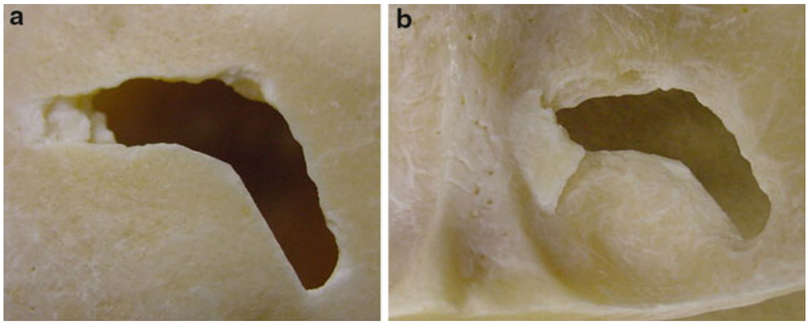
The documentation of injuries should include a description of the specific bone/side/aspect affected and the particular features present such as the type of fracture or defect, its size, and extent. Skeletal trauma may consist of a fracture, dislocation, subluxation, or defect. Fractures may be classified as simple and complete, partial/incomplete or "greenstick," comminuted, spiral, compression, depressed, hinge, or buckle. A number of references define and outline characteristics for each type of fracture, as well as the common eponymous fractures referred to in pathology (refer to Ortner & Putschar 1981; Mann & Murphy 1990; Buikstra & Ubelaker 1994; Galloway 1999; Kimmerle & Baraybar 2008; Waldron 2009).

Mechanisms of Injury

Once skeletal injuries are delineated, the morphology of wounds, defects, and fractures provides information on the mechanism of injury (Kimmerle & Baraybar 2008). The common mechanisms and general characteristics for each category are summarized below:

- Blunt Trauma
  - Characterized by an object that crushes tissue. Skeletal tissue bends and may have a depressed or bent appearance. If enough force is applied, the tissue will fracture.
  - An object may strike the individual or the individual may be expelled toward an object (i.e., a person's head hits the dashboard of a car during a motor vehicle accident).
  - Gunfire injuries and shrapnel or explosive injuries are forms of blunt trauma, but generally are categorized separately due to the amount of force and other characteristics also involved with these mechanisms such as burning and the presence of shrapnel.
  - Examples of objects resulting in blunt trauma include a fist, baseball bat, hammer, and floor (Figs. 3–5).
- Sharp Trauma
  - A penetrating object that cuts tissues and bone.
  - May be associated with blunt trauma, particularly with hacking types of weapons

Bone, Trauma in, Fig. 3 Patterned cranial defect resulting from blunt impact. The ectocranial (*A*) and endocranial (*B*) views are demonstrated (Modified from Kimmerle & Baraybar 2008)



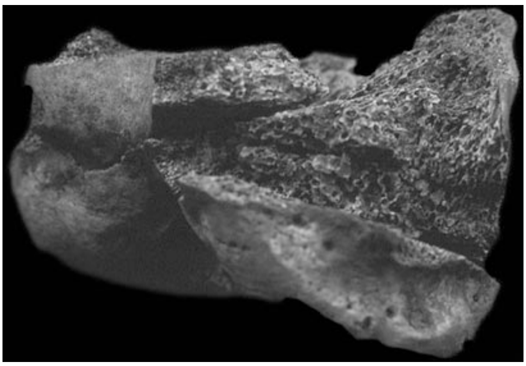
Bone, Trauma in, Fig. 4 Patterned cranial defect with concentric and depressed fractures, resulting from blunt impact from a long, linear object (Modified from Kimmerle & Baraybar 2008)

such as machetes or axes. Hacking trauma is often classified as sharp-blunt trauma due to the amount and nature of the force applied as well as the characteristics of hacking instruments.

– Sharp trauma includes different types of wounds: stabbing, incised, and puncture.
– Stab and incised wounds to bone often result in cut marks, whereas puncture wounds may result in patterned defects depending on the instrument/weapon.
– Sharp trauma such as cut or saw marks resulting from postmortem dismemberment should be carefully delineated as such. While it may not be possible to determine whether the person was alive at the time of dismemberment if there is not clear evidence of the cause of death, it should be pointed out when sharp trauma is present in the form of dismemberment as opposed to incised or puncture wounds from cases of stabbing. The number, location, and type of sharp defects in the areas of major joints provide strong evidence of dismemberment.
– Many postmortem artifacts such as animal scavenging and surface cracking due to weathering may mimic sharp trauma.

Bone, Trauma in, Fig. 5 Multiple blunt impacts to the right side of the skull, toward the posterior aspect of the cranium. Multiple points of impact evident by the depressed and concentric fracture patterns (Modified from Kimmerle & Baraybar 2008)

Bone, Trauma in, Fig. 6 Anterior view of body of a cervical vertebra illustrating numerous linear cut marks, resulting from sharp trauma (Modified from Kimmerle & Baraybar 2008)



Bone, Trauma in, Fig. 7 The lateral aspect of the distal articular surface of the left femur with multiple depressed and cut areas of bone resulting from numerous injuries with a machete. The presence of crushed, bent, and cut bone is indicative of hacking trauma (Modified from Kimmerle & Baraybar 2008)

  – Examples include knife, axe, hatchet, machete, and glass (Figs. 6, 7).
- Gunfire
  – Injuries characterized by a handgun, rifle, shotgun, submachine, or machine gun (Figs. 8–12).
  – The class of weapon, general distance of shot (close vs. distant), number, and sequence of injuries may be determined from skeletal injuries.
  – Skeletal defects tend to be patterned and reflect the shape of the projectile. Therefore, bullets that hit bone perpendicular have a circular appearance with a diameter consistent with the size of the bullet. Projectiles that are irregularly shaped or hit the bone at an angle or tangentially will produce a sideways or irregular-shaped defect.
  – Bullets that penetrate the body may fracture more than one bone and/or change direction within the body or calvarium, sometimes referred to as "ricochet." The number of wounds needs to be delineated

Bone, Trauma in, Fig. 8 Gunshot entrance wound, resulting from a handgun. The small circular defect has two very small radiating fracture lines (*A*) and (*B*). The bullet did not exit the skull but extended to the left side and ricocheted leaving behind gunshot residue evident in the radiograph

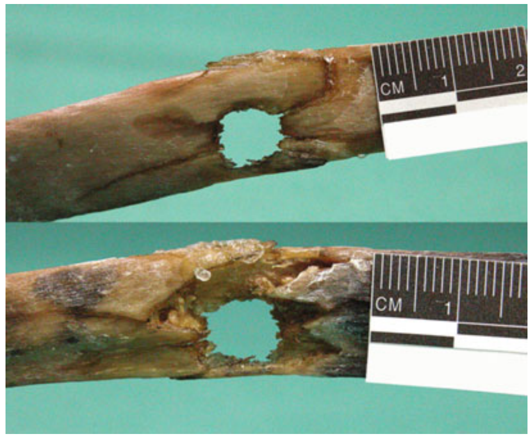
Bone, Trauma in, Fig. 9 Gunshot entrance wound resulting from an AK47. Note the larger diameter of the defect featured in Fig. 8 and the presence of radiating fractures (Modified from Kimmerle & Baraybar 2008)

Bone, Trauma in, Fig. 10 Gunshot exit wound. Note its irregular shape and the external beveling along defect margins (Modified from Kimmerle & Baraybar 2008)

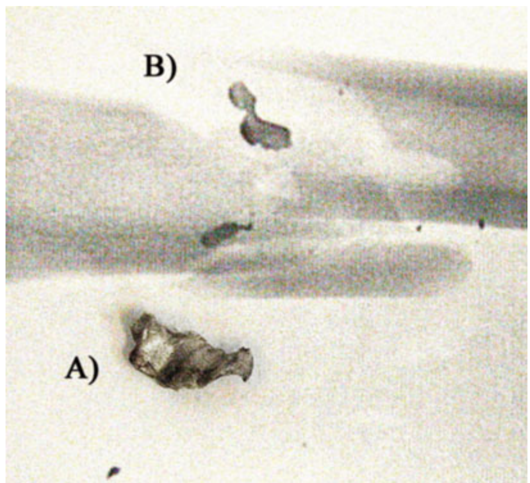
Bone, Trauma in, Fig. 11 Gunshot exit wound. Note the external beveling along defect margins and extensive fracturing (Modified from Kimmerle & Baraybar 2008)

from the number of injuries as one bullet may cause several wounds.

- Blast Injuries
  - Creates thermal, blunt, sharp, and penetrating trauma (Fig. 13).
  - Shrapnel creates irregular-shaped penetrating defects in skeletal tissue and may become embedded in bone.
  - Skeletal defects and fracture morphology are largely affected by extrinsic factors such as the type and amount of explosive, location of the incident (i.e., in an enclosed space vs. outdoors), and the type of surrounding materials which may become projected shrapnel.



Bone, Trauma in, Fig. 12 Gunshot wound, through and through to rib showing entrance and exit sides of the bone with radiating fractures and beveling (Modified from Kimmerle & Baraybar 2008)



Bone, Trauma in, Fig. 13 Shrapnel recovered from thigh region following mortar attack. The metal fragment (*A*) is shown next to the radiograph which depicts the fragment embedded in the bone (*B*)

- Burning Injuries
  - Causes discoloration, fractures, bone shrinkage, and dismemberment.
  - Trauma inflicted prior to burning is still evident even after severe burning.
  - Burning may result from the incident at time of death, such as an automobile accident or explosion. Burning may also be used postmortem in an attempt to hide or destroy evidence.

- Evidence of Chronic Abuse, Neglect, or Torture
  – Skeletal evidence of prolonged abuse or torture has been used in domestic cases involving children and the elderly and in international courts involving political detainees or prisoners of war.
  – Evidence of chronic abuse includes multiple fractures in various stages of healing, nutritional deficiencies, malnutrition or starvation, untreated medical conditions, or insufficient health and dental care.

Uncovering Abuse When the Baby "Falls"

Six cases of child deaths from Lincoln, Nebraska, resulting from blunt trauma are compared to illustrate patterns of intentional vs. accidental trauma. Five of the six cases involved female victims, ranging in age from several months to 3 years. Of these cases, five were homicides and one was an accident. Among the homicides, three parents reported that the infant "fell" accidentally upon seeking medical treatment for their children. Victims in all cases had multiple blunt injuries throughout the body: head trauma (5/5), neck (2/5), chest (2/5), abdomen and back (1/5), and extremities (4/5). In all cases, brain trauma was present, though only one case exhibited cranial fractures. Further, in only two cases was evidence of prior neglect or abuse present. In all cases, medical intervention was sought. Survival time ranged from 27 min to 4 days. The amount of activity among victims immediately following the injury ranged from immediate incapacitation to full activity/movement and alertness. The infant who survived the longest had shown the most amount of activity following the injury but went into cardiac arrest three days after the incident. In only one case were there no signs of trauma visible externally.

The only male victim (10 months old) suffered the greatest amount of injuries with multiple traumas to each region of the body. He further suffered a 5.2-cm cranial fracture and two fractures to the seventh and eighth ribs that were in the process of healing, thereby showing evidence of a prior incidence of abuse. Three soft tissue injuries were evident on the face and back of the head. In this case, the infant had soft tissue injuries evident on the abdomen and back with associated organ damage in the abdomen. It was alleged that the infant "fell" from the arms of his mother's boyfriend. In a second case, the infant reportedly "fell" in the bathtub yet was found to have soft tissue injuries on the head, face, buttocks, and hand, including human bite marks. This infant also had a 25-g subdural hematoma (pooling of the blood in the space between the dura and meninges or outer and middle layers of the brain covering) but no skeletal fractures.

It is common in cases of child abuse that the parent or caregiver tells authorities that the child fell or had an accident, even while seeking medical treatment for inflicted trauma (Kimmerle & Chrowstowski 2011). Therefore, it is incumbent upon investigators, medical examiners, and forensic anthropologists working on such cases to present clear evidence that will either support or refute such claims. Investigators had such a case when a 10-month-old male infant was taken to the emergency room by his father. It was alleged that the infant fell from the father's arms and hit his head on the floor. The infant sustained multiple injuries on the head, neck, chest, abdomen, and back, including multiple brain injuries. Postcranial fractures were present but no skull fractures were present. In this example, investigators had all lines of possible evidence open for interpretation. Since medical intervention was sought, there was abundant documentation about the injuries at the time of autopsy. However, this is not always the case, when the remains of abused children are hidden or buried. In such cases, it may be years before the remains are uncovered and the incidence is investigated. When this occurs, it may be that skeletal trauma is the only physical evidence present to support or refute allegations of abuse.

The injury occurred at 7:00 am and the infant died at 3:30 pm, having survived 8½ h with medical intervention. Immediately following the injury, the infant was incapacitated and never exhibited any sign of physical activity. The postmortem examination revealed healing fractures from prior injuries. In Table 5, the epidemiological factors for three cases are presented, the case study discussed here and two comparative examples

Bone, Trauma in, Table 5 Differential case factors for accidental versus inflicted trauma in comparative baby death cases

Factors	Case I	Case II	Case III
Manner	Homicide	Homicide	Accident
Circumstances	Reportedly fell from arms of caretaker	Reportedly fell in bathtub	Fell downstairs
Demography	10-month-old male	3-year-old female	1-year-old female
Injury location	Head, neck, chest, abdomen, back, extremities	Head, extremities	Head, extremities
Survival time	8.5 h	46.9 h	78 h
Amount activity	Immediately incapacitated	Immediately incapacitated	Unknown
Skeletal fractures	Skeletal fractures	No fractures	No fractures
Prior evidence of abuse	Fractures in various stages of healing	None	None

which illustrate some of the epidemiological variants present. All three cases represent infants, ages 10 months to 3 years, who either died as a result of a fall or were reported to have "fallen." In a comparative case (Case 2), the death was reported to have resulted from injuries the 3-year-old child received after falling in the bathtub. Further investigation of witness statements and an autopsy revealed in fact this was a case of abuse and it was ruled a homicide. In contrast, Case 3 consists of a 1-year-old female who fell and died of her injuries several days later. There was no history or indication of abuse, and the manner of death was ruled an accident. In all three cases, the children died of blunt trauma and all three sustained brain trauma, though only one case exhibited skeletal fractures (Case 1).

Establishing Cause and Manner of Death

The skeletal remains of a 20–30-year-old male along with clothing, a shotgun, pellets, and a shell casing were recovered in a remote, wooded area along a roadside during the winter months (Fig. 14). The bones of the face, cranial vault,

Bone, Trauma in, Fig. 14 Fragmented bone remains with clothing recovered from outdoor crime scene in snow

Bone, Trauma in, Fig. 15 Fragmented cranial vault (left lateral view) following near contact shotgun wound to the mouth. Note the scalloped edges along the inferior fractured margins

and mandible were fractured (Fig. 15). The fracture patterns and scalloped edges along the fractured margins of the left temporal, frontal, and occipital bones were indicative of a shotgun injury. Further, the fractured edges and semicircular defects were the same color and texture as the rest of the bone and were consistent in appearance and morphology of perimortem injuries.

The maxilla was completely fractured along the palatine suture and bilaterally in the transverse plane inferior to the zygomatic processes (Fig. 16). The palate exhibited an irregular-shaped defect (Fig. 17). The mandible was

Bone, Trauma in, Fig. 16 Maxilla and mandible of shotgun case. Pellets entered through the open mouth

Bone, Trauma in, Fig. 17 Fractured palate showing shotgun entrance wound

Bone, Trauma in, Fig. 18 Left mandible showing fractured condyle and ramus following shotgun wound to the mouth

bilaterally fractured in between the mandibular body and ascending rami. The left coronoid process was also completely fractured from the ascending ramus of the mandible (Fig. 18). The specific fracture patterns and defects present in this example demonstrate the causative agent while the manner of death is determined based on associated evidence and the police investigation. In this case, there was a single shotgun wound in the face and cranium, from front to back. While the mechanism of death may not be known without the presence of soft tissues, the cause of death is inferred from the shotgun wound to the head. Based on circumstantial information, the manner was ruled a suicide.

International Perspectives

Illegal detainments, torture, and extrajudicial executions are some of the most common forms of human rights violations throughout the world. They can also be some of the most challenging cases to prove as victims tend to “disappear” and cases may not be investigated until many years after the fact. International and local investigations for the prosecution of torture, war crimes, and genocide rely heavily on forensic anthropological and pathological evidence of perimortem injuries for these same reasons (i.e., examples tried by the International Criminal Tribunal for the Former Yugoslavia (ICTY): *The Prosecutor v. Rutaganda (ICTR-96-3), The Prosecutor v. Krstić (IT-98-33)*, and *The Prosecutor v. Brdjanin and Zupljanin (IT-99-36)*). For example, in the case of the *Prosecutor v. Limaj* et al. *(IT-03-66), Milutinovic* et al. *(IT-05-87), Popovic* et al. *(IT-05-88)*, skeletal evidence of torture was critical at trial. Numerous factures throughout the ribs and limbs exhibited bone remodeling in various stages of healing dating from weeks to months, thereby demonstrating evidence of repeated beatings (blunt trauma) during the period of detainment (Kimmerle & Baraybar 2008). Additional injuries in the form of skeletal defects resulting from gunshot wounds to the head and body showed no evidence of healing and were classified as perimortem trauma, proving the cause and manner of death was homicide due to multiple gunfire injuries. In this example, skeletal injuries provided evidence that several crimes were committed including torture and homicide.

Collectively, the body of research into skeletal evidence used to document torture is limited. A review of extrajudicial executions from various published reports and publications from Central and South America and the Balkans were discussed in Kimmerle and Baraybar (2008) representing a collective sample of 45 cases. In all of these examples, the mechanism of death was attributed to blunt trauma (BFT), sharp-blunt trauma (i.e., machete), or gunfire injuries (GSW) associated with some form of BFT resulting primarily from beatings prior to death. The type and location of skeletal fractures are documented, including evidence of antemortem fractures that were in various stages of healing at the time of death. In most cases, individuals were detained prior to death and the history of abuse reflects torture as documented by the associated medicolegal death investigations. Among the cases reviewed from the literature, BFT was the most common mechanism of injury (77.7 %), followed by gunshot wounds (66.6 %), and sharp-blunt trauma (24.4 %). The overall distribution of fractures illustrates that the thorax is most commonly affected (64.4 %), followed by the skull (35.5 %), arms and legs (2.0 %), and lower back (0.04 %). Several other interesting patterns were noted:

- All cases of documented torture involved males, aged 14–68 years.
- These cases typically represented enforced detainment, repeated beatings, and finally murder.
- All cases with fatal gunshot wounds also had blunt trauma from assault to the ribs and sternum, indicating beatings prior to death.
- Almost 78.0 % of cases of extrajudicial execution involved BFT to the chest, indicating beatings prior to death.
- In four of these cases, individuals also had previous fractures in various stages of healing – further indicating torture during their detainment prior to the fatal attack.

Evidence of sharp-blunt trauma was present in 11 cases involving machetes. Interestingly, among these cases, the arms and legs were also injured in addition to the thorax. “Defensive wounds” on the forearms and hands were present in 81.8 % (9/11) of cases. Only 35.5 % of cases involved the skull, but among these, gunshot injuries were also present in addition to blunt force injuries. It is important to note that the context is critical when trying to summarize trends such as these. In cases involving machetes, gunshot wounds were typically not present. Therefore, if one considers only cases with blunt force or gunfire injuries, the overwhelming majority of extrajudicial executions (88.2 %) include both mechanisms of injury.

Population level analyses of trauma may also provide evidence of the particular type of crimes committed and will be critical in attempting to prove cases of genocide and war crimes. Specifically, injuries that are widespread demonstrate patterns of abuse or maltreatment, such as the ubiquitous machete trauma present in the 1994 Rwandan genocide which provides evidence of the intent to kill civilians outside the context of lawful warfare.

Future Directions

Today, methods used in forensic anthropology and bioarchaeology document physical evidence of the patterns of crimes committed and increasingly provide critical evidence at trial. There is need for further research in the areas of skeletal trauma, histological timing of fractures from degraded bone, and the ways in which paleopathology and population studies can be used for analyses of modern populations. Increased research and education with specific regard to international applications will further help improve best practice standards and expand the role of forensic anthropology in criminal investigations.

Cross-References

- ▶ Burned Remains in Forensic Contexts
- ▶ Commingled Remains: Field Recovery and Laboratory Analysis
- ▶ Dental Anthropology
- ▶ DNA and Skeletal Analysis in Bioarchaeology and Human Osteology
- ▶ Forensic Anthropology: Definition
- ▶ Human Remains Recovery: Archaeological and Forensic Perspectives
- ▶ Osteology: Definition
- ▶ Pathological Conditions and Anomalies in Forensic Contexts
- ▶ Taphonomy in Bioarchaeology and Human Osteology
- ▶ Time Since Death in Bioarchaeology and Human Osteology

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Bone: Chemical Analysis

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Introduction

The general structure and chemical composition of bone are similar for all individuals, but there is some tolerance for variation in the elemental and isotopic composition of both the organic and inorganic components of bone tissue. This variation is tied to the local environment and to diet. Both trace elements and stable isotopes act as natural tracers that provide information to archaeologists about details of the lives of past people, including diet, place of residence, and migration. Following early attempts to use chemical variation in bone for information about the past, several doctoral dissertations in the areas of trace element analysis and stable isotope analysis of archaeological human bone appeared in the 1970s and early 1980s. Much of this research is presented in an edited volume by Price (1989) which resulted from the first Advanced Seminar on Paleodiet. Subsequent research has grown exponentially with a much greater emphasis on stable isotope analysis due to concerns about chemical exchange between soil and bone which may alter trace element contents in the burial environment.

Definition

Bones are the skeletal elements that provide structural support for the vertebrate body. Bone tissue has both organic (approximately 30 %) and inorganic (approximately 70 %) components. The organic component is predominantly collagen (90 %), a structural protein, and a small amount of other proteins, collectively referred to as non-collagenous proteins. The inorganic component of bone is made up of hydroxylapatite, a calcium phosphate mineral $[Ca_{10}(PO_4)_6(OH)_2]$. The chemical analysis of the organic component of bone most often refers to the study of stable isotopes of elements included in the collagen, such as carbon, nitrogen, and sulfur. The chemical analysis of the inorganic component of bone refers to the analysis of trace element substitutions in hydroxylapatite, and stable isotopes of carbon and oxygen in the carbonate (CO_3), that substitutes in minor quantities for phosphate (PO_4), an additional source of oxygen. Most trace elements substitute for calcium and, as such, are chemically similar to calcium (other alkaline earth elements, and lead). Some trace elements, such as strontium and lead, may be measured for overall quantity (elemental analysis) and for stable isotope variation.

Stable isotopes are variant forms of an element with the same number of protons and electrons but varying numbers of neutrons. Unlike radioisotopes, stable isotopes do not decay, so their quantity in a substance does not change over time. For most elements, one isotopic form predominates with very minor quantities of other isotopes. For example, 99 % of all carbon occurs as ^{12}C with 1 % ^{13}C. Nitrogen occurs as ^{14}N (99.6 %) and ^{15}N (0.4 %) while there are four stable isotopes of sulfur (Fry 2006). Stable isotope ratios for carbon, nitrogen, oxygen, and sulfur are usually expressed using delta terminology as follows:

$$\delta\ ‰ = \frac{R_{(sample)} - R_{(standard)}}{R_{(standard)}} \times 1000$$

where R = the ratio of the number of heavier to lighter isotopes.

Due to the difference in the number of neutrons, the isotopes of an element have different atomic weights and, therefore, react slightly differently in chemical reactions including those associated with physiological functions. This results in changes in the ratio of the heavier and lighter stable isotopes from one step to another in biochemical processes such as photosynthesis, digestion, and tissue formation. Details on stable isotope terminology, measurement, and standards can be found in textbooks by Fry (2006) and Hoefs (1997).

Carbon is found in both the organic and inorganic components of bone. In hydroxylapatite, carbonate substitutes for phosphate in minor quantities (approximately 5 %). Oxygen isotopes may be measured from carbonate or phosphate.

Trace elements are chemical elements that occur in minor quantities in a substance. Prior to the development of more sensitive analytical equipment, trace elements were defined as those present in quantities too small to be measured. With more sensitive instruments, trace elements can be measured and are normally present in parts per million (ppm) or parts per billion (ppb). In bone, trace elements from group two of the periodic table often substitute for Ca in hydroxylapatite. Such elements include magnesium (Mg), strontium (Sr), and barium (Ba).

Instrumentation

Stable isotopes of lighter elements, such as carbon, oxygen, hydrogen, nitrogen, and sulfur, are analyzed on a light isotope mass spectrometer (Katzenberg 2008). Heavier elements such as strontium are analyzed on a solid source mass spectrometer. Trace elements may be analyzed on a range of instruments, including atomic absorption spectroscopy, inductively coupled plasma emission spectroscopy, and neutron activation (Burton 2008).

Key Issues

Diet

Early studies on both trace element and stable isotope analysis focused on determining diet and dietary change over time. The trace element strontium was known to vary between plants and animals given constant background levels, based on studies in health physics (reviewed by Burton 2008). Researchers interested in the relative contributions of plant and animal foods in the diet attempted to analyze strontium as well as strontium/calcium ratios in prehistoric human skeletal remains to chart dietary change. Burton and Wright (1995) demonstrated that the relationship between strontium in bone and dietary input is not linear. Trace elements are also subject to exchange in the burial environment and are no longer the method of choice for paleodiet studies. Burton (2008) provides a detailed overview of trace element research on bone.

Stable carbon isotopes were first studied by archaeologists interested in the introduction of maize in the diets of people in the Americas. Maize consumption is evident in bone collagen since maize is a C_4 plant and therefore contains more ^{13}C relative to ^{12}C in comparison to C_3 plants. Economically important plants which use the C_4 mode of photosynthesis include maize, millet, sorghum, and sugar cane. These plants are adapted to hot and dry conditions. Most plant species growing in moist conditions follow the C_3 mode of photosynthesis and contain relatively less ^{13}C to ^{12}C. The difference in the stable carbon isotope ratio ($\delta^{13}C$) in these plant types is passed along to consumers. This was first demonstrated in the 1970s by Vogel and van der Merwe (1977) with numerous applications subsequently (see reviews by van der Merwe 1982; Katzenberg 2008). Plants obtain carbon from atmospheric carbon dioxide (CO_2). Organisms from the ocean obtain their carbon from dissolved carbonate in seawater, which is enriched in ^{13}C in comparison to atmospheric CO_2 and therefore, $\delta^{13}C$ values are higher in marine organisms and this difference is passed on to consumers. This was first demonstrated by Tauber in 1981 and Chisholm and colleagues in 1982 with subsequent applications by many scholars.

Stable isotopes of nitrogen have been used to explore trophic level differences in diet. There is enrichment of the heavier isotope (^{15}N) with each step in a food web (Minagawa & Wada 1984). In a terrestrial environment, leguminous plants generally have lower $\delta^{15}N$ values than nonleguminous plants. Animals feeding on plants will have $\delta^{15}N$ values approximately 3 ‰ higher than their food. Carnivorous animals will exhibit an additional 3 ‰ increase and omnivores will have values intermediate with respect to carnivores and herbivores. Unfortunately, this is not always the case as there are additional variables to consider. As is true for all stable isotope studies, the source of nitrogen determines the $\delta^{15}N$ values at the base of the food web. Fertilizers used to provide nitrogen to growing plants will have an impact on plant $\delta^{15}N$ values, which in turn, influences $\delta^{15}N$ values higher up the food web. For example, the use of manure will raise the $\delta^{15}N$ value of nitrogen available to plants. Because of such variables, it is important to analyze potential food items in addition to human skeletal remains when attempting a dietary reconstruction. In aquatic and marine systems, $\delta^{15}N$ values also increase with trophic levels but there are more steps in the food web, resulting in very high $\delta^{15}N$ values in aquatic and marine mammals and piscivorous fish. This makes it possible to use stable nitrogen isotopes to investigate the relative use of terrestrial and aquatic or terrestrial and marine foods in dietary reconstructions (e.g., Coltrain et al. 2004; Katzenberg et al. 2012).

Stable isotopes of oxygen have been used to study mobility in prehistoric societies. The tissue of choice for oxygen isotope analysis is tooth enamel (e.g., Buzon et al. 2011) but some studies have also been carried out on the phosphate in hydroxylapatite (e.g., White et al. 2007). Oxygen isotope ratios in human tissues reflect ingested water and oxygen isotopes in water vary due to latitude, altitude, and distance from the coast (Bowen et al. 2005).

Strontium isotopes have also been used in mobility studies as they reflect the underlying bedrock in a region. Derived through diet, strontium isotope studies must consider both the regional geology and the diet. Unlike the other isotopes discussed so far, strontium isotope studies do not use the delta notation. Instead, the ratio of $^{87}Sr/^{86}Sr$ is simply expressed as a number, usually to five significant decimal places depending on the precision of the analytical instrument (Bentley 2006). Strontium isotopes have been used to study migration in many regions of the world with increasing baseline data becoming available. Often, oxygen and strontium isotopes are both used to provide two perspectives for assessing mobility.

All bone chemistry studies are based on chemical tracers that are taken up during life. However, bone is a porous substance and researchers must always perform tests to determine whether chemical tracers have been altered in the burial environment. The chemical exchange that can occur after death is referred to as diagenesis. For studies of bone collagen, preservation is assessed from the percentage of carbon and nitrogen in the sample, and from the ratio of carbon to nitrogen (C/N) in the sample. Well-preserved collagen has a C/N ratio of 3.2. Some tolerance for variation is allowed, but most researchers reject samples if the C/N falls below 2.9 or exceeds 3.6 (Ambrose 1990). For bone mineral, it is more difficult to assess diagenesis (Burton 2008). Some researchers use infrared spectroscopy to evaluate the crystallinity of bone. Normally bone is poorly crystallized in comparison to hydroxylapatite in the earth, but with exchange in the burial environment, bone may become more crystallized and the relative amounts of calcium and phosphate may shift. Studies to detect diagenesis are ongoing.

Future Directions

Future directions of bone chemical research in archaeology involve increasing knowledge of other isotopic systems such as sulfur and hydrogen. Stable isotopes of sulfur are useful in detecting marine versus terrestrial foods in the diet, but sulfur is present in very low quantities in bone collagen. Increasingly sensitive analytical instruments have made it possible to analyze such isotopic systems in smaller quantities. Stable isotopes of hydrogen and oxygen have been used in wildlife studies for tracking movements, and the same types of studies can be done with humans (Bowen et al. 2005). Other improvements in analysis include the use of laser ablation to isolate small regions of a sample, such as parts of a tooth, to analyze seasonal variation in the diet (Sponheimer et al. 2006).

Cross-References

► Archaeological Chemistry: Definition
► Bone Chemistry and Ancient Diet
► Human Migration: Bioarchaeological Approaches
► Inductively Coupled Plasma-Mass Spectrometry (ICP-MS): Applications in Archaeology
► Isotopic Studies of Foragers' Diet: Environmental Archaeological Approaches

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Bone: Histological Analysis

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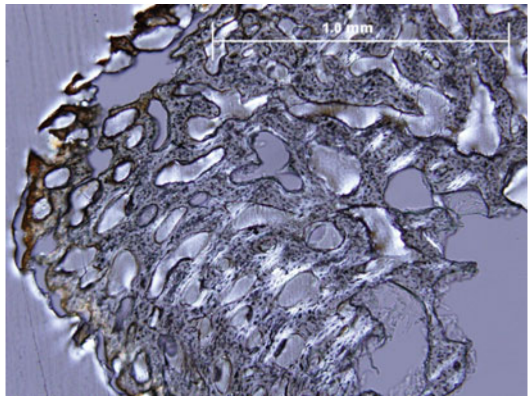
Introduction

The analysis of hard tissue (bone and tooth) can be approached on many levels, ranging from the macroscopic to the molecular level. Intermediate to this range is the tissue level or histological level of organization. By definition, *histology* means *the science of the tissues*. More specifically, *histological analysis* is the study of the microscopic anatomy of tissues in plants and animals. Thus, histological analysis requires specialized equipment to prepare tissues for analysis and to magnify structures, making them visible. There are two analytical approaches used in anthropology when studying microstructures. One, referred to as histomorphology, is the qualitative analysis of microstructure morphology and organization. The other, referred to as histomorphometry, is the quantitative study of the microscopic organization and structure of tissue. These analyses can be performed using a static or dynamic approach to studying tissue. Static histological analysis allows for the evaluation of a tissue at a particular point in time. For example, anthropologists typically study histological samples from deceased individuals, which would only provide an assessment of the tissue at the time of death. Dynamic histological analysis allows for the evaluation of bone over a period of time. In order to observe microstructural responses using this method, analysis is performed in vitro or in vivo and the subject is exposed to various labeling techniques for histological tracking of cells. Regardless of the approach, histological analysis is an essential tool in many disciplines outside of medicine and biology.

The histological analysis of hard tissue within the discipline of anthropology has been used to study historical human remains from archaeological sites, as well as to assist with modern forensic investigations. Through histomorphology and histomorphometry, anthropologists are able to develop techniques to distinguish human from nonhuman bone, estimate age at death, evaluate biomechanical load history, assess skeletal health, and categorize pathological conditions. To fully interpret the information gathered through these techniques one not only needs to appreciate the limitations of evaluation methods, but more importantly have an understanding of the biology underlying the creation of histomorphological structures and the intrinsic and extrinsic factors that affect bone (or tooth) microstructure.

Bone is a dynamic tissue, constantly changing over an organism's life and providing a record of structural, mechanical, and compositional changes that anthropologists study in order to interpret the biological information hidden within. Teeth, with their hard enamel, are the most likely remains of an organism to endure through time. While a wealth of information is stored within the histological structure of teeth, the following text will be limited to discussions regarding cortical bone histology. For further reading about dental histology and its use within anthropology, see Guatelli-Steinberg and Huffman (2011).

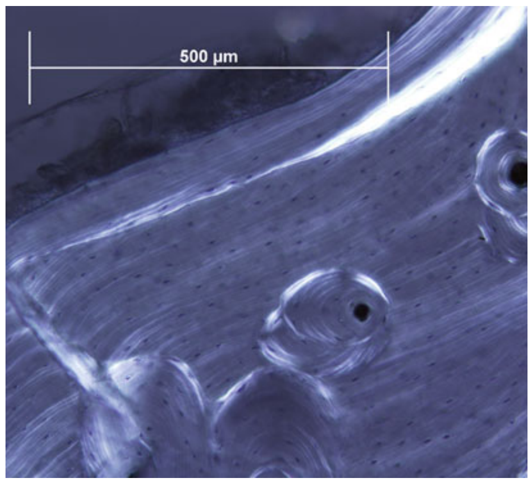


Bone: Histological Analysis, Fig. 1 Histologically, woven bone is characterized by wide spaces and poor organization. It is found in immature bone and at the sites of fracture repair or pathological conditions (Pig rib at 100× magnification)

Key Issues

Bone Biology and Cortical Bone Histomorphology

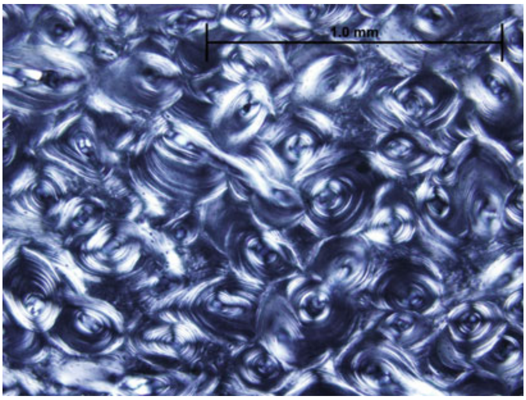
At the gross level, bone classifies as either cancellous (trabecular) or compact (cortical). Cancellous bone is porous, consisting of a network of thin spicules called trabeculae. Cortical bone is densely mineralized and relies on a vascular system to pass oxygen, nutrients, and waste in and out of bone. At the histological level, there are two basic bone types, woven and lamellar. Woven bone is laid down quickly; a structurally weak temporary construct of poorly organized collagen fibers and mineral crystals (Fig. 1). Lamellar bone takes longer to form but is stronger than woven bone due to its highly organized "plywood" arrangement of collagen bundles (Fig. 2). Embryonic skeletal development consists almost wholly of woven bone, which is slowly replaced by lamellar bone as an individual grows. As such, woven bone occurs rarely in the adult skeleton, except at sites of fracture healing and/or pathological conditions.



Bone: Histological Analysis, Fig. 2 Lamellar bone is characterized by organized, parallel bands of bone. The secondary osteons are signs of remodeling in these lamellae (Human rib at 200× magnification)

Mature compact bone is comprised of Haversian systems, which are characterized by uninterrupted, centripetally deposited lamellae surrounding a centrally located Haversian canal. The layers of concentric lamellae connect to each other via Volkman's canals, which are smaller and run at oblique angles to create a network for circulating blood and nutrients throughout the bone. Complete Haversian systems are bordered by a scalloped reversal line and are also known as secondary osteons (Fig. 3). Secondary osteons are a product of bone remodeling (bone turnover).

Two main processes directly shape bone, modeling and remodeling. In modeling, bone is



Bone: Histological Analysis, Fig. 3 Human Haversian bone showing secondary osteons (Human femur at 100× magnification)

removed in one location and added in another. Through periosteal and endosteal formation and resorption, bone modeling modifies bone size, shape, and relative orientation (Maggiano 2011). Bone remodeling, or internal bone turnover, is the process of continuous removal of older bone with the replacement of new bone throughout life. It occurs through the localized coupling of osteoclasts and osteoblasts forming an assembly of cells called the basic multicellular unit, or BMU (Frost 1969). Active BMUs follow a pattern of activation, resorption, and formation of bone known as the A-R-F sequence (Martin et al. 1998).

Unlike bone modeling, remodeling generally does not affect the overall size and shape of the bone. Bone remodeling is often described as having two functions: microscopic fracture repair and maintaining metabolic homeostasis of the bone matrix. Microscopic fracture repair is likely the primary function of bone remodeling, allowing the skeleton to adapt to its mechanical environment by reducing the risk of fractures and repairing damage created by repetitive cycles of mechanical loading (Burr 2002). Both modeling and remodeling can occur on the four bone envelopes: the periosteal, Haversian (intracortical), endosteal, and trabecular surfaces (Frost 1969, 1987; Parfitt 2002). Because each envelope is distinct, modeling and remodeling can occur at different times, rates, and magnitudes within the bone.

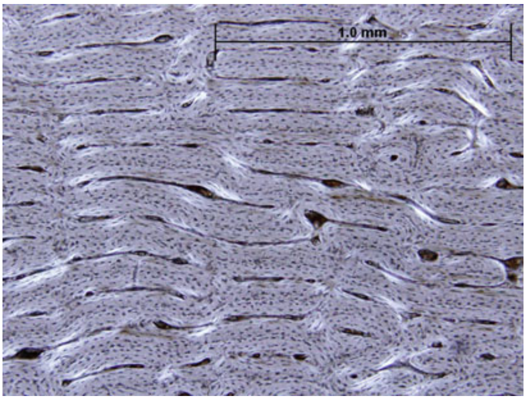
Applications of Bone Histology in Anthropology

Anthropologists are increasingly performing histological analysis to study both ancient and modern bone. As with other anthropological analyses of bone, the interpretation of histological results must be made within the context of skeletal biology. Histological analysis of skeletal remains in anthropology is applied to (but not limited to) the following categories: the differentiation of human from nonhuman bone, constructing the biological profile, reconstructing habitual activities or traumatic episodes in life, and the diagnosis of pathological conditions including an overall assessment of skeletal health. The following provides a brief summary of each type of analysis.

Human Versus Nonhuman

In instances where bone is too fragmentary, too weathered, or in some other way rendered unidentifiable by macroscopic observation, histological analysis can serve to differentiate human from nonhuman bone. Histological methods are less destructive, easier to perform, and less expensive than DNA analysis for distinguishing human from nonhuman bone. The typical method to differentiate human from nonhuman bone is to evaluate specific qualitative microstructural traits considered distinctive of nonhuman species. Researchers attribute two particular features of bone microanatomy to nonhuman species, plexiform bone and osteon banding. Plexiform bone is a fibrolamellar bone type described as having a "brick wall" appearance, a result of the linear vascular spaces that separate the lamellar "bricks" when plexiform bone is viewed in cross section (Martin et al. 1998: Fig. 4). Osteon banding is defined as distinct rows of five or more primary and/or secondary osteons, which often alternate with bands of lamellar bone (Mulhern & Ubelaker 2001).

In the absence of these easily observable and definitive nonhuman features, morphological characteristics of secondary osteons are often considered. Bone deposition and remodeling processes are similar in human and nonhuman mammals, making secondary osteons a prevalent



Bone: Histological Analysis, Fig. 4 Plexiform bone is brick-like in appearance and characteristic of non-human bone (Pig humerus at 100× magnification)

feature of bone microstructure in most animals. Early research focused heavily on size differences in human and nonhuman microstructure, but provided little in the way of broadly applicable methods for identifying human or nonhuman material. Jowsey (1966) established that secondary osteon size varied across species and that there are age-related changes in Haversian canal size. More recently, it has been shown that human osteons tend to be elliptical, whereas nonhuman osteons tend to be circular. This supports anecdotal evidence that nonhuman osteons appear more circular than human osteons, suggesting that circularity may be a key variable to differentiate human from nonhuman Haversian bone. While histomorphometric data (i.e., osteon area and osteon circularity) appear promising for differentiating human and nonhuman bone, current methods lack sufficient validation and should be used with caution.

Constructing the Biological Profile

In anthropology, constructing a biological profile for unknown skeletal remains consists of a series of analyses that include the estimation of sex, age, ancestry, and stature, as well as the recognition of pathological conditions. Within forensic anthropology, the biological profile may be used in two ways: the first is to provide biological information that may be used to support the identification of an individual and the second is to use the information to narrow a potential missing person's list to streamline investigations involving unknown human remains. Outside of forensic applications, the biological profile is used to construct the demographics of ancient human populations (paleodemography). Considering the components of the biological profile, the estimation of age currently constitutes the majority of histological research in anthropology. While histological methods have not been used to estimate sex or ancestry, research has demonstrated that a relationship between histological variables and these factors likely exist. Although research suggests allometric relationships (e.g., relationship of body size to shape) with histological structures, stature estimation is not within the scope of histological analysis. Therefore, this section discusses histological age estimation with consideration of sex and ancestry as contributing factors in histological variation.

Age Estimation

The estimation of age at death is an essential part in the reconstruction of population demographics and the individual analysis of human remains. Estimating the age at death of children and young adults can be performed with greater accuracy owing to methods that are based on the growth and development of the human skeleton. Skeletal growth and development are regulated by endocrine and genetic factors producing biological age indicators that have a more predictable relationship with chronological age. The estimation of age at death for adults, in most cases, demonstrates a progressive decrease in accuracy as chronological age increases. Most methods for adult age estimation are based on degenerative changes of the skeleton, which can vary between individuals, geographic populations, and ancestral groups. The premise of histological age estimation is based upon clinical and anthropological research demonstrating that bone turnover occurs in cortical bone at a predictable rate over an individual's lifetime. As turnover occurs over time, the relative density of secondary osteons will increase, which should be evident until remodeling rates begin to fluctuate during the later decades of life (Fig. 5).

Bone: Histological Analysis, Fig. 5 Mean osteon population density (OPD) values for a known age sample separated into age cohort showing the relationship of OPD with age

Since the introduction of the first quantitative histological approach for the estimation of age at death by Ellis Kerley in 1965, histological parameters of age-related bone turnover have been well-documented in the anthropological literature for various skeletal elements. Crowder (2005) reviewed some of the most frequently employed methods, determining that the assessment of bone histology is a useful method for estimating age, producing accuracy values that are comparable to many gross morphological methods. Considering the myriad of methods, only a few have received significant attention within the field culminating in multiple validation studies applied to archaeological, cadaveric, and forensic samples. Regardless of the method, analysis involves evaluating a cross section or portion of a cross section of bone at the histological level and collecting variables that exhibit a relationship with chronological age. As with any method, it is imperative to perform the analysis as it is described in the literature.

Current methods typically quantify the amount of intact or fragmentary osteons within the cross section or region of interest within a cross section. More recently, histologists have turned to osteon geometry (i.e., shape and size) as an age indicator creating new approaches to the analysis of bone. Two variables that have received considerable attention are osteon circularity and area, which have both been found to correspond with age. Osteon circularity examines the geometry of the osteon in relation to a circle. Osteon area establishes the amount of bone area within the reversal line of an osteon. Research has indicated that mean osteon area decreases and circularity increases in older individuals; however, the control mechanisms for osteon size and shape over time are not fully understood and may be related to factors such as bone formation rates, activation frequency, and osteon population density. The material currently available for elucidating the specific relationship between osteon geometry and age is at a preliminary stage and significantly more research is needed.

Sex and Ancestry

While it has been documented that bone density and the rate of bone remodeling differ between the sexes and between individuals from different ancestral groups, there is no agreement among studies that these differences exist with measurable consistency. Many histological methods for age estimation have developed sex-specific and ancestry-specific equations (Thompson 1979; Cho et al. 2002), while others indicate no significant differences between groups (Stout & Paine 1992). Sex differences observed in histological variables are likely related to biological factors involving the endocrine system that affect bone turnover in the female skeleton, such as pregnancy, lactation, and menopause. Females experience bone loss associated with a drop in estrogen levels following menopause, which manifests in the loss of trabecular connectivity and increased porosity within the Haversian envelope of cortical bone. Biocultural factors (i.e., fecundity, breastfeeding practices, types of food consumed, or activity levels) may produce or extenuate histological differences between males and females that significantly impact bone biology. For example, a division of labor between sexes in a population may produce higher activity levels in one sex, causing bone to respond differently to the mechanical stresses and resulting in a perceived sex difference.

Histological differences observed between ancestral groups may be attributed to the population variability in cortical bone mass and density. Differences in skeletal growth velocity and duration will result in differences in bone mass and density. African-Americans, compared to European-Americans, have a slower bone turnover rate and a higher subperiosteal apposition rate resulting in greater bone volume (Cho et al. 2002). While differences in hormone levels that govern growth and development vary between populations, cultural aspects should also be considered when evaluating population variation at the histological level. Socioeconomic status may produce differences in activity levels, diet, and overall health, which may manifest at the histological level in bone.

Considering that histological methods produce conflicting results regarding sex and ancestry, it is also possible that some perceived group differences are an artifact of small sample sizes, skewed sample distributions, or differences in histological sampling location. Therefore, caution should be followed when interpreting histological variables and results. Overall, population variation in bone histology likely reflects biological, genetic, and cultural factors.

Physical Activity

Biomechanical strain levels may vary depending on patterns of physical activity, which may be attributed to sex or ancestral group differences. Bone, being a dynamic tissue, will respond to biomechanical forces, or lack of forces, by altering bone resorption and formation rates (Inque et al. 2000). All bones receive biomechanical loading, including non-weight-bearing elements. Through histological analysis one may evaluate the microstructural changes caused by this biomechanical loading. A difficulty in anthropological studies is interpreting the load history where strain data are lacking or insufficient (Skedros 2011). The evaluation of mechanical loading in bone provides an understanding of bone adaptation within the lifetime of an individual in that bone structure and/or material organization will change in response to certain loading conditions (including reduction of loading as seen in disuse osteoporosis). The effects of stress/strain on bone are varied; however, bone must remain mechanically stable to reduce fracture risk. Biomechanical loading resulting from physical activity, assuming that the loading conditions are outside the normal physiological stress/strain range, provides stimuli that can accelerate intracortical bone remodeling. Studies from archaeologically derived contexts suggest the effect of habitual behaviors on bone results in both changes in gross geometry and intracortical bone remodeling. Therefore, one must consider that subsistence patterns and activity patterns vary between populations over geography and time.

Considerable research suggests that variation in the size and shape of osteons is linked to the biomechanical loading of bones. The analysis of this variation may be helpful in interpreting the load history of past and present populations; however, the challenge is in differentiating load history from other biological variables. While a well-substantiated framework for interpreting load history remains to be developed, Skedros (2011) introduced a worksheet/checklist of considerations to facilitate the interpretation in limb-bone diaphyses and ribs. Further work is needed to establish the control mechanisms determining osteon shape and size.

Pathological Conditions

Pathological conditions in skeletal remains can be often classified into particular disease groups through histological analysis. The interpretation of morphological structures at the histological level in archaeologically derived bone is particularly difficult due to postmortem changes and the maceration process, when compared to the information available from fresh tissue samples. Identifying pathological conditions in bone provides the basis for reconstructing the etiology and epidemiology of disease in past populations (Schultz 2001).

In the forensic context, the evaluation of pathological conditions in bone may assist with the determination of the cause of death. Of particular interest to forensic pathologists is identifying pathological conditions that increase the fracture risk of bone. Two conditions commonly explored that result in abnormally brittle bones are *osteogenesis imperfecta* and osteoporosis. In addition, metabolic conditions, dietary deficiencies, or other pathological conditions often lead to abnormal secondary osteon counts, which if used for histological age estimation, will produce inaccurate results. When evaluating bone for potential pathological conditions, it is important to consider the role of diagenesis and the impact of taphonomic factors that may mimic the histomorphology of diseased bone (Schultz 2001). Diagenesis refers to post-depositional changes that may affect both the chemical and structural integrity of the bone caused by taphonomic agents, such as water intrusion, bacteria, and fungi (Jans et al. 2004). Failure to recognize diagenetic agents may affect the reliability of histological analyses.

Conclusions

Skeletal remains are a storehouse of information regarding the biological processes experienced during the life of the individual. The use of histological methods in anthropology can strengthen other analytical results and provide information that cannot be obtained from gross methods alone. Through the qualitative evaluation of histomorphology and quantification of bone remodeling through histomorphometry, anthropologists are able to develop techniques to estimate age at death, evaluate load history, and assess skeletal health, contributing to the comprehensive understanding of skeletal biology.

Cross-References

- ▶ Age Estimation
- ▶ Ancestry Assessment
- ▶ Bone Differentiation (Human and Nonhuman) in Archaeological and Forensic Contexts
- ▶ Dental Anthropology
- ▶ Osteology: Definition
- ▶ Pathological Conditions and Anomalies in Archaeological Investigations
- ▶ Pathological Conditions and Anomalies in Forensic Contexts
- ▶ Sex Assessment
- ▶ Skeletal Biology: Definition
- ▶ Stature Estimation
- ▶ Taphonomy in Bioarchaeology and Human Osteology

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Bones: Preservation and Conservation

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Introduction

This entry discusses the conservation of a common archaeological remain: bones, or more specifically bony elements. Our main purpose is to consider bony elements, common to all vertebrate, human and animal, from archaeological contexts and their final destinations in museums and laboratories.

Definition

"What Is Bone?"

Bone is made of two main elements: organic (collagen-protein) and mineral (hydroxyapatite $Ca_{10}(PO_4)_6(OH)_2$). These elements have very different functions and properties that in combination allow bone to be at the same time hard and flexible, and as such it is an excellent raw material for several archaeological artifacts (White & Folkens 2000), such as Amazonian flutes, Paleolithic and Neolithic needles, and Paleolithic sculptures.

In a body, bones serve to protect and support soft tissues, to produce blood cells, as a storage facility for fat and a reservoir of calcium. Bony elements vary in size and shape according to the species and the individuals, but these are normally also related to sex and domestication. Living bone is constantly transforming, it can repair and reshape itself depending on the type of stress it is put under.

The proportion of mineral and organic parts in bony materials depends on the function of the structure: Bones, teeth, tusks, antlers, and shells, all have different functions and therefore the compositions and forms can differ quite a bit, for example, teeth have more mineral parts than bone, shafts are hollow while tusks are dense and compact, etc. The composition of bony elements affects the way these structures can be manipulated and has implications on their reactions to taphonomic processes following deposition (and after being excavated!).

Key Issues/Current Debates/Future Directions/Examples

Taphonomic Processes: "What Damages Buried Bony Elements?" and "What Can Preserve Bony Elements?"

The word taphonomy entered the academic record in 1940 when the Russian researcher Yefremov applied it to define "the study of the laws of burial" in paleontological contexts. Eventually its meaning was extended to the study of fossilization processes, paleoecological biases resulting from the passage of a body (human or animal) from a living community to a fossil one, and from the environment where the body was buried (Behrensmeyer 1978).

Even though bony elements have a very significant percentage of mineral components – giving a false impression of being a stone-like material – there are numerous processes that can damage the structure of bones, be it mammal, reptilian, avian, or fish:

1. Decomposition: The bacteria responsible for soft tissue decomposition can also "attack" the organic part of the bones.
2. Environment: Exposition to weather conditions, rain, sun, wind, snow, and temperature can cause cracking and breaking.
3. Burial and Transportation: A rapid burial is an essential element for conservation, long-term transportation can physically destroy bones rapidly.
4. Soil characteristics: Acidity, mineral composition, granulometry (clay, sand or silt), they all affect preservation. In fine sands, the surface of bones can become coarse with time, while in clay, soil "attaches" itself to bone, being difficult to separate – some cleaning procedures might even damage the bones if the sediment is too attached.
5. Pre-depositional treatment: Human and animal bones frequently undergo some kind of treatment prior to being buried or discarded. One should expect treatments that vary from defleshing to cremation, boiling, painting, etc. All of these activities have an impact on preservation. For instance, burnt bones survive quite well, but are normally highly fragmented, while teeth usually explode into micro unidentifiable fragments when burnt. Mummification processes, be they natural or artificial, can help preserve not just bones, but also soft tissue and keratin elements (like hairs and nails).

Most bones found in archaeological sites are in fact decomposing not fossilizing; the site's environment affects the rate of this process. For instances, in tropical areas, where the soil is normally very acidic and the weather conditions are quite rough (temperature and humidity are high), bones sometimes do not preserve beyond a few hundred years (or less), and when they are recovered, the deterioration is so advanced that it renders identification and other analyses (like dating) difficult or impossible. Meanwhile in Europe, where the soils are neutral or slightly basic, it is quite normal to find non-fossilized bone in archaeological sites thousands of years old. Some kind of equilibrium is needed in order for long-term preservation to exist.

It is important to note that finding preserved bone does not mean finding fossils. Fossils are bones or teeth that no longer have organic parts, because they have been replaced by mineral elements.

What Can We Learn from Bony Materials?

The study of bony materials can provide information about a range of archaeological questions and these applications justify the long-term storage of bone (Lyman & Fox 1997):

1. Differentiating human from animal contexts (see Figs. 1 and 2)
2. Estimating, minimum individual number, sex, age, stature, and health
3. Domestication processes for animals
4. Cultural materials and artifacts
5. Feeding habits
6. Disposal habits
7. Environment
8. Population patterns
9. Funerary practices
10. Death patterns (isolated, catastrophic, etc.)

How to Preserve Bony Elements?

Unfortunately, few museums currently have the proper means to care for all their archaeological artifacts. Simple and practical actions do exist that can help preserve bony elements. To conserve such artifacts correctly, one must understand:

1. The conditions where the elements were found. Changing the environment too abruptly and permanently usually leads to deterioration of the organic parts and sometimes to total destruction.
2. The bony elements state at the moment of their retrieval. If the conservation conditions at the field site are precarious, it may be necessary to apply stabilizing agents such that the elements can be removed and the excavation finished in the laboratory.

Bones: Preservation and Conservation, Fig. 1 Animal bones recovered from an Amazonian Site. Notice conservation (Photo by V. Moraes)

Bones: Preservation and Conservation, Fig. 2 Funerary urn containing one cremated individual, the bones are very fragile (Photo by C. Moraes)

3. The final destination: Most organic materials react rather badly to environment variation. So in order to preserve these elements, there must be continuity! This means understanding and controlling the environment at the final destination.

Collagen (organic part) in the bony elements reacts to removal from the soil by drying and shrinking or by moistening and swelling; in both cases, this leads to cracking of the bone's surface and, sometimes, inner structures.

"When," "How," and "Why" to Clean Bones Are Dependent on the Conditions in Which the Bony Elements Were Found and the Projected Analyses

Before starting the cleaning procedures, it is necessary to make a thorough evaluation of the bony element, noting how preserved or damaged it is. Dry and wet materials react differently once taken from dry soil or flooded areas and the preventive actions (glues, consolidants) that might have been needed may subsequently interfere with the cleaning procedures. Another important factor to be taken into consideration is that bones (human and animals) are often transformed into artifacts or by pre-depositional treatments; therefore, cleaning should not "erase" or "remove" these traces, when possible X-rays can assist in this process of evaluation.

Differently from other more robust archaeological remains, like stone and some ceramics, washing with abundant water and brushes can damage bony elements by removing the superficial layers or causing them to crack and eventually break into small fragments. Therefore, many archaeologists are experimenting dry-cleaning their materials with scalpels and using controlled solvents in specific areas. Scalpels are delicate to use because they are very sharp and therefore dangerous, but it is easier to clean with a scalpel, even hard and attached clay soils can be removed without much effort, and if by misfortune, the archaeologists "carves" the bone, it leaves a very distinctive mark, easily differentiated from prehistoric artifacts. Wooden utensils demand the application of more strength during cleaning procedures and can eventually cause the bone to shatter, but it is still a good utensil. Solvents are good for removing incrustations that cannot be cleaned mechanically, but they must be used carefully because in large amounts, they can erode the bone's surface.

Bony elements that are found in wet/damp conditions are best cleaned before the surrounding soil dries out completely. Once dried, bones should not be remoistened, as abrupt climatic changes should be avoided.

Issues of Long-Term Storage

Like in all scientific work, in archaeology, one should leave part of the material studied for future analyses: thinking of future researchers who might create better techniques or have different opinions.

Conducting archaeological excavations implies recovering old materials that need to be cared for a very long time. Appropriate storage areas are a problem for archaeologists and museums in general. The need for space is forcing some archaeologists to rethink their fieldwork plans and to choose smaller expeditions where fewer materials are recovered.

Scientific collections demand special care. Most recovered bones were in a slow (or not so slow) process of decomposition, and this needs to be taken into account when planning excavation and long-term storage. Remembering that all organic materials should only be stored once they are completely stabilized, one must first think of the bone's condition and which materials will be in direct contact with the bony elements (see Fig. 3).

As Cronyn (2004) states stabilization can either be passive or active – unfortunately, most laboratories only have the first option. A passive stabilization involves controlling the "new" environment and allowing the bony materials to dry (or keeping them wet) until they achieve an equilibrium. The density of the bony materials (bones, ivory, etc.) will also have an impact on the time it will take for stabilization to occur. When bony materials have to go through an abrupt change in environment, like the removal from wet conditions, the application of a chemical product (Cronyn 2004) to consolidate and "force" stability is usually needed – the most frequently used are PVAC and polyethylene glycol.

Once the archaeological remains are stabilized, storage considerations should include appropriate conditions:

– Bony materials should be in direct contact with "soft" materials, like plastic bags or preferably bags made of polypropylene, that are neutral and not toxic.
– Storage should not be in paper bags or cardboard boxes that decompose rapidly and attract animals like termite and ants.
– The integrity of the bony material is a key element; when cracking and breaking are observed, it is valuable to consider storage in areas where there is little handling.
– Cracking bones should not be kept in direct contact with each other.
– Large and heavy bones should not be stored with small fragments or teeth.
– Common sense is always the best policy.

Bones: Preservation and Conservation, Fig. 3 An example of storage procedures: human bones being stored in polypropylene material (Photo by A. Rapp Py-Daniel)

Cross-References

- ▶ Anaerobic Conditions (Bogs, Waterlogged, Subaquatic): Preservation and Conservation
- ▶ Bioarchaeology, Human Osteology, and Forensic Anthropology: Definitions and Developments
- ▶ Bioarchaeology: Definition
- ▶ Bone Chemistry and Ancient Diet
- ▶ Bone Density Studies in Environmental Archaeology
- ▶ Bone Tools, Paleolithic
- ▶ Bone: Chemical Analysis
- ▶ Conservation in Museums
- ▶ Dry/Desert Conditions: Preservation and Conservation
- ▶ Frozen Conditions: Preservation and Excavation
- ▶ Zooarchaeology

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Boni, Giacomo

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Basic Biographical Information

Giacomo Boni was born in Venice, Italy, on April 25, 1859. He studied architecture in

Venice and worked there as an architect, but is best known for his excavations at Rome, especially those in and around the Forum Romanum undertaken from 1898 onward. He saw military service in World War I and resumed his fieldwork in 1916. He was appointed as a member of the Italian senate in 1923 and died in Rome, Italy, on July 10, 1925, and is interred in the Orti Farnesiani on the Palatine Hill.

Major Accomplishments

Boni's excavations in Rome resulted in many significant archaeological discoveries and it is for this work that he is most well known; in fact, Boni was a pioneer in terms of excavation methodology. Boni's stratigraphic excavations in the center of Rome were revolutionary, as no one had ever undertaken deep soundings at Rome that followed stratigraphic principles before (Ammerman 1990: 630). Indeed, Boni's stratigraphic excavation was one of the first of its kind in the field of Classical archaeology. Beginning in 1903, Boni's excavation reached a depth of more than 6 m, taking him below the modern water table, an excavation in which his early experience as an architect working in Venice proved useful. In the deep soundings at the center of the Forum Romanum, Boni would document more than 30 anthropic strata that told the story of the artificial landfill project undertaken in the archaic period to raise the ground level of the Forum itself. These layers, and Boni's work, would be returned to in the middle of the twentieth century by Swedish archaeologist Einar Gjerstad.

Boni's excavations also revealed important finds in an around the area of the Forum Romanum. These included the Iron Age necropolis near the Imperial temple of Antoninus Pius and Faustina known as the *Sepolcretum* (1902), the *Lapis Niger* (1899–1905), and the *Regia*, as well as sites on the slope of the Palatine Hill including the House of the Griffins. Despite interrupting his work to serve in World War I, Boni returned to digging at Rome and continued to work there until the end of his life.

Cross-References

▶ Forum
▶ Lanciani, Rodolfo
▶ Topography of Rome

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Bowdler, Sandra E.

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Basic Biographical Information

Sandra Bowdler was born in 1946 and is now Emeritus Professor in Archaeology at the University of Western Australia. She grew up in Sydney, Australia and obtained a first class Honours degree with University Medal in Anthropology at the University of Sydney in 1971. She then worked as a tutor at the University of Papua New Guinea before going on to undertake a Ph.D. through the Research School of Pacific Studies at the Australian National University. Her Ph.D., on aspects of the archaeology of Hunter Island, Tasmania, was conferred in 1979. Towards the end of her Ph.D. Sandra Bowdler took up a lecturing post at the University of New England where she stayed for 4 years before working as a consultant archaeologist, particularly to the Forestry Commission of New South Wales. In 1983 she was appointed as foundation chair in archaeology at the University of Western Australia - a testament to the contribution that she had made to the discipline so early in her career. Professor Bowdler continued in that position until her retirement in 2008.

Major Accomplishments

In the course of her archaeological career Sandra Bowdler's research has spanned a diversity of themes, theoretical concerns and geographic areas although primarily her interest has lain in the Australasia and Southeast Asia regions. Sandra's earliest research on coastal midden sites in New South Wales was particularly concerned with the way in which Aboriginal people had organised themselves. In writing up her first professional excavations of these middens Sandra attempted a new type of midden study which was both "testable," in line with the then "New Archaeology," but at the same time was "about people". Social groups, especially women, had been invisible in Australian archaeological writings and Bowdler's (1976) study remains one of the few pieces of research in Australia that has exploited the potential of using gender as an analytical category. Her interest in the way in which we construct or engender the past has continued throughout her career. Sandra's early research on coastal middens expanded to include an interest in all aspects of coastal archaeology but particularly the unique conditions imposed for colonisation (e.g. Bowdler 1977, 2010), Tasmania (e.g. Bowdler 1984a) and the use of small offshore islands (e.g. Bowdler 1995).

Sandra brought a new level of professionalism to consulting archaeology in Australia during her brief period as a consultant in the 1980s. Consultancy in Australia has expanded exponentially recently, led by the pace of oil and mineral exploration and Sandra's challenging contributions on significance assessment (e.g. Bowdler 1984b) and the imperative to make consultancies relevant to timely research questions, remain as important today as they were at the time of publication.

Working as a consultant meant that Sandra also had to confront the many of grievances of Indigenous peoples in the heritage process and in archaeological practice generally. Questioning the objectivity of concepts of "significance," and whether or not scientific objectivity was possible in a heritage framework were big issues for archaeologists at the time. Sandra advocated the primacy of Indigenous interests in archaeology. When the rights of Indigenous people to repaint their sites was questioned by some academics and rock art practitioners following the 1987 Ngaringin Cultural Continuity Project, Sandra took a strong ethical stand arguing that Indigenous rights should take precedence over non-Indigenous national heritage agendas and urging those critical of the repainting project to "ask themselves what is more important, the preservation of a few relics of the recent past, or the active continuation of that living culture?" (Bowdler 1988: 523).

In the 1990s Sandra became increasingly interested in the Southeast Asian region, in the colonisation of Sunda and Sahul by modern humans and in comparisons between the material cultures of the two regions. This led to comparative studies of Pleistocene stone industries from Australia and Southeast Asia and her interest in the Hoabinhian culture complex (e.g. Bowdler 2006).

Despite her retirement Sandra continues her interest in archaeology alongside her new venture in music festival administration of the "Festival Baroque".

Cross-References

- ▶ Balme, Jane
- ▶ First Australians: Origins
- ▶ Gender, Feminist, and Queer Archaeologies: Australian Perspective
- ▶ Hunter-Gatherers, Archaeology of
- ▶ Indigenous Archaeologies: Australian Perspective

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Braidwood, Robert John

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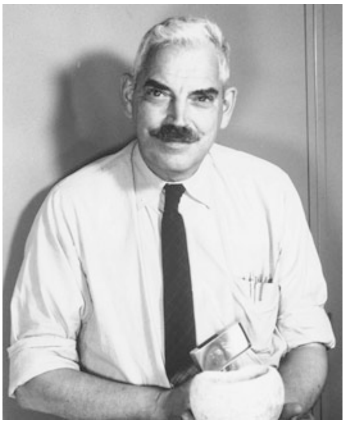
Basic Biographical Information

Robert John Braidwood (Fig. 1) was born July 29, 1907, in Detroit, Michigan. He completed a degree in architecture at the University of Michigan in 1929 and spent several months in an architectural office. However, the Great Depression made his future as an architect tenuous. He decided to go back to school to take courses in anthropology, a field that had interested him during his undergraduate years. He took an ancient history class taught by Leroy Waterman, director of the University of Michigan excavations at Tell Umar (the ancient city of Seleucia) in Iraq. Braidwood's skill at drafting and free-hand lettering made such a positive impression on Waterman that he invited the young man to join the 1930–1931 season at Seleucia as surveyor and draftsman. Braidwood returned to Michigan to complete his B.A. (1932) and M.A. (1933) in anthropology and was then hired (1933–1938) by the University of Chicago's Oriental Institute as field assistant to the Syrian Expedition working in the Amuq (the Plain of Antioch). In 1937,



Braidwood, Robert John, Fig. 1 Braidwood with Jarmo artifact, Oriental Institute, University of Chicago, c. 1965. Photo courtesy of P. J. Watson

he married Linda Schreiber, whom he had first met during their undergraduate years at Michigan, the two forming a team that endured for the next 66 years. In 1938, he entered a doctoral program at the Oriental Institute (also taking coursework in Anthropology), which he completed in 1942. From 1941 to 1945, Braidwood was a part-time faculty member of the University of Chicago. In 1945 he was promoted to professor with joint appointments in the Oriental Institute and in Anthropology, a position he held until his retirement in 1978. He and Linda continued to participate in the Turkish Prehistoric Project for several more years.

Braidwood was the first archaeologist to seek empirical evidence (floral and faunal remains) for the beginnings of agriculture and pastoralism in Western Asia. He began his work initially at the site of Jarmo in northern Iraq (Braidwood & Braidwood 1950, 1953). Funding from the US National Science Foundation in 1954–1955 (the third Iraq-Jarmo Project field season) enabled Braidwood to add a botanical expert, a zoologist, a geologist, and a radiocarbon specialist to his field staff. When the 1958 nationalist revolution in Iraq made fieldwork there impossible, he transferred this collaborative research team to Iran (the Iranian Prehistoric Project 1959–1960) and then to Turkey (the Joint Turkish Prehistoric Project-Istanbul/Chicago, Diyarbakır region, 1963–2003) (Braidwood & Çambel 1980). Jarmo was the first "oldest food-producing community" to be revealed, the precursor of many other such communities now known in the Levant, Turkey, Iraq, Iran, and elsewhere (Braidwood 1967, 1973; Braidwood et al. 1983). Archaeologists around the world have joined the Braidwoods in pursuing evidence for the origins of plant and animal domestication and of food-producing economies in many regions of Asia, Europe, Africa, Oceania, and the Americas.

Braidwood received numerous honors over his career. He was elected to the National Academy of Sciences, the American Academy of Arts and Sciences, and the American Philosophical Society. He was made a foreign correspondent or honorary fellow of the German Archaeological Institute, the Austrian Academy of Sciences, and the Society of Antiquaries. He was also awarded honorary degrees by the Sorbonne and the University of Rome. In 1971, the Archaeological Institute of America presented him with its Gold Medal for Distinguished Archaeological Achievement, and the American Anthropological Association designated him its Distinguished Lecturer in Archaeology. In 1995, the Society for American Archaeology awarded him the Fryxell Medal for Interdisciplinary Research in Archaeology.

Major Accomplishments

The "agricultural revolution" is foundational to the origins of urbanized, state-based civilization in southern Mesopotamia. Braidwood's interest in the topic derived in part from publications by Harold Peake and Herbert Fleure (*The Corridors of Time*, eight volumes, Yale University Press, 1920s–1930s), V. Gordon Childe (1934), and Raphael Pumpelly (1908). His primary accomplishment was introducing, demonstrating, and advocating interdisciplinary archeological field research aimed at recovering primary evidence (physical remains of the earliest plant and animal domesticates) documenting agropastoral origins in western Asia. Moreover, he initiated a major conceptual shift regarding West Asian agricultural origins when he based his fieldwork program – not in the lower Tigris-Euphrates region – but rather in the natural habitat zone of the first domesticates (e.g., goats, sheep, wheat, barley, legumes): rain-watered uplands above the irrigation-based, earliest Mesopotamian cities. He referred to this nuclear zone as "the hilly flanks of the Fertile Crescent" (Braidwood & Braidwood 1950, 1953; Braidwood & Braidwood et al. 1983).

Braidwood also implemented a radical change in the organization of Near Eastern fieldwork. Fieldwork was traditionally carried out at big sites employing dozens, even hundreds, of workmen whose main job was to open up large-scale exposures of architectural remains. Recovery of artifacts was centered primarily on those that were complete or nearly so, beautiful, or intrinsically interesting to those directing the excavations. Braidwood's crews of workmen were smaller and much more closely supervised by field staffs that included botanical, geological, and zoological experts at a time when the collaborating scientists had to bootleg field and analytical time from their regular jobs. It was only many decades after the NSF-funded Jarmo field season of 1954–1955 that new subdisciplines of archaeobotany/paleoethnobotany, geoarchaeology, and zooarchaeology came to characterize modern archaeology.

Another of Braidwood's accomplishments was to highlight the period immediately preceding the first appearance of established agropastoral economies. He called this the "era of incipient food production" and was the first archaeologist to direct attention toward elucidating key characteristics of those Early Holocene foraging/hunting-gathering peoples who created the first agricultural and pastoral economies.

As early as the 1950s, Braidwood was also advocating ethnographic research in Near Eastern villages where many ancient techniques and practices (e.g., building and maintaining adobe or puddled-adobe structures; caring for mixed flocks of sheep and goats and processing their wool, hair, and milk; growing and processing wheat, barley, and legumes) were so successful that they could still be seen and documented thousands of years later in contemporary communities (e.g., Watson 1979; Kramer 1982).

Braidwood's primary contributions to archaeological knowledge center upon his research and publications concerning one of the most important transitions in the human past, namely, the origins of agriculture and pastoralism in western Asia. His work on this topic inspired an international research trajectory whose practitioners continue to expand, revise, and refine knowledge of agricultural and pastoral economies ancestral to the array of food-producing systems currently supporting human societies upon this planet.

Cross-References

▶ Archaeobotany of Early Agriculture: Macrobotany
▶ Childe, Vere Gordon (Theory)
▶ Ethnoarchaeology
▶ Near East (Including Anatolia): Origins and Development of Agriculture
▶ Paleoethnobotany
▶ Zooarchaeology

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Brazil: Cultural Heritage Management Education

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Introduction

Although cultural heritage management (CHM) has become a legal and effective concern in Brazil since the end of the 1980s, professional training as regards its legal and methodological specificities is still at its beginnings, mostly due to an apartheid between "archaeological" (i.e., Native-American) and "historical" (colonial or more recent) heritages. While historical heritage has long been recognized and explored, usually by means of historical and architectural perspectives (with museological/educational resonances), most of Native American heritage remained within academic research circuit and under specific legal protection background. This has promoted little concern for issues such as site management and collections curatorship, as well as its use for educational approaches.

Historical Background

The development of an "official Brazilian culture" (since Independence Day) has segregated Native American societies (and their material record) into the "ghetto of the exiled memories," that is, their existence is known but from a very exogenous and diffuse perspective (Bruno 2007). Thus, Native cultural contents have been systematically kept outside from formal education, as well as from the first legal diplomas (from 1937) regarding national heritage, focused, as they were, on "historical" heritage. The first "national museums," appearing by the end of the nineteenth century, are historical in nature and devoted also to Natural History and Ethnology. There is interest in archaeological research, but it has never been considered mainstream at any official institution, the first formal archaeologist been hired only in the 1920s. But, interestingly, these museums have gathered, since their very beginning, several important archaeological collections assembled by amateurs or naturalists, usually treated as of secondary importance.

From the 1950s on, systematic archaeological research takes off, but the predominance of research interests led by foreign initiatives (or "missions") prevents adopting the notion of management as a priority. In the following decades (up to the 1990s), most archaeological investigations have been performed by academic research groups housed at universities, usually more concerned with scholarly perspectives than management approaches (Funari 2004).

Heritage management in Brazil has appeared as a way to cope with the increasing destruction of archaeological remains due to fast economic development. This is the spirit of the first archaeological law, from 1961: to preserve, it is necessary to prevent/punish the destruction. With a few exceptions, there is no concern as regards management or education. Through the following decades, the IPHAN has been responsible for the protection and management of archaeological sites and collections, but with a legal and operational apparatus apart from historical/architectural sites and also strange from general national politics on museums and historical heritage management. (The Instituto do Patrimônio Histórico e Artístico Nacional – IPHAN (National Historical and Artistic Heritage Institution), established in the 1930s, has always been a reduct of architects; the first archaeologists have been hired only in the 1980s).

The formidable expansion of preventive (or "contract") archaeology (CRM projects) since the end of the 1980s and the overwhelming multiplication of recorded archaeological sites have evinced the need for the development of heritage management plans and strategies in three different levels: legal (with more specific diplomas regarding how to proceed as regards archaeological contexts), educational (law-enforced inclusion of heritage education programs into CRM projects), and museological (regarding the organization and management of the archaeological collections). Again, it must be stressed that these policies have been developed with no formal connection with established national heritage and museums programs, having a legal and operational apparatus on its own (for a more comprehensive review see DeBlasis 2010).

Current Debates

Heritage Management and Archaeology in Brazil: The Status of Art

As stated above, the inception of "education" into archaeological professional and academic career is recent and law-enforced in Brazil, becoming mandatory in every single research project since 2002. Legal diplomas, albeit well intentioned, have created a sort of "cake recipe," a report formula that (re)produces rather innocuous results from a scientific and educational standpoint, unfortunately supported by regulating agencies.

Education through, or for, heritage has long been an important concern into museums relationship toward the public (especially art education) and other means of scientific diffusion, as well as interpretive communication (tourism), particularly as regards historical heritage. These programs have strongly benefited from the development of robust pedagogical approaches such as the well-known *liberation education*, essentially based in learning and enhancing critical consciousness from the concrete experience of the surrounding reality (Freire 2000, 2005) and "educational city," enhancing urban identity and citizenship. There is also a strong focus on environmental education and sustainability, as well as education toward social inclusion, mostly among risk groups. Museological pedagogy, exploring communication through collections/landscapes and using memory indicators (and the so-called places of memory), has also known an enormous development, together with heritage education through material/cultural evidence (Horta 1984; Hooper-Greenhill 1995).

Particularly as regards archaeology, educational efforts have been confined to a few museums (usually linked to universities), focusing on the scientific perception of the discipline and exploring, occasionally, experimental archaeology. Through the last 10 years, a bigger concern with public archaeology has emerged, due to the growing awareness, by archaeologists, of the social, ethnical, and political problems involved on the praxis of their profession (DeBlasis 2010). A very interesting case came out within a project near the Xingu indigenous reservation, located at the southern Amazonian area, where archaeology (and archaeologists), with the support of the IPHAN, has led local community interests to be included into the scope of the project and to the creation of additional reservation territories based on indigenous knowledge.

Future Directions

Although it is possible to recognize the existence of advanced heritage legislation in Brazil, well tuned to environmental and sustainability perspectives, it is still poorly connected to formal education. Curiously enough, the management of archaeological heritage has taken an alternate path, apart from the mainstream educational tendencies and divorced from national museums politics. The protection of archaeological collections is a nuclear management problem today, due to its impressive accumulation in regional museums appearing everywhere, with few curatorial concerns. Despite the recent multiplication of grad schools of archaeology all over the country, the attention given to these and other management problems is still very timid. The distance between standard research procedures and effective management initiatives, on one side, and formal heritage education, on the other, needs urgent bridging. This rather peculiar situation, that is, the absence of site and collections management issues at the school curricula, as well as the overwhelming expansion of CRM projects all over the country, jeopardizes the continuity and acquisition of higher standards in heritage education in Brazil.

Besides these difficulties, public outreach of the archaeological heritage studies, whether academic or CRM based, is slowly growing, and in fact archaeologists themselves have become more attentive to it. Cultural sections of the most important newspapers show full-page texts on brand new discoveries; ecological TV programs bring archaeological reports every now and then, and easy reading books for the general public have also been published. Public education has become one of the forefront activities on recent archaeological research projects, and archaeologists now go to local schools and community centers to speak about the past, the environment, the things they find, history, and material culture – after all, what the hell are they (we) doing? It also has become common seeing flocks of school kids visiting archaeological excavations, often conducted by trained guides. Important to remember, public education has become mandatory in CRM projects from 2002 on, and these activities also must be reported at the project outset. But very often, unfortunately, the lack of prepared personnel brings, to these opportunities for effective educational contact and interaction, a rather deceptive outcome.

To overcome this situation, CHM education must be expanded to encompass a fully humanistic, as well as technical, professional formation for archaeologists and heritage managers. Archaeological practitioners need to go beyond descriptive standards and normative interpreting categories. They must dare to incorporate the living landscapes into their imaginary and cartography and realize that their work makes a difference for a more encompassing, socially and environmentally diversified future.

Cross-References

▶ Australia: Domestic Archaeological and Heritage Management Law
▶ Community Archaeology
▶ Community Partnerships in Safeguarding World Cultural Heritage
▶ Constructivism in Archaeology Education
▶ Cuba: Archaeological Heritage Rescue and Management
▶ Cultural Heritage Management and Images of the Past
▶ Cultural Heritage Management: Business Aspects
▶ Cultural Heritage Management: International Practice and Regional Applications
▶ Cultural Heritage Management: Project Management
▶ Heritage Areas
▶ Heritage and Public Policy
▶ Heritage Landscapes
▶ Indigenous Knowledge and Traditional Knowledge
▶ Local Communities and Archaeology: A Caribbean Perspective
▶ Multicultural Archaeology
▶ Postcolonial Archaeologies
▶ Sustainability and Cultural Heritage
▶ Sustainable Cultural Tourism Policies: Overview

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Brazil: Historical Archaeology

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Introduction

Following a general trend in South America, historical archaeology in Brazil has experienced a growth since the mid-1980s. This contribution reviews its history and development, particularly in the last 20 years. It begins by focusing on the wider South American context and proceeds with an analysis of some of the most outstanding projects undertaken in Brazil over the last two decades or so.

Definition

Historical archaeology in Brazil is a field that started to be developed in the 1960s, initially without any difference, whether in goals or in methods, from the prehistoric archaeology. In the last 20 years, it has had a significant development, insofar as the focus on a descriptive culture-historical approach has being gradually substituted by approaches more influenced by contemporary social theory. In recent decades, Brazilian and other South American historical archaeologists, in an effort to move away from the strong influence of North American historical archaeology, have been concerned with building a proper identity for the field, based on the historical and cultural particularities of South American countries (Funari et al. 1999; Lima 1999; Senatore & Zarankin 2002).

Historical Background

Historical Archaeology in South America

The emergence of historical archaeology in many South American countries occurred concurrently with the development of prehistoric archaeology, during the first half of the twentieth century; however, it was only in the 1960s that more systematic studies started to take place. During the 1960s and 1970s, research on historical sites was usually conducted by non-archaeologists – amateurs, historians, and architects (Lima 1993; Funari 1994). Basically, their investigations shared as a main goal the contribution towards the building of national identities based on the colonial European splendor. These early works are characterized by a set of common features, such as the straightforward correlations between material culture and documentary data, the rescue of valuable historic artifacts and structures, and supplying information for restoration projects.

It was only in the 1980s that archaeology in South America started to develop as an independent field of knowledge, being recognized its potential in the construction of alternative discourses about the past. As a consequence, historical archaeology started to enjoy an independent status for the first time. In this way, archaeologists began to create multiple visions about recent history, which could be opposed to or different from official history or "master narratives."

B

Brazil: Historical Archaeology, Fig. 1 Map of Brazil showing the locations mentioned in this text

This multiplication of counter-hegemonic discourses was closely related to the end of military dictatorships and the consolidation of democratic governments in Latin America (Funari 1994). The new sociopolitical context allowed archaeology to experience an accelerated growth, a process which was particularly intensified during the 1990s. This growth was reflected in the development of several research programs that focused on the study of diversified problems and regions, in the creation of specific courses in undergraduate and graduate programs, in the spread of national and international meetings, and in the increasing number of publications.

Historical Archaeology in Brazil

Historical archaeology in Brazil (Fig. 1) emerged during the 1960s, when some scholars started to give attention to southern Jesuit missions from the seventeenth and eighteenth centuries in the states of Paraná and Rio Grande do Sul and to northeastern European-indigenous contact sites from the sixteenth century in the state of Pernambuco (Lima 1993). Most of these former historical archaeologists had been trained as prehistorians in that same decade to participate on a wide research program, the Programa Nacional de Pesquisas Arqueológicas (National Program of Archaeological Research), coordinated by Betty Meggers and Clifford Evans, from the

Smithsonian Institute. This program identified some of the major archaeological complexes for the Brazilian territory. These archaeologists, following the goals of the culture-historical approach, were concerned with the identification and spatial-temporal delimitation of complexes of artifacts. Such complexes, named traditions and phases, were considered as material correlates of specific prehistoric cultures. In the case of the historical sites, the major focus was on pottery, analyzed with the purpose of building typologies to be inserted in specific historical phases and traditions (e.g., Symanski 2009). Although subjected to several criticisms, this approach was productive during the 1960s and 1970s, when scholars such as Igor Chmyz, Marcos Albuquerque, José Brochado, and Pedro Mentz Ribeiro studied the locally made pottery found in European-indigenous contact sites. Their goal was to discuss acculturative processes involving indigenous populations in contact with colonizers, an issue that continued to be approached up to the mid-1980s.

During the 1970s historical archaeology in Brazil experienced a slow development. Among its major accomplishments was its insertion in restoration projects of architectural national monuments, like fortresses and churches, but employed as a mere technique, totally subordinated to architecture. As new perspectives appeared in the 1980s, archaeologists became increasingly conscious of the potential of the discipline to investigate subjects that could lead to reinterpretations of the official history, such as unprivileged groups, social memories, and daily practices (Lima 1993). In this way attention started to be given to more ordinary kinds of sites. Tania A. Lima and Margarida D. Andreatta began to study urban and rural households in São Paulo and Rio de Janeiro, while Carlos M. Guimarães excavated maroon settlements in Minas Gerais. Paulo E. Zanettini (e.g., 1996), in turn, studied the peasant village of Canudos, in Bahia, which was the core of a messianic movement of contestation violently suppressed by the Brazilian army in the early Republican period (1896–1897).

Although most of the works undertaken in historical archaeology in the 1980s were still descriptive in nature, some scholars started to apply more analytical approaches. This was the case of Carlos Guimarães' study of settlement patterns in maroon sites of Minas Gerais (e.g., Guimarães 1988) and of Tania A. Lima's and Paulo E. Zanettini's studies on the relationships between European wares and household socioeconomic variability in Rio de Janeiro (e.g., Lima 1995) and São Paulo.

Key Issues/Current Debates

The 1990s witnessed an increasing interest in types of sites that had been overlooked until then. These included mining areas, collective trash dumps, colonial houses, slave quarters, cemeteries, colonial roads, and plantations. This diversification was largely the result of two factors: the establishment of contract archaeology, which slowly emerged in the previous decade, and the expansion of graduate programs in archaeology (Symanski 2009). Regarding the theoretical landscape, the setting established since the 1990s has been characterized by a diversity of influences, including processual, symbolic, poststructuralist, and critical approaches.

The processual approach influenced urban archaeology projects in the cities of São Paulo and Porto Alegre, through the systemic concept of city site, and consumer behavior studies concerning the relationships between European wares and household socioeconomic status (Symanski 2009). In the cities of São Paulo and Porto Alegre, the concept of city site has been used as a heuristic tool in general programs of cultural resources management developed by these cities' town halls cultural offices. The goal has been to consider any site located in the urban space as a product of the wider urbanization process and thus to study the material remains of this process and their relationship with the development of urban lifeways. Consumer behavior studies, in turn, have focused on the variability of nineteenth-century European wares in urban and rural contexts, discussing, on one hand, diachronic changes in these items as related to changes in social practices in direction to a Western European ideal of domesticity and, on the other, synchronic changes according to specific social and cultural backgrounds that could have influenced the consumers' choices. These studies have demonstrated that European ideals of consumption were far from being uniformly incorporated by the Brazilian society, rather, distinct social and cultural groups attributed distinct sets of value to these items, in some cases, as those of the urban elites, emulating European tastes and social behaviors but in others, as seem to have been the case with some farmers, peasants, and slaves, rejecting or adapting such values according to local cultural logics.

In the mid-1990s, Tania Lima published three articles that can be considered the foundations of the post-processual historical archaeology in Brazil (Lima 1994, 1995, 1996). Based on a strongly poststructuralist perspective, she studied the practices and representations of nineteenth-century society in Rio de Janeiro and the ways in which this changed as a result of European-influenced ideals of modernization that were increasingly incorporated during the second half of that century. Through the analysis of contexts which included cemeteries and households, Tania Lima discussed issues such as the representations linked to death, practices of personal hygiene and health, and the habits and rituals involving the social and private consumption of meals. During this same period, Pedro Funari was engaged in developing a critical and interpretative program for Brazilian historical archaeology, discussing the disciplinary status of the field, the relationship between written documents and material culture, and the rescue of the history of underprivileged and marginalized groups (Funari et al. 1999). These works represent the starting point of the development of works that, since then, have explored a diversity of issues including power relations, gender, social and cultural identities, and the structuring role of the built environment and landscape.

In Brazil, as in other Latin American countries, there has been a strong focus on the processes of change caused by the development and expansion of industrial capitalism. This system produced changes in practically all spheres of social and private life, including the separation between domestic and working spaces, the segmentation of meals, the mechanical measurement of time, the intensification of the process of urbanization, and the adoption of European-influenced ways of life. Although the influence of North American historical archaeology perspectives regarding these issues is undeniable, archaeologists studying the emergence of modern society in Latin America have tended to highlight the economic, social, and cultural specificities of this region (Lima 1999; Funari 2002; Senatore & Zarankin 2002). A case in point is Tania Lima's research which focused, on the one hand, on the strategies developed by the European industrialized countries, through the imposition of ideologies and practices involving the growing consumption of their industrialized items, and, on the other, on the creative ways in which Brazilian society was able to mix these practices with its own traditions, creating hybrid expressions (Lima 1999). Some scholars, like Ana Sousa, Luis Symanski, and Fernanda Tocchetto (e.g., 2003), have followed this line of investigation, discussing how groups with distinct social and cultural backgrounds, such as urban merchants, planters, industrial laborers, peasants, and slaves, differentially incorporated, rejected, or even ignored the ideology of industrial capitalism, despite the ubiquity of European industrialized items in these sites.

Landscape archaeology is another avenue of inquiry that has revitalized Brazilian historical archaeology in the last decades. Pioneering these approaches was Tania Lima's (1994) study on the representations of death in the nineteenth-century cemeteries of Rio de Janeiro. In this work she discusses the ways in which changes in these representations were related to wider changes in the social, economic, and political dimensions of Brazilian society, during its transition from the Imperial to the Republican period. Subsequent works include Marcos Souza's study of the socio-spatial organization of a southern colonial fortress in Laguna (Santa Catarina state) and its role as an expression of the colonizing ideology of the Portuguese Crown (Souza 1995); Ana Souza's analysis of the role of a southeastern colonial road in the production and reproduction of social relationships among its users, including planters, peasants, merchants, slaves, and travelers (Souza 1995), and Beatriz Thiessen's discussion of the ways in which the façade and Greek-style sculptures of an early twentieth-century German-Brazilian beer industry in the city of Porto Alegre expressed the discourses of an emerging bourgeois in the early Republican period (Thiesen 2006). Landscape approaches have been applied as well in plantation archaeology. This is exemplified by Marcos Souza's discussion of the arrangement of the landscape of the plantation – *engenho* – São Joaquim, in Pirenópolis (Goiás state), which was constructed according to Enlightenment ideals that created differentiated temporalities among planters and slaves (Souza 2007). Symanski's (2007) study on the tactics applied by enslaved groups to subvert the hierarchically organized space of the plantations of Chapada dos Guimarães (Mato Grosso state) is another good example of a landscape-scale analysis.

The processes of construction and maintenance of ethnic and cultural identities have also received growing attention from scholars. Regarding the archaeology of southern Jesuitical missions, Fernanda Toccheto's work represents a departure from the traditional focus on acculturation, approaching the maintenance of traditional techniques of ceramic production among the indigenous population as a strategy of cultural resistance to Jesuit domination (Tocchetto 2003). It must be noted that since the 1990s, research on the Jesuit missions decreased insofar as archaeologists started to study the material remains related to African slavery. Research of this kind of context was inaugurated by Carlos Guimarães in 1980, as aforementioned. In 1990, Carlos Guimarães and his colleagues excavated the Quilombo do Ambrósio, recovering a significant amount of low-fired earthenware, pipes, and zooarchaeological material. In 1992 and 1993, Charles E. Orser, Pedro Funari, and Michael Rowlands conducted research on the largest maroon settlement known from Brazil, namely, the seventeenth-century Quilombo dos Palmares, located in the state of Alagoas (Funari 1999). They recovered indigenous and colonial coarse earthenwares and European majolicas. Additionally, early in the 1990s, Tania Lima and colleagues excavated the slave quarters of the coffee plantation São Fernando in Vassouras (Rio de Janeiro state), recovering a small assemblage composed of European whitewares and glass fragments (Lima et al. 1993). This scarcity of material was interpreted by the authors as indicative of the slaves' very low standards of life and supported the idea – currently surpassed – that the contexts of African slavery in Brazil were characterized by the paucity of material culture.

More recently, research on plantations in Central, Western, and Southeastern Brazil, carried out, respectively, by Marcos Souza, Luis Symanski, and Camilla Agostini, has revealed a large amount of material items related to slave lifeways, including coarse earthenware vessel forms such as pans, bowls, and storage jars; European whitewares consisting of plates, cups, saucers, and bowls; glass bottles, copper ornaments, and iron tools. Discussions regarding these artifacts have taken into account their role in the building of a sense of collectivity in the slave community, the development of an internal economy in the slaves quarters, the affirmation of discrete identities in the plantations space, and the existence of a market specifically directed to slaves and African-descent consumers, characterized by low-price commodities such as coarse earthenwares.

A growing interest in the archaeology of African-Brazilian experience has encouraged scholars to apply models of cultural encounters more sophisticated than acculturation, which, traditionally, has been the dominant model in the study of Jesuit missions and Euro-indigenous contact sites. This is the case with models of creolization, transculturation, and ethnogenesis, which tend to highlight the selective appropriation and reinterpretation of the culture of the "other," as well as the mutual cultural influence between colonizers and colonized, which results in the emergence of new cultural forms. The case of the

Quilombo dos Palmares has been approached from the perspective of such models by Scott Allen, who has studied the ceramics from this site, and Pedro Funari (1999), who highlighted the multicultural configuration of this maroon settlement and the processes of interaction between maroons and other groups that occupied the region.

Marcos Souza (2000), in his study of the colonial mining village of Ouro Fino (Goiás state), has discussed the ways in which a culturally diversified population, composed by Portuguese, Portuguese-Brazilians, Amerindians, Africans, and African descents, used regionally made material culture to build a wide sense of regional identity founded over a baroque worldview. Nevertheless, this effort to build a common creole culture was rejected in the domestic sphere, where Souza notices the maintenance of strong ethnic and gender asymmetries, expressed in the dichotomy between European majolicas and the locally made pottery, which reflected the differences between white men and enslaved women of African descent.

The research carried out by Marcos Souza and Luis Symanski (2009) on three sugar plantations and one maroon settlement in Chapada dos Guimarães (Mato Grosso state) addressed the process of creolization of African and African-descent groups through a diachronic perspective on the period between 1780, when the first sugar plantations were established in the region, and 1888, when most of these establishments were abandoned due to the abolition of slavery in Brazil. In the earlier decades, the African component was restricted to a low number of regional identities, predominantly from the Mina Coast, in West Africa, and from Benguela, southern Angola, and the locally made pottery presented little decorative variability, predominating designs in zigzags, diamonds, and waves, generally incised over exposed coils in the upper part of the vessels. This setting changed during the second third of the nineteenth century, when large numbers of Africans, from Western, Central, and Eastern Africa, arrived in the region and Mina and Benguela slaves strongly dropped in number. The locally made pottery from the contexts of this second period, in turn, presented a much larger decorative variability, with the introduction of new techniques, such as stamped, impressed, punctured, and finger-nailed decoration, in a wide diversity of motifs and combinations. Finally, in the last third of the nineteenth century, a creole generation, which was born on these plantations, started to dominate the demographic regional setting, coming to represent more than three quarters of the slave population in the 1870–1888 period. During this period, decorated vessels strongly dropped in popularity, demonstrating that the decorative dimension of the locally made pottery had little significance to this more culturally homogeneous, creole generation. These correlations suggested that Africans used these items to express cultural differences whereas African-Brazilians did not, demonstrating that in this region, the process of creolization was strongly linked to generational changes in the slaveholdings.

Marcos Souza has also studied the slave quarters of the São Joaquim sugar plantation in Pirenópolis (Goiás state), focusing on the active role that material culture exerted in the social universe of the enslaved groups. He concludes that the process of creolization in that context involved the formation of a coherent cluster of references by those groups, which was constantly recreated and reinvented over the generations (Souza 2007).

Another field that has seen significant development in recent years is underwater historical archaeology, particularly through the work of Gilson Rambelli (e.g., 2002), who has studied shipwrecks along the Brazilian coast. Rambelli has created a Laboratory of Underwater Archaeology and is responsible for the formation of a new generation of Brazilian underwater archaeologists.

Also, Pedro Funari has recently raised awareness among Brazilian archaeologists the diverse issues regarding archaeological practice, the political enrollment of archaeologists inside the local communities in which they work, and the effects that interpretations about the past can have over the present. The growing importance of these discussions has led Funari to create a Public Archaeology Center at the University of Campinas, São Paulo (Funari 2004). This focus on the political role of archaeology has also led to the emergence of new issues, such as the archaeology of repression (Funari et al. 2009), the decolonization of the discipline, and the development of what Daniel Miller has termed "material culture studies," which involves the archaeology of present daily life (Zarankin 2010).

International Perspectives

Although most of the academic production in historical archaeology in Brazil is still directed just to a national or sometimes Latin American audience, this picture has tended to change since the 1990s, when some Brazilian archaeologists started to discuss the singularities of social conformation at the local level, highlighting the role of agents in the definition of the practices they use to construct their identities (e.g., Funari et al. 1999; Lima 1999, 2002b). The work of Pedro Funari and Tania Andrade Lima, especially, is well known internationally, being frequently cited in articles and books in Europe and United States. Currently, Brazilian historical archaeology is entering a phase of growing internationalization, with an increasing number of scholars publishing articles in some of the major international journals dedicated to the field. It must also be noted that Brazil has had an important role in the development of historical archaeology in Latin America in this century, particularly by spreading academic research results. This is in great part due to the publication, since 2008, of the journal *Vestígios – Revista Latino-Americana de Arqueologia Histórica*, a biannual periodical edited by Andrés Zarankin and Carlos Magno Guimarães and published by the Federal University of Minas Gerais, the aim of which is to promote interaction between scholars working in the field of historical archaeology across Latin America.

Future Directions

In the last 20 years, Brazilian historical archaeology has attained a state of maturity, constituting a fully integrated field of study in the country's research agenda. The heterogeneity that currently characterizes the field is also its major strength, insofar as it guarantees a plurality of perspectives, critical for the building of more inclusive, multivocal pasts, which are essential for the social development of a country historically characterized by enormous social inequalities. The current development of the field in Brazil illustrates a growing concern with the study of underprivileged groups, such as slaves, peasants, immigrants, Amerindians, and urban proletarians. These studies will serve not only to highlight the living and working conditions and identities of these groups in the past but also to strengthen the memory and identities of the contemporary descendant communities, insofar as public archaeology has been growing as an important part of archaeological agenda in academic as well as in cultural resource management researches.

Cross-References

▶ African Diaspora Archaeology
▶ Brazil: Cultural Heritage Management Education
▶ Capitalism in Archaeological Theory
▶ Capitalism: Historical Archaeology
▶ Colonial Encounters, Archaeology of
▶ Critical Historical Archaeology
▶ Cross-Cultural Interaction Theories in Classical Archaeology
▶ Funari, Pedro Paulo A. (Historical Archaeology)
▶ Hispanic South America: Historical Archaeology
▶ Historical Archaeology
▶ Historical Archaeology in Latin America
▶ Landscape Archaeology
▶ Latin American Social Archaeology
▶ Lima, Tania Andrade
▶ Modern World: Historical Archaeology

► Orser, Jr., Charles E.
► Plantation Archaeology
► Post-Processualism, Development of
► Processualism in Archaeological Theory
► Urban Archaeology

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Breadfruit: Origins and Development

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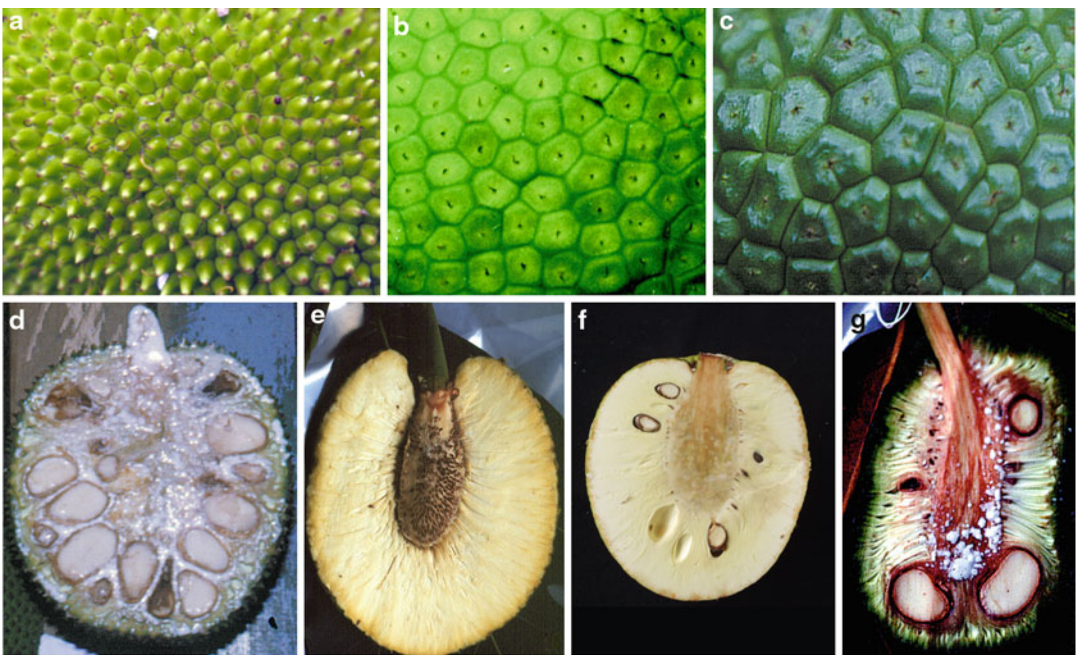
Basic Species Information

Taxonomy

Breadfruit has been a major staple crop for millennia in the islands of Oceania, where hundreds of cultivars have been developed and named. The first accepted botanical description of breadfruit dates back to 1773 by Sydney Parkinson, one of the artists who accompanied Joseph Banks on the voyage of the *Endeavour*. Since then a proliferation of names for breadfruit and its close relatives have been published, leading to much confusion in the literature about the correct scientific name for and the delimitation of the domesticated breadfruit. Recent examination of both morphological and molecular characters of hundreds of samples of breadfruit from throughout Oceania as well as related species has lead to a better understanding (Zerega et al. 2005a). The domesticated breadfruit is *Artocarpus altilis* (Parkinson) Fosberg (the most commonly seen synonyms include *A. communis* (Forster) and *A. incisa* (Thun.) L.f.). Two closely related species that contributed to breadfruit domestication are *A. camansi* Blanco and *A. mariannensis* Trécul (Fig. 1). Hybrids *A. altilis x mariannensis* also exist (Fosberg 1960).

Species Description

Artocarpus altilis is a large evergreen tropical tree that can reach up to 30 m tall. It is monoecious with separate male and female inflorescences on the same tree and produces copious amounts of white sticky latex throughout the plant. There is great diversity in the leaf and fruit (breadfruit is technically a compound fruit) characteristics of breadfruit. Adult leaves are typically glossy, dark green, and pinnately lobed and range in size. The number and size of the lobes can vary greatly, with



Breadfruit: Origins and Development, Fig. 1 Breadfruit and its relatives. Fruit surface and cross sections of *A. camansi* (**a**, **d**), *A. altilis* (**b**, **e**, **f**), and *A. mariannensis* (**c**, **g**) some cultivars having no lobes at all. Fruits are variable in size (up to 20 cm wide × 30 cm long), skin color (typically yellowish to greenish), flesh color (creamy white to pale yellow), surface texture (smooth, bumpy, or spiny), and whether or not seeds are present. Seedless cultivars are typically triploid.

Although the tree is primarily grown for its starchy fruit, it is a multipurpose crop. The tree itself is used in multicropping agroforestry systems in the tropical Pacific Islands. The wood is prized for its resistance to termites and is used for dugout canoes, carvings, and in construction; the bast fibers can be used to produce cloth and cordage, the latex can be used as an adhesive, for caulking or birdlime; and all parts of the tree are used for a variety of medicinal purposes (Jones et al. 2011a).

Geographical Distribution

Oceania is home to the greatest morphological and genetic diversity of breadfruit, and this is where the crop was originally domesticated. In the eighteenth century, Europeans began distributing a select few cultivars beyond the Pacific Islands and today it can be found in over 80 countries throughout the tropics. However, the diversity of cultivars outside of Oceania is extremely low (Zerega et al. 2005b). Breadfruit remains most widely cultivated in Oceania, with the Caribbean region second. Breadfruit is considered an underutilized crop that has great potential in the future and its distribution throughout the tropics continues to expand. Outside of the tropics, it is often well known due to its role in the infamous mutiny aboard the *H.M.S. Bounty* in 1789.

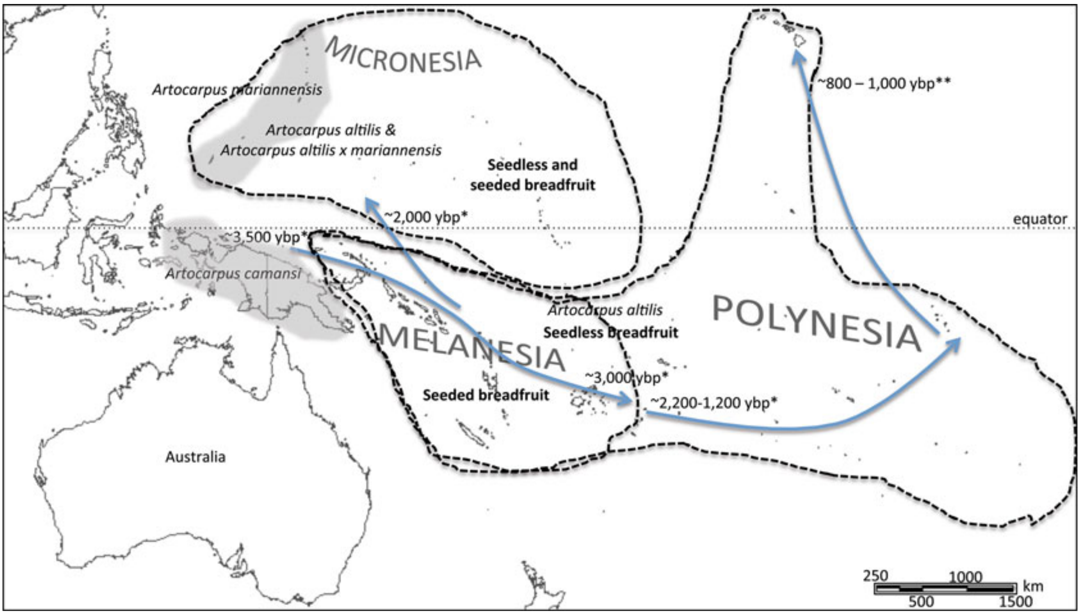
The progenitor species of breadfruit, *A. camansi* (breadnut) and *A. mariannensis*, are both cultivated for their fruits and seeds in their native ranges and beyond. Breadnut is native to New Guinea and the Moluccas and probably naturalized in the Philippines. It is also cultivated for its seeds in parts of Southeast Asia, the Caribbean Islands, tropical Central and South America, and Africa. *Artocarpus mariannensis* is native to the Mariana Islands and Palau and has been introduced to other Micronesian and Polynesian islands.

Major Domestication Traits

The hundreds of named breadfruit cultivars found in Oceania were domesticated from either *A. camansi* alone or from both *A. camansi* and *A. mariannensis*. Selection in breadfruit appears to have focused on increased flesh content, at the expense of seeds (many cultivars are seedless), and through a decrease in the fruit core size. In addition, the fruit surface texture is smoother in the domesticate, making it easier for peeling (Jones et al. 2013). These characteristics may have been selected for since they make pit fermentation easier – a traditional way for Pacific Islanders to store food and ensure a predictable food supply. The change in seediness correlates with a change in propagation methods; the progenitor species are seed propagated, while breadfruit is predominantly vegetatively propagated with most of the seedless cultivars being sterile triploids. Seeded cultivars are most common in the southwestern Pacific Islands, while seedless cultivars are most common in Micronesia and the eastern islands of Polynesia. Virtually all breadfruit found elsewhere in the tropics is seedless. In addition to the loss of seeds, other changes occurred in the texture and color of the fruit flesh and surface, as well as in leaf shape, size, and leaf pubescence. To date, limited studies have been conducted on the change in nutritional content of breadfruit compared to its progenitor species (Jones et al. 2011b).

Timing and Tracking Domestication

Archaeological remains of breadfruit have been found on several islands throughout Oceania; however, available records are limited and a systematic study aimed at tracing the history of its domestication based on these data does not exist. Breadfruit is a significant part of the culture in Oceania, and there are numerous legends throughout the islands about its origins. Although the exact details differ, many of these stories in Polynesia describe the tree arising from the body of a god or man who willingly sacrificed himself in order to provide sustenance to a family or



Breadfruit: Origins and Development, Fig. 2 Distribution and proposed human-mediated migration of breadfruit and its relatives. The native range of *A. camansi* and *A. mariannensis* are shaded in gray. The range of domesticated breadfruit and hybrids and their level of seediness are indicated within the dotted lines. Arrows indicate general directions of human migrations and are simplified from actual migration routes. Times are estimates of Lapita migrations likely carrying breadfruit or its progenitors and are given in years before present (YBP) and come from Kirch (2000)* or McCoy et al. (2010)**

village during a time of famine. The similarities suggest that the stories may have been passed along with the breadfruit from island to island.

Genetic and morphological data from hundreds of breadfruit cultivars and the two progenitor species are now available and have begun to paint a picture of breadfruit origins and its path of human-mediated distribution throughout the islands of Oceania (Zerega et al. 2004). Breadfruit in Melanesia and Polynesia bear the genetic fingerprint of breadnut alone, while much of the breadfruit in Micronesia bears the fingerprint (and morphological characteristics) of both progenitor species. Considering these data in light of what is known about human colonization of the islands helps explain this pattern (Fig. 2).

The Lapita were a seafaring people on the move out of Southeast Asia, and they quickly fanned eastward from northern New Guinea about 3,500 years ago, spreading through Melanesia and Polynesia bringing plants (like breadnut) with them. *Artocarpus* seeds remain viable for only a few weeks, so as the distances of voyages increased into the more remote and not yet colonized islands of Polynesia, vegetative propagation through root cuttings would have been the preferred method of transport – this is also true for many other important crops in Oceania which are vegetatively propagated, including *Colocasia esculenta* (taro), *Dioscorea spp.* (yams), and *Piper methysticum* (kava). Successive generations of vegetative propagation eventually gave rise to seedless triploid cultivars that were preferentially selected. Additionally, the genetic diversity and level of seediness of breadfruit decreases eastward from Melanesia into Polynesia with the progressive narrowing of the gene pool with subsequent migrations. Generally, the prominence of seedless cultivars increases as one travels from New Guinea eastward through Melanesia (where seeded cultivars are common) into western Polynesia (where few-seeded and seedless cultivars are prevalent) and into eastern

Polynesia (where virtually all cultivars are seedless triploids). Finally, a long-distance migration from eastern Melanesia (possibly from Vanuatu or the Solomon Islands) into Micronesia brought *A. camansi*-derived breadfruit into the range of *A. mariannensis* where the two species hybridized, giving rise to a new suite of breadfruit diversity bearing the genetic fingerprints of both progenitor species.

Cross-References

▶ Human Migration: Bioarchaeological Approaches
▶ Oceania: Historical Archaeology
▶ Plant Domestication and Cultivation in Archaeology

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Basic Biographical Information

James Henry Breasted (1865–1935) was an American Egyptologist best known for his work as a historian, philologist, and epigrapher and as the founder of the Oriental Institute at the University of Chicago. Born in 1865 in Rockford, Illinois, Breasted was from a family of modest means; his father was a hardware store owner and, later, a traveling salesman. Consequently, Breasted's path to academia was fraught with financial struggle. The need to support his family was a factor in the considerable amount of educational outreach work – from public lectures to popularizing books – that he accepted; as a result, he became one of the most widely known historians of his generation (Ambridge 2010; for examples of popular work, see Breasted 1908, 1916).

Between 1880 and 1890, Breasted studied at several institutions: Northwestern College in Naperville, IL, where he concentrated in Latin; the Chicago College of Pharmacy; and the Chicago Theological Seminary. After excelling in Hebrew at the seminary, he was encouraged to pursue graduate work in Semitic languages with William Rainey Harper at Yale University (Breasted 1943: 13-25; Abt 2011: 4-16). After a year of study at Yale, and with the encouragement of Harper, Breasted departed for Germany in order to obtain a doctorate in Egyptology, a field of study not yet well established in American academia. In 1891 he matriculated at the Humboldt University of Berlin (known at the time as Friedrich-Wilhelms-Universität) and studied for the next 3 years under Adolf Erman, one of the foremost Egyptologists in Germany. By the fall of 1894, Breasted had completed his doctorate with a dissertation on the sun hymns of the New Kingdom pharaoh Akhenaten; married Frances Hart, a fellow American expatriate living in Berlin; secured a position as assistant in Egyptology at the University of Chicago; and embarked on his first tour of Egypt (Breasted 1943: 33-40, 58-66; Abt 2011: 23-40). He would remain with the University of Chicago for the duration of his career.

Major Accomplishments

Breasted excelled in languages; among those that he commanded were German, French, Latin, Hebrew, Arabic, ancient Egyptian (including Coptic), and Assyrian. With his educational background rooted in philology, he gradually pioneered new epigraphic methods of copying, recording, and photographing ancient inscriptions. Crucial to the development of his epigraphic methodologies were the years from 1894 to 1908, when he was granted several leaves of absence from the University of Chicago in order to conduct research abroad. From 1899 to 1901, he toured the major museums of Europe, where he photographed, transcribed, and translated all of the museums' historical inscriptions of ancient Egypt (Wilson 1936: 99; Breasted 1943: 103-15; Abt 2011: 75-8). This work contributed to Adolf Erman's Egyptian dictionary – the *Wörterbuch der ägyptischen Sprache* – and culminated in Breasted's own multivolume *Ancient Records of Egypt*, published in 1906. His first tour of Egypt occurred in the winter season of 1894/1895, during which he recorded inscriptions at major archaeological sites in the Nile valley north of Aswan. In the winter seasons of 1905/1906 and 1906/1907, he led expeditions through both Upper and Lower Nubia from Naga in the south to Beit el-Wali in the north, further refining his epigraphic methods (for photos of these expeditions, see Larson 2006).

In the years between 1908 and 1919, Breasted focused on teaching, writing, and administration; he was the chair of the University of Chicago's Department of Oriental Languages and Literatures as well as the director of the Haskell Oriental Museum (now the Oriental Institute Museum). The most notable publications from the first half of his career include his popular and widely read *A History of Egypt from the Earliest Times to the Persian Conquest* (1905); *Ancient Records of Egypt* (1906); *Development of Religion and Thought in Ancient Egypt* (1912); and *Ancient Times, a History of the Early World* (1916), a textbook written for high school students.

Ancient Times had a significant impact on the future of American Egyptology when the book received a favorable response from Frederick Gates, business advisor to John D. Rockefeller, Sr. and his son, John D. Rockefeller, Jr. Consequently, Breasted sought research funding from the Rockefeller Foundation and in 1919, John D. Rockefeller, Jr. committed to 5 years of financial support, enabling Breasted to found the Oriental Institute at the University of Chicago. The Institute's first project in 1919/1920, led by Breasted, was a 9-month reconnaissance survey throughout the Middle East, a region of the world undergoing profound changes in the aftermath of World War I. On this trip, Breasted's team evaluated such sites as Ur, Lagash, Babylon, Assur, Nineveh, and Khorsabad (Emberling 2010).

With continued funding from Rockefeller, Breasted established permanent field headquarters for the Oriental Institute in Luxor, Egypt. Named "Chicago House," the site still serves as the base for the Institute's ongoing Epigraphic Survey of Theban temples, a project initiated by Breasted in 1924. By 1928, Breasted secured a multimillion-dollar grant from the Rockefeller Foundation, resulting in a permanent endowment for the Oriental Institute and the construction of the Institute's research center, completed in 1931 (Abt 2011: 284-6, 345-9). Although Breasted did not identify himself as an archaeologist – he acknowledged the difference between the goals and methodologies of his epigraphic work and those of excavations run by such archaeologists as Flinders Petrie and George Reisner – in his capacity as director of the Oriental Institute he initiated excavations at such sites as Megiddo, Çatal Hüyük, Khorsabad, Tell Asmar, and Persepolis.

The heavy administrative duties of the Oriental Institute slowed Breasted's own research during the second half of his career. Two notable publications from this period are *The Edwin Smith Surgical Papyrus* (1930) and *The Dawn of Conscience* (1934). His wife, Frances, died in 1934; in June of 1935, he married his wife's younger sister, Imogen. The marriage was short-lived, however, as Breasted fell ill on the return journey from a tour of the Middle East in that same year. By the time his ship arrived in New York, Breasted had developed a streptococcal infection and he died on December 2, 1935, at the age of 70. He was survived by three children: Charles, James Henry, Jr., and Astrid.

Cross-References

- ▶ Empire in the Ancient Near East, Archaeology of
- ▶ Histories of the Archaeological Discipline: Issues to Consider
- ▶ History and Archaeology: Relationship Over Time (US Perspective)

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British Isles: Medieval Archaeology

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Introduction

As a geographic entity the British Isles refers to the two large northwest European islands of Great Britain (England, Scotland, and Wales) and Ireland and the smaller offshore islands which belong in their jurisdictions. The term is not popular in the Republic of Ireland, independent of British rule since 1922 and a republic since 1949, but, with attempts to re-brand the two islands as an Atlantic archipelago not having had much success, Irish commentators across a multiplicity of scholarly fields refer instead to "Britain and Ireland" (or "Ireland and Britain"). Historically, the "British Isles" is acceptable, however, and has no relationship with issues of modern sovereignty.

Definition

Traditionally, there are two problematic areas of definition, one of the discipline itself and one of the temporal boundaries and internal temporal subdivisions of the Middle Ages. These matter less to those medieval archaeologists (increasing in number) who engage directly with archaeological theory than they do to archaeologists of a more traditional, cultural-historical, persuasion, but they remain at the core of the discipline nonetheless.

Regarding the former, there are two ways of viewing Medieval Archaeology. One is period based: it is simply the study of the archaeological record of the Middle Ages and differs from prehistoric archaeology only insofar as a historical record provides clues to understanding and dating material remains. The second is sensitive to the particular epistemological challenges posed by a written record alongside a material record and is conscious of the skills required to negotiate the historical record without feeling reliant on those skills. In many ways, this distinction between two types or conceptions of Medieval Archaeology parallels a similar distinction in the field of Historical Archaeology.

Regarding the second of the two problematic areas of definition, the debate as to the start and end dates of the Middle Ages is a slightly irrelevant one in that there was no understanding among medieval people that they were in the middle of anything. But the consensus now is that if a start date for the Middle Ages in the British Isles is required, the best option is to assign the collapse of the Roman Empire in the early fifth century and the near-simultaneous diffusion of Christianity from that Roman world into the "Celtic West," to the very end of the premedieval period. This brings the insular chronology into line with that of much of Continental Europe, especially western Europe and the Mediterranean lands. The watershed in England, southern Wales, and southern Scotland is marked specifically by the departure of Roman legions and, in eastern England, by the beginnings of Anglo-Saxon period, the latter a phenomenon that is still hotly debated. The transition from premedieval to medieval is less well defined in other parts of Britain, but the indigenous populations of these areas, speaking what are described by modern scholars as Celtic languages, would not have been unaffected by the presence of Roman culture and so would not have been unaffected by its ending, even if it took time for the cultural implications of the Roman departure to be absorbed. Ireland was not part of the Roman Empire, but the earliest documentation of Christianity dates from the early fifth century and specifically the sending by the pope of a bishop (Palladius) to minister to Christians (presumably Roman traders) resident on the island. A later though still fifth-century bishop, Patrick, is credited with the conversion of the people of Ireland, though other unnamed missionaries must have been involved and the process must have continued into the 500s if not also the 600s.

There is less consensus on the end date of the Middle Ages, mainly because moments or events which stand out as historically pivotal do not necessarily chime with shifts in worldviews or changes in material practice, the indicators that archaeologists use in periodizing. For archaeologists who like historical correlatives, the period of Henry VIII's reign (1509–1547) provides two key touchstones: his establishment of the Protestant Church in the 1530s and the dissolution of the monasteries between 1536 and 1541. Archaeologists who work more independently of historical narratives prefer to focus on the emergence of Renaissance culture or the shift from "feudalism," which is a hotly contested concept, to "capitalism," which is slightly less hotly contested (Gaimster & Stamper 1997; Gaimster & Gilchrist 2003). For these phenomena there is no fixed chronology and certainly none that can be applied to all parts of the British Isles. There is at least some agreement that, even in the most remote parts of the islands, the medieval period is over by the start of the seventeenth century.

Key Issues/Current Debates/Future Directions/Examples

Aspects of the medieval past on the two islands, whatever the chronological boundaries given to that past, have been the specific subject of archaeological investigations as we might understand them today since the early twentieth century (Gerrard 2003). Archaeological work of the 1800s, fitful with respect to the medieval heritage, is best regarded under the heading of "antiquarianism": conservation work on medieval monuments in Great Britain, for example, usually necessitated wall-chasing trenches, dug and emptied with little concern for data other than structural and material. Among the key works establishing the modern discipline was E.T. Leeds, *The Archaeology of the Anglo-Saxon Settlements* (1913), a work which, through opening up the potential of archaeological investigations to reveal the origins of the English people, laid the foundation for the especially enduring richness-of-tradition of Anglo-Saxon archaeological scholarship, a foundation built upon by the discovery of the Sutton Hoo Anglo-Saxon burial in 1939. There are no such benchmarks in Ireland until the publications of the excavations of a series of early medieval sites by Hugh O'Neill Hencken of *The Harvard Mission to Ireland 1932–36*. To the preoccupation with Anglo-Saxon and Celtic archaeologies during the first decades of the last century was added a concern, mainly in the 1970s, for Viking Archaeology, the impetus being the urban excavations in York and Dublin. By that stage the discipline had its own dedicated society, the Society for Medieval Archaeology, founded in 1957, the journal of which, *Medieval Archaeology*, still generously offers a forum for pan-European investigations but is still largely comprised of papers on British themes. Research on the High Middle Ages, the period starting with the Norman invasion of England of 1066, followed by the Anglo-Norman spread into lowland Scotland and (especially) eastern Ireland in the twelfth century, was less systematically conducted, reflecting somewhat ironically the much greater diversity and volume of high-medieval archaeological material on the one hand and the availability of an historical record to provide an overarching interpretative framework on the other. That is not to say that there was no systematic research; on the contrary, projects like the excavations at Wharram Percy, and organizations such as the Medieval Pottery Research Group (founded in 1975), created a rich tradition. Works of synthesis only appeared late in the century (Clarke 1984; Barry 1987; Yeoman 1995), after the Society for Medieval Archaeology had celebrated its quarter-century anniversary with a volume of essays (Hinton 1983) which revealed a youthful discipline in thrall to historical narratives and, arguably, struggling to achieve some rapprochement with the New Archaeology (or processual archaeology, as we call it now).

The last quarter of the century has seen significant growth in Medieval Archaeology in these islands. The expansion of lectureships in British and (mainly in the 1990s) Irish universities puts it alongside longer-established areas on the educational curriculum. Medieval Archaeology remains a strongly cross-disciplinary pursuit in these islands, and most archaeologists possess a cognizance of the historical record and an ability to make sense of it without feeling enslaved by it. Traditional questions remain on the agenda – the origins of the English village and, by extension, the origins of Englishness itself; rural settlement in Scotland and Wales; and the fugitive archaeology if Gaelic-Irish communities in high medieval Ireland – but answers, while not definitive, are more advanced. More significantly, progress in "scientific archaeology" – the reconstruction of diet from skeletal remains and DNA analysis of human populations and remote sensing (such as LiDAR) on the other – has had a transformative impact on our understanding of medieval populations and their activities and, to the credit of practitioners, has been advanced with full cognizance of the importance of connecting "scientific" understandings to "cultural understandings." Moreover, there has been a parallel growth in awareness of the value of thinking theoretically beyond traditional culture-history (although it is markedly less advanced in Ireland, where even the New Archaeology was eschewed in the 1970s), than in the United Kingdom; comparison between the publication celebrating of the Society for Medieval Archaeology's half-century anniversary (Gilchrist & Reynolds 2009) and that of 25 years earlier shows the extent to which the subject has grown in recent years.

Cross-References

- ► Burial Excavation, Anglo-Saxon
- ► Council for British Archaeology (CBA)
- ► Crannog Investigations in Scotland
- ► Medieval Pottery Research Group (MPRG)
- ► Society for Medieval Archaeology
- ► Urban Archaeology
- ► York Archaeological Trust

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British Museum

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Basic Information

Situated in Great Russell Street, London, the British Museum (http://www.britishmuseum.org/) was created by an Act of Parliament in 1753 and opened to the public in 1759. Governed by a board of 25 trustees in accordance with the British Museum Act of 1963 and the Museums and Galleries Act of 1992, the museum is a nondepartmental public body, sponsored by the Department for Culture, Media and Sport. The museum's stated purpose is "to hold for the benefit and education of humanity a collection representative of world cultures and to ensure that the collection is housed in safety, conserved, curated, researched and exhibited" (British Museum n.d.).

The British Museum originated with the collection belonging to physician and naturalist, Sir Hans Sloane (1660–1753), which consisted of natural history specimens, ethnographic material, antiquities, jewelry, coins, medals, prints, and Orientalia. This was combined with a large library of manuscripts assembled by Sir Robert Cotton, and the Harleian Library, the manuscript collection of the earls of Oxford. Expanded in

1757 with the addition of King George II's donation of the old Royal Library, the museum thus originally mainly consisted of natural history specimens, books, and manuscripts. In 1772, the museum acquired its first collection of notable antiquities with the Greek vases belonging to Sir William Hamilton. In 1807, it created a specific Department of Antiquities which, in 1860, was divided into three: Greek and Roman Antiquities, Oriental Antiquities, and Coins and Medals. In the early 1880s, the museum divested itself of its Natural History collection, consequently making space for its expanding collection of antiquities. In 1997, the books and manuscripts making up the National Library were moved from the British Museum to their new home at St Pancras, and the museum's circular Reading Room subsequently incorporated, in 2000, into the redesigned Great Court (Wilson 2002).

Today the Museum is made up of ten departments, primarily consisting of antiquities, which together contain eight million objects: The Department of Ancient Egypt and Sudan houses material from the Nile Valley, spanning the Predynastic Neolithic c.10,000 BCE to the Coptic Christian period in the twelfth century CE. It includes such famous objects as the colossal bust of Ramesses II, the Gayer Anderson cat, the Amarna Tablets, and the Rosetta Stone. The Department of Greece and Rome houses Mediterranean antiquities dating from the Bronze Age to the fourth century CE and includes bronze sculpture, Greek vases, elements from the Mausoleum at Halicarnassus and the Temple of Artemis at Ephesus, and the controversial Elgin Marbles. The Department of the Middle East focuses upon the material culture of Mesopotamia, Iran, the Levant, Anatolia, Arabia, Central Asia, and the Caucasus from the Neolithic period to the present. It contains objects such as Sumerian material from the royal cemetery at Ur, the Old-Babylonian "Queen of the Night" plaque, the Black Obelisk of Shalmaneser III, and the lion-hunt reliefs from the Assyrian palaces at Nimrud and Nineveh.

The museum's Department of Prehistory and Europe focuses on the Paleolithic and Neolithic periods, the Bronze and Iron Ages, Roman Britain, and the Medieval and Renaissance periods up to the present. It houses such objects as the seventh-century CE Sutton Hoo Anglo-Saxon ship burial and the Lewis Chessmen. It works in conjunction with the Department of Portable Antiquities and Treasure which coordinates the Portable Antiquities Scheme through which archaeological objects found by members of the public are recorded, and which administers the Treasure Act 1996 on behalf of the UK Government. The Department of Asia contains material spanning the Neolithic c. 4000 BCE to the present and includes the Buddhist limestone reliefs from Amaravati. The Department of Africa, Oceania and the Americas combines ethnographic, historical, archaeological, and contemporary material and includes the controversial Benin bronzes. The Department of Coins and Medals is concerned with the history of coinage from the seventh century BCE to the present. The Department of Prints and Drawings contains the National Collection of Western prints and drawings, dating from the fifteenth century to the present day. And the Department of Conservation and Scientific Research works with the other departments to conserve and study the collection.

Major Impact

The British Museum can claim to be the first national museum in the world. Its collection is among the largest and most extensive in existence and formed the basis of what later became the Natural History Museum which opened in 1881 and the British Library created in 1973. The museum has a long association with archaeological excavation, beginning with Charles Fellow's expedition to Xanthos in Asia Minor in 1840. It supported Austen Henry Layard's excavations in Assyria which resulted in the discovery of Ashurbanipal's great library of cuneiform tablets. The museum was also involved in the creation of the Egypt Exploration Fund in 1882. The museum maintains an active role in many national and international archaeological fieldwork projects. It encourages its staff to participate in excavation and fieldwork and is one of the chief British sources of funds for research excavation. The museum is also inextricably involved in the debate about the Return of Cultural Property, with the Elgin Marbles, the Rosetta Stone, and the Benin Bronzes as the most prominent among the contested objects in its collection (Wilson 2002).

The museum is the UK's most popular visitor attraction (FitzGerald 2012) and seeks to actively engage with the public. Museum facilities such as departmental study rooms and libraries are accessible to members of the public undertaking their own research. The museum collection is available online with a searchable database containing 2,036,885 objects, 703,883 of which are accompanied by photographs. The British Museum Press publishes books relating to exhibitions and aspects of the collection, and the museum also has three online journals – *The British Museum Studies in Ancient Egypt and Sudan*, *British Museum Technical Research Bulletin*, and *Bronze Age Review*. The museum website also includes a blog containing regular posts by members of staff on recent news, exhibitions, acquisitions, aspects of the collection, and archaeological excavations. The museum works in partnership with universities to offer higher education courses, actively encourages visits by school groups, and holds family-focused events.

Cross-References

▶ Conservation in Museums
▶ Encyclopedic Museum
▶ Ethics of Collecting Cultural Heritage
▶ Heritage Museums and the Public
▶ Heritage Theory
▶ Parthenon (Elgin) Marbles: Case Study
▶ Repatriation: Overview

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British Pioneers and Fieldwork Traditions

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Introduction

From its antiquarian origins, the development of field method in Britain reflects attempts by archaeologists to balance the merits of survey against excavation, research against rescue, and empiricism against theorized interpretation. While early methods lacked consistency, most were based on a modified form of empiricism known as inductivism: observations in the field gathered together to create interpretative statements (Marsden 1983). Richard Colt Hoare (1758–1838), excavator of more than 500 sites in the early 1800s, memorably summed up the position by declaring that "We speak from facts not theory" as the epigraph to *Ancient Wiltshire* published between 1812 and 1820. Importantly, a community of practice emerged to foster a network of amenity societies.

Key Issues/Current Debates/Future Directions/Examples

The late nineteenth century was a watershed in the development of archaeological fieldwork. Positivism strengthened as the preferred philosophy, suiting archaeology well by perpetuating distinctions between *facts* as things that could be observed and *laws* or *interpretations* as statements making sense of the facts. Maintaining the integrity of the facts therefore became important, and one of the main steps toward achieving this involved structuring investigation methods and recording systems. Leading this field was General Pitt Rivers (1827–1900) whose interests in social evolution carried through to developing a method of excavation that charted sequences of activity at particular sites. In practice, this meant recording every object so it could be replaced accurately in its findspot through the use of plans and section drawings – essentially three-dimensional recording of finds. A generation later, Mortimer Wheeler (1890–1976) added the need to record strata (every layer) three dimensionally as well. To achieve this, he developed an excavation method that still bears his name – the Wheeler system – in which the area of investigation was divided into squares with balks between. Each square was separately excavated, and the plans and four sections of each carefully drawn (Wheeler 1954).

Continental methods of *open-area excavation* were meanwhile imported into Britain, notably by Gerhard Bersu (1889–1964) at Little Woodbury, Wiltshire, in 1938–1939. This approach to excavation and recording had far-reaching consequences after the Second World War, but even during the war, a small team of archaeologists led by W.F. Grimes (1905–1988) recorded sites in this way before they were destroyed by the construction of military installations. Noteworthy was Grimes' rigorous open-plan excavation of the Burn Ground long barrow, Gloucestershire, in 1940–1941, where he planned every stone in the mound. After the war, rebuilding programs coupled with industrial expansion, agricultural extensification, urban regeneration, and infrastructure renewal created many opportunities for archaeological investigation. Subsequent changes in methodology can be gauged from five successive textbooks on the subject by Richard Atkinson (1946), John Coles (1972), Philip Barker (1977), Ian Hodder (1999), Steve Roskams (2001), and Martin Carver (2009).

Operationally, work has expanded into hitherto under-investigated environments such as occupied towns, wetlands, uplands, agricultural land, and coastlands, often with rich rewards. Practically, there was much experimentation with the shape and size of excavation trenches, including uses of quadrant methods, *planum* systems, and large-scale open-area excavation taken from continental innovations. However, in Britain, attention remained focused on the removal of individual layers or *contexts* as they became widely known, in the reverse stratigraphic order to deposition. Teasing apart complicated sequences, finding natural construction or erosional surfaces, positive and negative features, deposits, and cuts became a technical as well as an intellectual challenge. Finds were associated with contexts as the basic unit of recovery, and the application of archaeological site science promoted systematic sampling for ecofacts and artifacts down to microscopic levels as well as the recovery of environmental indicators and chemical characterization.

In field survey, the tradition based on the idea of cultural property and monuments promoted by Pitt Rivers was continued for much of the twentieth century by government-sponsored *Royal Commissions* which had the remit of recording everything visible on the surface (Crawford 1960). Aerial photography was adopted for archaeology immediately after World War 1 and exported to the countries of the then British Empire. The postwar period saw the development of *landscape archaeology*, a set of more sophisticated and analytical approaches that focused on wide geographical areas and assumed that the land was regularly overwritten by successive generations to form a *palimpsest* (Darvill 2001). Aerial photography, remote sensing, ground surveys, place-name studies, and past cartography were among the many primary sources used to create landscape regression models – snapshots of a landscape as it might have been at a particular period. Uniquely, in England, where treasure hunting on private property remains legal, a new voluntary scheme has encouraged the reporting of objects found by metal detectorists. The *Portable Antiquities Scheme* has produced an immense harvest of reported finds, creating a rich geographical database of dated artifacts, the majority of metal.

From the 1960s, representatives from museums, universities, local and national archaeological societies, local authorities, and the government agencies began working together to meet the needs of *rescue archaeology* in their locality. While the rescue of archaeological sites in Britain is not obligated by law, in 1990, its justification was embedded in Planning Policy Guidance Note 16 (=PPG16 *Archaeology and Planning*) for England, with similar statements for other parts of Britain, and these have remained the basis for the funding of archaeological intervention by the private sector. In excess of 4,800 investigations a year were being undertaken in England alone by the year 2000. This has coincided with a revolution in IT, resulting in innovative approaches to on-site data capture and the subsequent production and processing of plans, sections, photographs, and descriptive records. Compiled in *client reports*, these are presented to the commercial sponsors of the work in fulfillment of contact.

More than 95 % of archaeological fieldwork in Britain is now prompted by planned commercial development. It comprises predetermination work such as desk-based assessments, field evaluations, and environmental impact assessments, and post-determination work that focuses on mitigating impact, implementing conservation measures, recording buildings, and investigating deposits faced with destruction through a range of techniques that include both trenching and open-area excavation. Conceptually, the *archaeological resource* of the 1970s and 1980s, *heritage* as it was called in the 1990s, has now been redefined as *historic environment assets*. Large-scale projects remain common, including, for example, the high-speed railway line from London to the Channel Tunnel and Terminal 5 at London's Heathrow Airport. But size is less important than quality. Since revisions to the planning system in 2010 and the gathering strength of *localism* as a political philosophy, integrating archaeology with local communities and using the knowledge generated to create public value have taken center stage.

Economic instability and the global recession are having an effect on archaeological fieldwork traditions in Britain at the time of writing (early 2012). The profession has already scaled back, and more cuts are anticipated in order to meet lower demand for archaeological services (Aitchison 2010). On the brighter side, current conditions allow the chance to take stock of achievements over the past 20 years: to rebalance the scope and aims of fieldwork, reconcile positivist and relativist approaches under the rubrics of creative science and community engagement, promote academic recognition and definitions of the discipline, and integrate opportunities offered by development-driven research with the power of problem-orientated research – in fact, a twenty-first-century version of the agenda faced 300 years ago by the founders of Britain's fieldwork traditions.

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▶ Archaeological Record
▶ Excavation Methods in Archaeology
▶ Landscape Archaeology

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British School at Athens

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Basic Information

The British School at Athens is a research institute for Hellenic studies across all fields and periods. Situated in the center of Athens, the school consists of a hostel for resident scholars, an extensive library with map and archive collections, a small museum, and the Fitch Laboratory for science-based archaeology. At Knossos, the BSA maintains a residential field center and Stratigraphical Museum which form the base for its excavations and research in Crete. Work conducted by the school was published in the *Journal of Hellenic Studies* until the establishment of the first volume of the *Annual* for the 1894–1895 session. Each year since 1955 the school has produced a digest of all fieldwork in Greece, *Archaeology in Greece*, jointly with the Hellenic Society and now supplemented online in a collaboration with the French school. The school's website is at www.bsa.ac.uk.

Foundation and Early History

As the discipline of archaeology rapidly developed in the nineteenth century, a number of countries established foreign schools in Greece. The first to open in Athens was the École française d'Athènes in 1846, followed by the Deutsches Archäologisches Institut in 1874, and in 1881 the American School of Classical Studies. The idea for a British institute in Athens was championed by Sir Richard Jebb, whose "Plea for a British Institute at Athens" in the *Fortnightly Review* in May 1883 provided the impetus for a public meeting held by the Prince of Wales, later King Edward VII, at Marlborough House in London, with guests including Lords Salisbury and Rosebery and the Prime Minister, William Gladstone. A committee was formed for the school which gathered donations toward the construction of a building in Athens.

During a visit to Athens in 1878, Jebb had contacted Charilaos Tricoupis, then foreign minister of Greece. In 1882 Tricoupis became prime minister and the following year offered a plot of land donated by the monastery of Petraki for the school on the slopes of Mt. Lykavittos. Opened in November 1886, the school building (now the Director's residence) was completed according to a design by the first Director, Francis Penrose, who had studied Athenian architecture for the Society of Dilettanti. Increased student numbers necessitated the building of a separate hostel at the lower end of the garden in 1897, which after three subsequent enlargements now comprises accommodations, offices, and common areas and is linked to the Penrose Library, built in 1904 and itself subsequently enlarged.

Financially, the school was reliant upon subscriptions and donations until Her Majesty's Treasury was persuaded to support the institution with an annual grant. Today, the school's principal funding is provided by the British government through the British Academy.

Major Impact

Archaeological Fieldwork

From its origins, the school was interested in a wide spectrum of fields: anthropology and ethnography, history, epigraphy, linguistics, art, and architecture. Among its archaeological fieldwork the school has excavated widely in the Cyclades, Crete, Laconia, and Macedonia. One of the earliest major digs was at Phylakopi on Melos, begun in 1896, which began a long-standing focus for the school on the prehistory of Greece. Duncan Mackenzie's stratigraphical work here was advanced for its time, providing him with skills he would later bring to Knossos in 1900 as the deputy of Sir Arthur Evans.

In the early years of the twentieth century, the school began its long association with Sparta and its surrounding Lakonian territory. Excavation began at Sparta in 1906, and investigations over a hundred years have uncovered the shrine of Athena Chalkioikos and the city's theater, the Sanctuary of Artemis Orthia, the Menelaion, Agios Stephanos, Kouphovouno, and Pavlopetri.

The school also maintains a long association with Mycenae. In 1920 the then Director of the school, Alan Wace, began working within the citadel as well as excavating the prehistoric cemetery outside it, investigating all nine tholos tombs in the surrounding area; his work was continued by Lord William Taylour in several seasons between 1960 and 1969; Wace's daughter, Elizabeth French (BSA Director, 1988–1994), has continued the school's work there in cooperation with the Greek Archaeological Service in the Mycenae survey.

Other important excavations carried out by the school include the following: the harbor and sanctuary site at Perachora in the Corinthia, conducted between 1930 and 1933 by the then Director Humfry Payne; work of the islands of Chios and Mytilene, including the 1930s excavations of Winifred Lamb at Kato Phana and Thermi, respectively; and at Lefkandi in Evia, where investigation of the settlement of Xeropolis began in 1964 under Mervyn Popham and Hugh Sackett, followed by discoveries in the cemeteries, including the remarkable Toumba building.

The BSA also has a strong tradition in archaeological survey from the broad regional surveys of Wace and Thompson in Thessaly and Macedonia and John Pendlebury on Crete to the pioneering intensive surveys of Melos by Colin Renfrew and John Cherry. In more recent years large-scale field surveys have investigated Laconia, Boeotia, Kythera, and the Knossos valley, adding greatly to the methodological underpinning of this important field.

Crete

The school has a history of involvement in Crete beginning with the formation of the Cretan Exploration Fund in 1899, a joint venture between Sir Arthur Evans and the then Director D. G. Hogarth. Evans began digging at Knossos in 1900, while Hogarth investigated the Dictaean Cave, one of the supposed birthplaces of Zeus, and at the Minoan palace site of Kato Zakro. In 1901 and 1902, R. Carr Bosanquet excavated at the east Cretan site of Praisos, discovering inscriptions in the non-Greek language of Eteocretan; he later excavated the Minoan town of Palaikastro, where further excavations have continued since the 1960s.

Evans continued his work at Knossos for 21 years, with regular reports in the *Annual of the British School at Athens*. The spectacular excavations caught the imagination of the world in much the way that Schliemann's earlier excavations of the shaft graves at Mycenae had done. In 1926 Evans donated his entire Knossos estate to the school, including the palace, his own house (the Villa Ariadne), various other excavated areas, and outlying buildings. A Knossos curatorship was instituted, thus establishing a permanent BSA presence on site. In 1955 the school donated the bulk of the estate to the Greek state, retaining the Curator's house and a residential and study facility, and is responsible for the Stratigraphical Museum, where the bulk of recent excavation finds are housed.

BSA Collections

The BSA library covers all aspects of Hellenic studies, holding more than 70,000 books and over 1,300 periodical titles with special emphasis on art, archaeology, epigraphy, archaeological sciences, Modern Greek, and Balkan history and society. The archives form the official repository for the records of the BSA, including documents from fieldwork projects, corporate papers, personal collections of BSA members, various historical documents associated with the early travelers to Greece, a photographic archive, and a unique collection of drawings from the Byzantine Research Fund. A museum houses a study collection of antiquities donated or excavated by the school and a sherd collection of survey pottery from across Greece. The core of the original library and antiquities collection were donated in 1899 by the executors of the Philhellene George Finlay (1799–1875), who first came to Greece in 1823 aged 24, became actively involved with the Greek struggle for independence with Lord Byron, and settled in Athens for the remainder of his life.

The Fitch Laboratory

Founded in 1974, the Mark and Ismene Fitch Laboratory promotes the integrated use of scientific methods and techniques in the archaeological study of material culture. Its research focus is on the study of ancient pottery and metals from Greece and the central and eastern Mediterranean employing optical microscopy and chemical analysis techniques. The Fitch houses reference collections of animal and fish bones, seeds, and pottery thin sections.

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Brown Top Millet: Origins and Development

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Basic Species Information

Brown top millet, which goes by the scientific name *Brachiaria ramosa* (L.) Stapf. or *Urochloa ramosa* (L.) R.D. Webster, is known locally as *pedda-sama* and *korne*, and has a limited cultivation largely confined to southern India. Domestic and wild/weedy forms of brown top millet are found in agricultural systems, often within the same field. It is used as both a human food crop and fodder. Outside of India, it is grown in some parts of the USA as a fodder crop, largely to provide food for game birds, and was introduced from India around 1915. Although its distribution is highly relict today, restricted to parts remote parts of Andhra Pradesh, Karnataka, and Tamil Nadu states in southern India (Kimata et al. 2000), it appears to have been a major staple crop in the late prehistory of the wider region of the Deccan (Fuller et al. 2004).

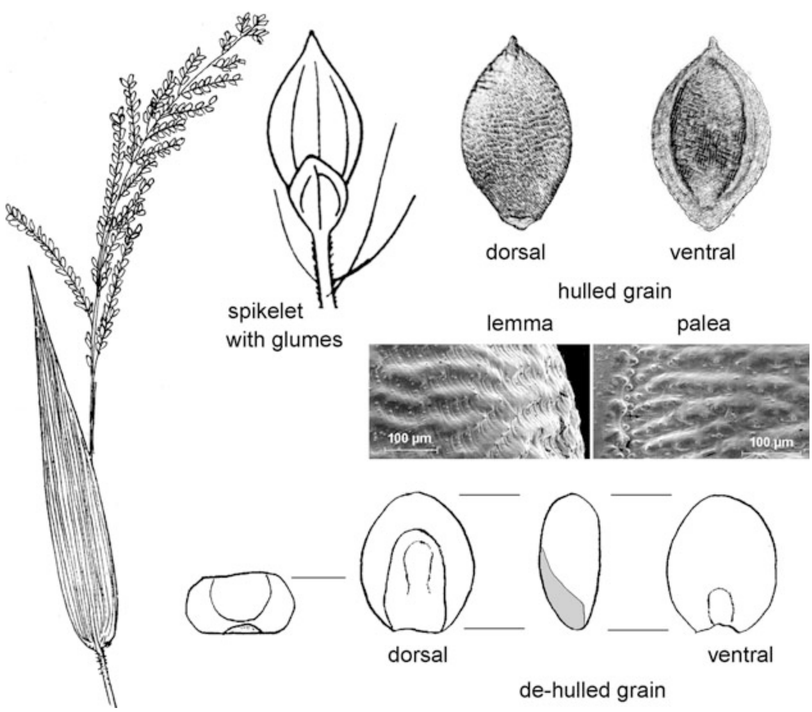
In several parts of India, brown top millet is known by local names which translate to "illegal wife of little millet [*Panicum sumatrense*]," reflecting its tendency to grow within fields of little millet as a mimic weed (Sakamoto 1987). Brown top millet can grow with either a compact or open panicle and can have either shattering or indehiscent spikelets. The domestic form, however, tends to act like other domestic cereals and is both compact and partially indehiscent

(Kimata et al. 2000). Where brown top millet occurs as a weed of other millet fields, it is usually treated as an insurance crop.

Major Domestication Traits

Brown top millet is particularly tolerant of drought and is well adapted to semiarid areas. It grows well at altitudes of 2,000–2,500 m, with 75–150 cm annual rainfall (Roecklein & Leung 1987). Cultivation is more common in the dry areas of Karnataka and Andhra Pradesh at lower elevations, South India, than in other parts of the world. Brown top millet grows and matures over around 90 days, a shorter time than several other millets including pearl millet (*Pannisetum glaucum*). It is usually grown as a single crop and not incorporated into mixed field systems. Harvesting in the early morning while the dew is still on the crop reduces the amount of grain lost through panicle shattering. Shattering (dehiscence) is reduced compared to the wild forms, but it is still partially shattering. The crop tends to be cut at the base, then winnowed, dehusked, and polished. Because it is semi-shattering, its grains can become dislodged just by being dried which reduces the need to thresh, although it requires dehusking like most other millets. Straw and chaff is often used as animal fodder; however, the grain is reserved for human consumption and is said to be tastier than rice. Brown top millet tends to be ground into flour and used to make flat breads (*roti, dosa*) or polished and boiled to make gruel (*anna, kheer*). Some of these foods are used in religious rituals, which may partly account for its persistence in cultivation (Kimata et al. 2000).

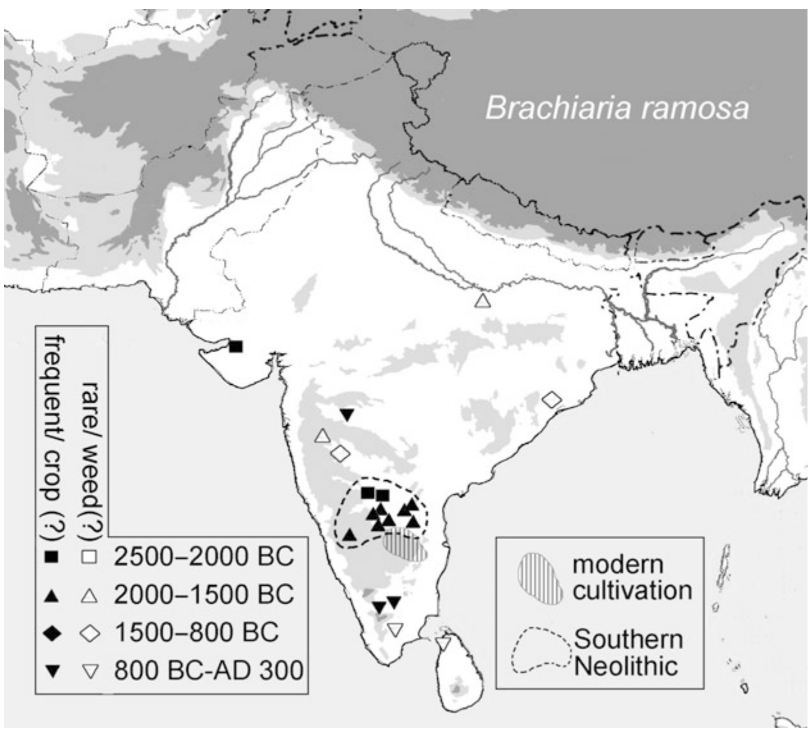
The identification of brown top millet grain and spikelets can be difficult due to its similarity to *Setaria italica* (Fig. 1). Although the panicle is distinct from *Setaria* by being looser and non-bristly, the grains themselves are very similar. Grains are ovate to round and have a long embryo, roughly two thirds to three fourths of the length of the grain. They tend to be smaller than *Setaria italica* and squatter in cross section. The surface of well-preserved grains can be used for identification as these have a distinctive undulating pattern, although this again has similarities to *S. italica* (Fuller et al. 2004). The husk



Brown Top Millet: Origins and Development, Fig. 1 Drawing of *Brachiatia ramosa* panicles, spikelet, hulled and de-hulled grains, showing the rugose husk patterns of the lemma and palea. SEM images of lemma and palea patterns inset has a fine beaded and rugose pattern, which again has some resemblance to that of *Setaria* spp., but it is somewhat coarser than *S. italica* and finer than *S. verticillata*.

Timing and Tracking Domestication

The domestication of brown top millet probably occurred in South India, in the Deccan, and it spread during prehistory outward to other parts of India (Fig. 2). Charred grains identified as "*Brachiaria ramosa* type" have been recovered from most Neolithic South Indian sites where systematic archaeobotanical work has occurred. On these sites brown top millet has a high ubiquity and relative frequency. Dating the time of domestication is complicated by the fact that little archaeobotanic work has been carried out on early Neolithic or preceramic period (Mesolithic sites); however, the evidence suggests that this crop, along with other South Indian crops (i.e., *Macrotyloma uniflorum, Vigna radiata* and *Setaria verticillata*), developed from indigenous wild populations around the beginning of the third millennium BCE (Fuller 2006). During this period, local millets and legumes were incorporated into an agro-pastoral system, part of the ash-mound culture of the southern Neolithic of India, which employed both mobile cattle pastoralism and small-scale crop cultivation. Brown top millet spread out from the Deccan to Tamil Nadu in the south (Cooke et al. 2005) and Gujarat in the north by the end of the second millennium BCE. Small quantities of the grain have also been found from Chalcolithic (late second–early first millennium BCE) sites in Odisha (Orissa) in the east and some sites in the Ganges plains (Harvey 2006), however, the number of grains recovered does not suggest cultivation and may represent wild plants. Over time, brown top millet has seen reduced use, although it was still present at the site of Paithan in Maharashtra up to the seventh century CE. Its gradual reduction in use can be attributed to



Brown Top Millet: Origins and Development, Fig. 2 Distribution map of archaeological finds of *Brachiaria ramosa* in relation to the Southern Indian Neolithic and modern cultivation of this crop displacement by alternative, more productive millets, including the African millets (*Sorghum bicolor*, *Eleusine coracana*), as well as foxtail millet (*Setaria italica*) that probably contributed to this. Today brown top millet is a relict cultivar but one with some important ritual uses.

Cross-References

- ▶ Agriculture: Definition and Overview
- ▶ Archaeobotany of Early Agriculture: Macrobotany
- ▶ Domestication Syndrome in Plants
- ▶ Domestication: Definition and Overview
- ▶ Finger Millet: Origins and Development
- ▶ Genetics of Early Plant Domestication: DNA and aDNA
- ▶ Millets: Origins and Development
- ▶ Plant Domestication and Cultivation in Archaeology
- ▶ Plant Processing Technologies in Archaeology

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Buckley, Kristal

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Basic Biographical Information

Kristal Buckley (AM) received her B.A. (Hons) from Australian National University in 1980. She holds a Graduate Diploma in Social Sciences from the University of New England (1985). Her Master of Public Policy degree was conferred in 1998 from the University of Melbourne.

Major Accomplishments

Kristal Buckley (AM) has served as an International Vice-President of ICOMOS since 2005, and has been an active contributor to many aspects of the work of the International Executive Committee including the ICOMOS World Heritage programme and Scientific Council, and with ICOMOS members and National Committees in the Asia-Pacific region. Trained in archaeology, anthropology, and public policy, Kristal Buckley is a lecturer in Cultural Heritage at Deakin University's Cultural Heritage Centre for Asia and the Pacific in Melbourne, Australia. She has worked as a heritage consultant in private practice and in government. She served as a full member of the Heritage Council of Victoria for 9 years, and has represented cultural heritage professionals at advocacy and advisory forums at the national level. Her work in Australia has included Indigenous and non-Indigenous heritage projects, policy, and management, with an emphasis on community involvement. She is a member of the ICOMOS ISC for Intangible Cultural Heritage. She has also worked as an advisor to governments in environmental policy – particularly in relation to sustainability and climate change and was recently appointed as Member of the Order of Australia for significant service to conservation and the environment, particularly in the area of cultural heritage, and to education.

Cross-References

- ▶ Australia's Archaeological Heritage
- ▶ Australia: Cultural Heritage Management Education
- ▶ Community Archaeology
- ▶ Indigenous Archaeologies: Australian Perspective
- ▶ Indigenous Peoples, Working with and for
- ▶ Stakeholders and Community Participation

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Buckwheat: Origins and Development

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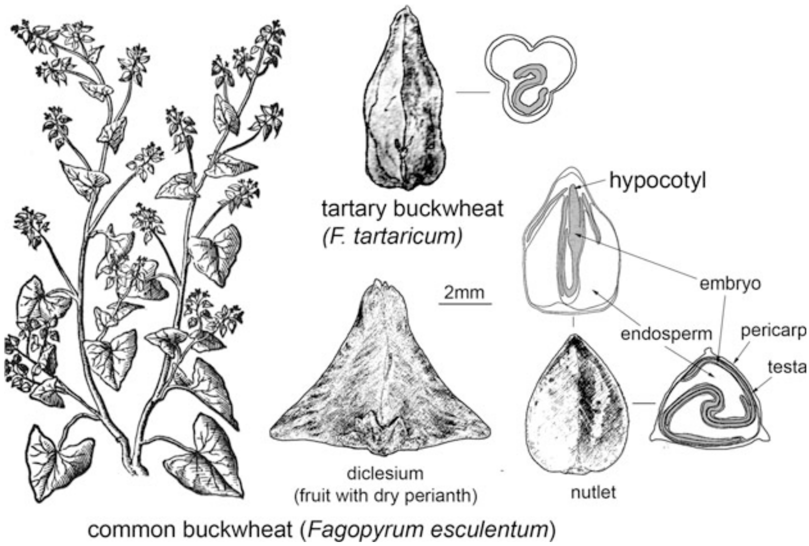
Basic Species Information

Buckwheat, including common buckwheat (*Fagopyrum esculentum* Moench.) and tartary buckwheat or bitter buckwheat (*Fagopyrum tartaricum* (L.) Gaertn.), is one of only three important non-grass starchy grain crops, or pseudo-cereals, the others being grain amaranth (*Amaranthus* sp.) and various chenopods, such as Andean quinoa (*Chenopodium quinoa*). An important crop of marginal lands, buckwheat, is grown in nearly every country that cultivates grain crops and is usually consumed locally (Campbell 1976), but it is especially important in colder regions of high altitude or high latitude in Asia. It is mainly grown for the starchy white endosperm of its seeds which produces buckwheat flour used for pancakes and *blini*, and soba noodles (Japan). The whole hulled seeds are used as breakfast food and to thicken soups. Dehulled grains, milled to remove the pericarp, are used in *kasha*, a traditional Russian dish. Buckwheat has a level of around 9 % protein, has 330–350 kcal per 100 g, and does not contain gluten. Buckwheat is grown as a green manure, is a common animal feed, and is also a major honey-producing plant (Campbell 1997; Van Wyk 2005).

The name *Fagopyrum* is derived from the Greek *fagos*, beech and *pyrum*, wheat. The common name, buckwheat, is from *Buchswein*, German for beech wheat on account of the triangular seeds that look like small beech nuts. Other common names include: *Sarrisin* (French); *grano saraceno*, *fagopiro* (Italian); *kyoubaku*, *soba* (Japanese); *trigo-sarraceno* (Portuguese); *grano sarraceno* (Spanish). Many of the common names, *Sarrasin*, *gran saraceno*, *trigo-sarraceno*, *grano sarraceno*, mean Saracen grain, demonstrating buckwheat's eastern origins, although it actually comes from much further east (van Wyk 2005). For Chinese, it is *qiao-mai*, and in Hindi *kotu*. Less widely cultivated is *F. tartaricum*, the Siberian, Indian, Tartary, or bitter buckwheat, which is especially important for its height tolerance in the Himalayas and Tibet. Another species occasionally cultivated in northeastern India and southwest China is *Fagopyrum emarginatum*.

Major Domestication Traits

Buckwheat is an annual plant with a succulent hollow angular stem, swollen nodes, and



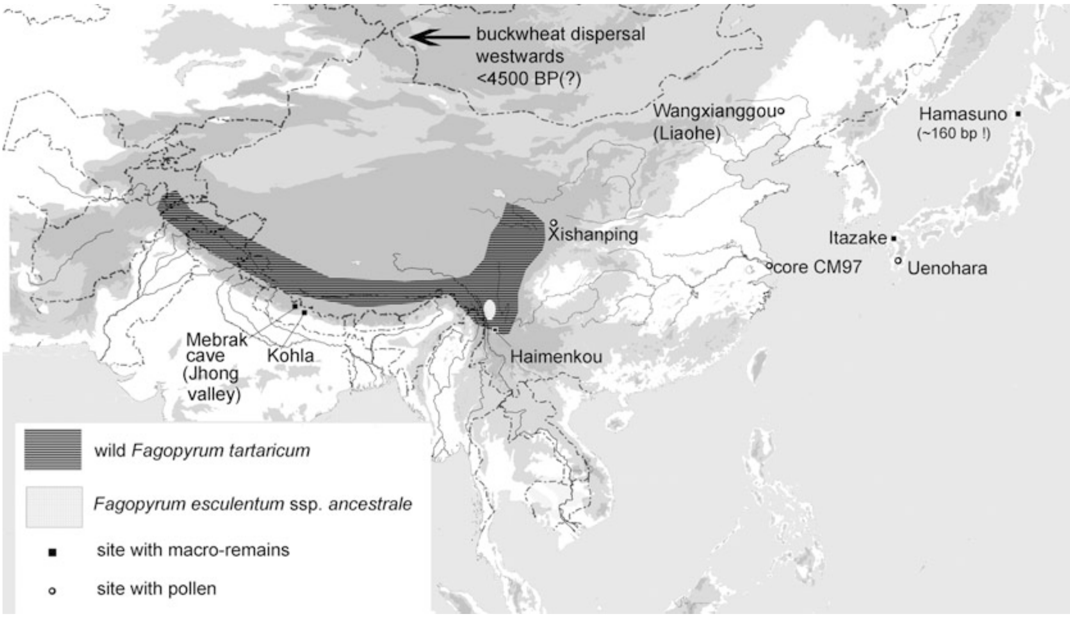
Buckwheat: Origins and Development, Fig. 1 Images of buckwheat, showing the growth habit of cultivated buckwheat (*Fagopyrum esculentum*), the fruit and nutlet with cross sections, with a comparison of the nutlet and cross section of tartary buckwheat (*Fagopyrum esculentum*)

alternate triangular acute leaves 5–10-cm long (Fig. 1). It has terminal and axillary white pink red or yellow flowers, which produce small dry fruits (achenes), which are gray brown to black. These may be technically classified as a diclesium, and after removing the outer dry bracts, yield an edible reddish nutlet with white starchy endosperm (Fig. 1) (Stevens 1912). Comparison of domesticated and wild species suggests selection for annual habit, non shattering inflorescence, low seed dormancy, and increased seed size, much as in cereal crops (Fuller & Allaby 2009). Common buckwheat is normally self-incompatible, and tartary buckwheat readily self-pollinates (Campbell 1976). Plants grow to full height of around 1 m in about 6 weeks and the seeds ripen at around 10–11 weeks. This short growth cycle allows for cultivation in highly marginal habitats and short high elevation summers, although buckwheat has low yield compared to other grain crops. Buckwheat extends easily to above 3,000 m under cultivation, and is grown alongside barley at the highest elevations. Tartary buckwheat is even better adapted to the highest elevations, up to c. 4,000 m.

Buckwheat originates in the Tibetan plateau or nearby mountains of Yunnan, southwest China. There 16 wild species of *Fagopyrum*, all focused on the Himalayan and southwest China region (Campbell 1997). The wild progenitor of *F. esculentum* is thought to be *F. esculentum* ssp. *ancestralis*, which has a limited distribution in the mountains of western Yunnan and Sichuan (Fig. 2). It has a narrow distribution, growing at 1,000–1,500 m above sea level in barren rocky habitats with poor soils along the Jinsha River, Yunnan, and the Yalong River in Sichuan never entering cultivated fields (Ohnishi 2004). Wild tartary buckwheat, *F. tartaricum* ssp. *potanini*, is more widespread on the Tibetan plateau (Fig. 2; see Campbell 1997; Ohnishi 2004).

Timing and Tracking Domestication

Archaeological remains are rare, and much evidence for its spread comes from pollen appearances in palaeoenvironmental sequences. These data have been recently assessed by Boivin et al. (2012), with particular reference to the dispersal westward toward Europe. Pollen finds in three areas of China from c. 4500 BP suggest that cultivation began by the early Third Millennium BCE at the latest (Fig. 2). Finds include from the Liaohe river basin in northeast China after c. 2200 BCE, Xishanping in Gansu to the northwest, where pollen could be as early as c. 2500 BCE, although there are some stratigraphically inconsistent AMS dates might be only about 1000 BCE (Li et al. 2007). Additional evidence comes from the



Buckwheat: Origins and Development, Fig. 2 Map showing distribution of wild *Fagopyrum tartaricum*, the subzone of wild *F. esculentum*, and archaeological and palynological sites that have produced early evidence for buckwheat

Lower Yangzte, suggesting some buckwheat cultivation in the hills south of the Yangzte as early as 4500 BP. Finds from Japan all occur after 4000 BP, with an early reported nutlet from Hamanasuno in north Japan being shown to be intrusive by AMS dating. A few macro-remains finds can be placed in the First Millennium BCE, including from central Nepal and at Haimenkou, Yunnan (Boivin et al. 2012). Later evidence from Nepal is that of Kohla, a site at over 3,000 m from the twelfth to thirteenth century CE.

The westward dispersal across Eurasia is particularly controversial. Some have suggested that pollen evidence indicates Neolithic presence in Europe by the Fifth Millennium BCE (Janik 2002), but a critical review of the archaeological and historical evidence would suggest buckwheat reaches the eastern margins of Europe not earlier than about 4,000 years ago, and central and western Europe only in the late Middle Ages, c. CE 1300 (Boivin et al. 2012). Despite the importance of this crop for allowing expansion of human settlement into some of the most marginal and cold environments, there is still little known of its early cultivation and dispersal.

Cross-References

- ▶ Agriculture: Definition and Overview
- ▶ Archaeobotany of Early Agriculture: Macrobotany
- ▶ Domestication Syndrome in Plants
- ▶ Domestication: Definition and Overview
- ▶ Genetics of Early Plant Domestication: DNA and aDNA
- ▶ Plant Domestication and Cultivation in Archaeology
- ▶ Plant Processing Technologies in Archaeology

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Basic Biographical Information

Jane Ellen Buikstra (1945–) is one of the most influential and outstanding American anthropologists in the field. Her scientific and academic work has had global influence. She obtained her Bachelor's degree in Anthropology from DePauw University in Indiana in 1967, and her Master's (1969) and Doctorate (1972) degrees from the University of Chicago.

She had faculty positions at Northwestern University, University of Chicago, and University of New Mexico. She was Research Associate at the Field Museum of Natural History, the Museum of the American Indian, the University of Florida, and the National Museum of Natural History. Buikstra is currently a Regent's Professor of Bioarchaeology and Director of the Center for Bioarchaeological Research of the School of Human Evolution and Social Change at Arizona State University, Tempe, Arizona.

She has a long association with the Center for American Archaeology where she is President of the Board of Directors. This institution has had a very important role in the development of bioarchaeology. Associated field seasons in Kampsville, Illinois, have included training and educational programs associated with continuous research in numerous archaeological sites including Koster and Mound House as part of contract work with the Central Illinois Expressway program.

Buikstra defined and promoted the field of bioarchaeology, a specialty of archaeological research focused in the integration of information recovered from human remains in the reconstruction of ancient lifeways. This approach has redefined the role of physical anthropologists and archaeologists working with mortuary remains. The specialist trained in the study and recovery of human biological evidence is involved from the recovery fieldwork up to a range of specialized studies including chemistry, diet, growth and health, genetics, and paleodemography. In the area of paleopathology, Buikstra is recognized for promoting the use of rigorous differential diagnosis in the evaluation of lesions in human remains (e.g., Buikstra & Roberts 2012).

Buikstra has received numerous awards and distinctions in recognition of her accomplishments. She was elected a member of the National Academy of Sciences in 1987; was the Harold H. Swift Distinguished Service Professor at the University of Chicago, the Leslie Spier distinguished Professor of Anthropology at the University of New Mexico, and the George E. Burch Fellow in Theoretic Medicine and Affiliated Sciences at the Smithsonian Institution; and received the Pomerance Award for Scientific Contributions to Archaeology from the Archaeology Institute of America.

Buikstra's work has focused on the study of prehistoric skeletal collections incorporating cultural and biological data to evaluate evolutionary change, growth, health, and development. Her studies include important contributions to more fully understanding mortuary behavior, demography, paleopathology, biological distance, and paleonutrition, among numerous topics related to the adaptation and history of prehistoric societies. Buikstra has published numerous articles, books, reviews, and nontechnical publications (see Further Reading section below).

Her publications and academic work show an intense dedication to the promotion of science, the field of anthropology, and the status of women. Buikstra has mentored students and scientists from all over the world, including Indonesia, Australia, Peru, Chile, Argentina, Spain, China, and Ireland, and has contributed to academic programs and professional meetings. Buikstra and her collaborators have significantly influenced aspects of the scientific work involving the recovery, study, and conservation of human remains, both ancient and modern.

Major Accomplishments

Buikstra has received numerous grants to support her research including from the National Science Foundation, the National Institute of Health, Wenner-Gren Foundation, National Geographic Society, National Endowment for the Humanities, the Illinois Department of Transportation, and the Illinois Historic Preservation Agency, among others. She has directed and participated in bioarchaeological projects in most parts of the world, numerous projects in the North American Midwest, as well as in the Canadian Arctic, Argentina, Brazil and Peru, as well as in Spain, Israel, Turkey, and Honduras.

Buikstra has actively participated in professional associations and committees. She has served in different capacities including the top positions in the American Anthropological Association, the American Association for the Advancement of Science, the American Association of Physical Anthropologists, the American Board of Forensic Anthropology, and the Society for American Archaeology.

Buikstra has also contributed as editor of several professional journals such as *American Anthropologist*, the *Journal of the American Association of Physical Anthropologists*, *Evolutionary Anthropology*, the *International Journal of Osteoarchaeology*, *International Journal of Paleopathology*, the *Journal of Forensic Sciences*, and the *Journal of Anthropological Research*, *Chungara*, of the University of Tarapaca in Chile. She has participated, in and promoted research groups that have proposed standards for the analysis of ancient human remains, the evolution of infectious diseases such as tuberculosis, and research and ethical aspects of the fields of forensic and biological anthropology and archaeology.

The ongoing career of Jane Buikstra is characterized by excellence in science reflected in her numerous publications and academic work and her strong commitment to teaching and professional development which has outreached to different parts of the globe.

Cross-References

▶ Age Estimation
▶ Ancestry Assessment
▶ Archaeology: Definition
▶ Biological Distance in Bioarchaeology and Human Osteology
▶ Bone, Trauma in
▶ Children in Bioarchaeology and Forensic Anthropology
▶ Commingled Remains: Field Recovery and Laboratory Analysis
▶ Cremation in Archaeological Contexts
▶ Demographic Transitions
▶ Dental Anthropology
▶ DNA and Skeletal Analysis in Bioarchaeology and Human Osteology
▶ Ethics and Human Remains
▶ Forensic and Archaeological Analyses: Similarities and Differences
▶ Forensic Anthropology: Definition
▶ Human Skeletal Remains: Identification of Individuals

▶ Osteology Reference Collections
▶ Osteology: Definition
▶ Pathological Conditions and Anomalies in Archaeological Investigations
▶ Pathological Conditions and Anomalies in Forensic Contexts
▶ Sex Assessment
▶ Skeletal Biology: Definition
▶ Stature Estimation

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Building Biographies

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Introduction

Developing a biography of a building can be an important way of obtaining information about the activities and beliefs of past societies. The term “building biography” was first used in historical studies, where the approach is different from that of archaeology. In the historical tradition, the house is studied more as the frame around which a family or other social group or institution is investigated, as a case study to gain inside into social conditions of a certain period in a certain area (Russell Ellis et al. 1985; Dakers 1993; Silver 1994; Zaknic 2004; Alexander 2008). Such studies incorporate non-architectural evidence, such as photos and written records made during the lifetime of the building. As these forms of evidence are not available in much archaeological research, an archaeological building biography must focus on evidence from the architectural body itself.

The archaeological building biography was developed from the biographical study of artifacts, a concept influenced by anthropological theory that perceives artifacts as objects with a life history, from which conclusions can be drawn about the human society that produced them and used them. While the term “building biography” is used explicitly only in some archaeological publications (Gerritsen 1999a; Rogasch 2012), the underlying concept is employed in many more.

Definition

A building biography interprets architecture by focusing on the sequences of human activities and decisions that went into creating a building, using a building, and abandoning a building, part of a building, or a group of buildings. It is an interpretative model based on which research questions can be developed, and appropriate methods of analysis can be chosen to answer them. The aim is to reach an interpretation of larger processes in past societies from a detailed study of human activities that are preserved in the architectural record.

Key Issues/Current Debates/Future Directions/Examples

The key assumption of the biographical approach is that when people interact with "things," the people, the things, and the relationships between them are altered during and by this interaction. Among the many possible different paths each of these intertwined biographies could theoretically take, only certain biographical possibilities are actually realized, and this range of acceptable options is determined by the given social context (Kopytoff 1986: 66, 68; Bernbeck 2008: 52).

The possible archaeological application of the concept was first explicitly outlined in a book edited by Appadurai (1986) in his book *The Social Life of Things*, and subsequently embraced by many archaeologists and used on a broad range to research questions (for overviews, see *World Archaeology Journal* 31(2) 1999; Skibo & Schiffer 2008). A number of terms are used to capture the target of these studies: "life" or "social life"(Appadurai 1986; Horne 1994: 170; Tringham 1995: 98), "use life" (Banning & Byrd 1987: 321; Tringham 1995; Tringham & Stevanović 2012), "life history" (Appadurai 1986: 41; Tringham 1995: 97; Gerritsen 1999a: 82; Holtorf 2002; Tringham & Stevanović 2012), "life course" or "life cycle" (Horne 1994: 185; Boivin 2000: 367; Matthews 2005), "development cycle" (Banning & Byrd 1987: 309, 321; Boivin 2000: 367), "career" (Appadurai 1986: 41; Horne 1994: 185) and "biography" (Appadurai 1986: 17; Tringham 1995: 97; Gerritsen 1999a: "biography" and "cultural biography").

Archaeologists concerned with research into architecture soon adopted the biographical approach. Through building biographies, archaeologists have reconstructed household-related processes (Banning & Byrd 1987: 321; Tringham 1995: 97; Gerritsen 1999a; Boivin 2000; Matthews 2005; Tringham & Stevanović 2012); rituals and beliefs (Banning & Byrd 1987: 322; Gerritsen 1999a); issues of ownership (Banning & Byrd 1987: 323; Gerritsen 1999a: 95); the interplay between architecture and the surrounding landscape (Tringham 1995: 97; Gerritsen 1999a: 93); community construction (Düring 2005; Rogasch 2012); and mobility practices (Gerritsen 1999a; Bernbeck 2008; Rogasch 2012).

The following beneficial results of the biographical approach to architecture have been pointed out by researchers using it, and their reviewers:

1. *Comprehensiveness*: A biography considers the entire life of a building, from pre-construction to post-abandonment, and thus fully appreciates all available data and interpretational possibilities.

   Traditionally architectural studies focus on what they perceive as the main or intended use phase of the building (Tringham 1995: 81). However, recent archaeological research has demonstrated the interpretational potential of knowledge employed and choices made during and even before a construction process (Gerritsen 1999b: 109; Love 2012) and behavior during house abandonment (Gerritsen 1999a: 83-5, 87-91; Matthews 2005; Rogasch 2012).
2. *Resolution*: As a biography renders importance to the small scale, it fosters meticulous analysis and the recognition of important differences in the biographies of different architectural units, whose interpretation can lead to a clearer and more realistic picture of societies. This counteracts the tendency in architecture studies to brush over inconsistencies in search for a greater truth (Tringham 1995: 95; Vellinga 1999: 98-99): in terms of temporal resolution, that often results in a more fine-grained relative sequence of events even in the absence of absolute dating.

3. *Dynamism*: Such high-resolution sequences facilitate the identification of dynamic processes happening around a building (Vellinga 1999; Nevett 1999), which reflects complex realities observed in modern societies (Horne 1994; Carsten & Hugh-Jones 1995) better than the traditional archaeological thinking of seeing architecture as static (Tringham 1995: 65; Vellinga 1999: 98). The term "biography," as drawing comparisons with human life histories, points out the unplanned nature of life ways that resulted in biographies which could not have been foreseen when the life started.
4. *Workability*: It is possible and relevant to apply the biographical approach on different scales: the biography of one wall, one post, one room, one building (Rogasch 2012), a settlement (Bernbeck 2008), up to the biography of a landscape with built and unbuilt spaces (Vermeulen 2001; Pollard & Reynolds 2002; Gerritsen 2003; Darvill 2006; Roymans et al. 2009). It can therefore be applied to all evidence at hand, even if only fragments of buildings have been excavated.

For a *critical evaluation* of the biographical approach in general, see Holtorf's (2002) work who states that the concept is too loosely defined and used rather arbitrarily ("intellectual virus") to solve very different kinds of problems (also remarked by Nevett 1999: 102).

Nevett (1999: 102; similarly Vellinga 1999) criticizes that biographical studies often simply collect a lot of facts without actually subjecting them to systematic analysis, thus resulting in "lack of explanatory force of the biographical approach" (Gerritsen 1999b: 109) or even the perception that "the application of the biographic approach to the study of late prehistoric houses is ultimately inadequate" (Vellinga 1999: 101).

This shows again that a building biography is a model of interpretation that does not replace analysis. The biography has to be filled with detailed evidence generated through traditional tools of architecture research such as stratigraphical research or studies of building materials and constructions techniques. The number of very recent publications in the list of references below demonstrates that the biographical study of architecture is constantly being refined and will develop further in the near future.

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▶ Buildings Archaeology
▶ Buildings, Archaeological Study of
▶ Historical Archaeology

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Buildings Archaeology

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Introduction

This entry seeks to outline the context and current practice of buildings archaeology. It focuses primarily on the UK but sets current practice here within the wider context of Northern Europe, the USA, and Canada. The entry commences with a definition of the discipline, during which its emergence in the late twentieth century as a subdiscipline of archaeology is charted. Key issues and current debates in the practice of buildings archaeology are then considered. These include its internationally significant role in the documentation and preservation of global cultural heritage, the development of recording methods and techniques, and interpretative issues such as the application of stratigraphic analysis to standing buildings, the impact of theoretical paradigm shifts on the discipline, and the potential of new virtual and visualization technologies to transform both methodological and interpretative approaches in the future.

Definition

"Buildings' archaeology" can be defined as the application of the archaeological principles of systematic recording, analysis, and interpretation to "above ground archaeology" or standing buildings. In many countries, buildings' archaeology has emerged from well-established traditions of researching and analyzing buildings within disciplines such as art and architectural history. Indeed, the development of the discipline often provoked anxiety and hostility from specialists within these fields. However, in the UK, a distinctive approach to recording buildings also emerged in the 1980s out of the specific context of "rescue archaeology." Here, buildings' archaeology rapidly became associated with the application of "metrically accurate" recording methodologies and "stratigraphic" principles of analysis to the phasing and interpretation of buildings. During the 1990s and early part of the twenty-first century, the emergence of buildings' archaeology has coincided with, and informed, approaches to the "documentation" and preservation of cultural heritage. Throughout this period, the interpretation of buildings has also been informed and enhanced by critical engagement with developments in contemporary archaeological theory. While these trends are most evident in the approaches followed in the UK, they have much in common with the well-established German tradition of "*bauforschung*" or "*stadtbaugeschicte*," which form part of both commercial practice and many archaeology curricula (Grossman 2001), with the Swedish and Danish practice of buildings' archaeology, building history and "documentation hermeneutics" (Haedersdal 1999–2000), and Belgian building recording (Mignot & de Meulenmeester 2003).

Historical Background

Buildings archaeology in the UK traces its origins to the emergence of a systematic and scientific approach to the observation and recording of buildings by early Antiquarians associated with the Society of Antiquaries of London, founded in 1707. During the nineteenth century, architectural history emerged as a self-conscious specialism, particularly in the field of ecclesiastical buildings, where the analysis of past examples of Gothic architecture was linked both to the desire to develop systematic typologies of the style and to its use as a source for contemporary architectural designs within the Oxford and Cambridge movements.

It was only in the later part of the twentieth century, however, that the discipline of buildings' archaeology really emerged in the UK. Throughout the 1970s, groups of like-minded archaeologists and architectural historians began to develop what became known as "church archaeology": a multidisciplinary approach to excavating, recording, and researching all aspects of church sites, buildings, fittings and fixtures, and burials. Techniques were informed by the contemporary development of "rescue" archaeology, where large-scale open-area excavations at sites such as Coppergate (York) and The Brooks (Winchester) shed important light on the below-ground remains of medieval buildings and provided a model for the integrated historical and archaeological analysis of medieval structures (Carver 2009). Rescue archaeology also led to rare examples of the systematic excavation and recording of a pair of medieval and later town houses along the city wall at Shrewsbury. Gradually, as traditional industries declined and development pressures increased in the 1980s and 1990s, larger numbers of industrial structures also formed the focus for archaeological recording of both buildings and the evidence of industrial processes which had occurred within them.

Gradually, the significance of historic buildings as part of the archaeological resource began to be accepted in the UK. In 1979, the Ancient Monuments and Archaeological Areas Act provided statutory protection for those buildings which had been designated scheduled ancient monuments, while in 1990, listed buildings were also protected under the Listed Buildings and Conservation Areas Act, although parish churches and cathedrals are subject to separate legislation under the Ecclesiastical Exemption (revised 2010) and Care of Cathedrals Measure (revised 2011).

Key Issues/Current Debates

From tentative origins within church, rescue and industrial archaeology, buildings' archaeology emerged gradually in the 1990s as a distinctive subdiscipline within the field. However, its development sparked strong responses from other disciplines, particularly architectural history. Church archaeology had demonstrated how the methods of below-ground recording, particularly the idea of a "total" recovery of data destroyed during the excavation process, could be transferred to the recording of standing buildings. However, doubts were raised about the problems inherent in the "misapplication to building recording of the practices of dirt archaeology." Buildings archaeology was largely a nondestructive recording process, associated only rarely with the creation of "preservation by record" where a building was to be completely destroyed. However, building recording methods did seek to replace art historical approaches to recording buildings, which were considered to be partial and subjective, with a more objective and totalizing approach to recording.

At the heart of this debate lay a fundamental difference of opinion about what constituted authority within the disciplines of architectural history and archaeology in the UK. A consensus began to emerge, first that the idea of the "total" record was a chimera, and, second that from the moment a decision was taken to record a building, choices were made about what – and what not – to record. The subjectivity of the recording process itself was acknowledged (Grenville & Morris 1992: 301), and the importance of recording and interpretation being driven by clear research questions and a thorough understanding of building types was also emphasized. Today, one of the most important legacies of this debate for buildings' archaeology is the idea that although it is impossible – and perhaps undesirable – to be objective in the recording of buildings, it is still important to document the process in a systematic and accessible manner, which can be interrogated and reinterpreted by subsequent scholars.

As early as the 1990s, the value of recording as "an essential prerequisite and accompaniment to the repair and conservation process" was emphasized by buildings' archaeologists and conservation practitioners in the UK. The role of buildings' archaeology was argued to be not simply that of facilitating alteration but also informing decision-making. This might involve weighing up possible development proposals against the perceived value or significance of a building, and academics argued strongly that a necessary precursor of conferring value on a building was scholarly "understanding." These debates had important implications for the relationship between buildings' archaeology and conservation.

Example 1

A landmark volume, *Buildings Archaeology*: *Applications in Practice* (Wood 1994), brought together academics and practitioners from across the commercial and public sector, including English Heritage (EH), the RCHME, the National Trust, National Parks, and archaeological units in a series of thematic essays and case studies demonstrating the value of buildings' archaeology within the heritage and conservation sector. "Extensive" survey examples featured in the volume included a survey of an entire building type – "bastles" – by the Northumberland National Park and a survey of three nineteenth-century industrial Welsh "housing stocks," both of which were designed to target recording and conservation resources effectively. More "intensive" survey examples included targeted recording for limited alterations in English Heritage's secular buildings and the detailed recording by the Lancaster Unit of major conservation works at the scheduled monument Furness Abbey in advance of major restoration works. Two further case studies involved intensive survey prior to demolition of vernacular buildings and dismantling prior to re-erection at Kellington church.

Another example of this role of buildings' archaeology is Pearson and Meeson's (2001) edited volume, *Vernacular Buildings in a Changing World*: *Understanding*, *Recording and Conservation*. Many of the case studies in this volume were concerned to emphasize the significance and the potential of the vernacular architecture resource and to highlight the particular vulnerability of vernacular, often unlisted buildings, to insensitive alteration and development without adequate archaeological recording. Through a series of case studies, the volume reflects critically on tensions within the system: the lack of effective use by Conservation Officers of PPG15; the misconception that "conservation" was synonymous with resistance to change; and the lack of dialogue between buildings' archaeology and other professions, such as conservation architects, surveyors, structural engineers, and planners.

Throughout the latter part of the twentieth century, debates about the interrelationship of legislation and planning guidance, academic research frameworks, and commercial practice have continued to dominate the discourse of buildings' archaeology. Of particular significance in recent years has been the way in which research-based building recording has been placed at the heart of heritage practice and planning guidance, largely as a result of the widespread dissemination of international heritage conventions and charters such as Athens, Venice, Burra, and Faro. The global cultural and economic impact of developments in international conservation charters and conventions has recently been explored by Letellier and The Getty Institute's (2012) two-volume publication, Volume 2 of which consists of a series of international conservation-led recording case studies (see also ICOMOS 1990). In the UK, the high-level philosophical concepts such as "significance" and "value" defined in these charters have become embedded in national policy guidelines, such as EH's (2008) *Conservation Principles*. *Informed Conservation* (Clark 2001) has also had particular resonance for buildings' archaeology, coining the acronym CoBRA (Conservation-Based Research and Analysis) to describe "the research, analysis, survey and investigation necessary to understand the significance of a building and its landscape and thus inform decisions about repair, alteration, use and management."

Example 2

Informed Conservation not only explained the value of understanding as the basis of defining significance but also discussed the appropriate levels of information required for different kinds of conservation projects, the forms of strategic document used and the specific analytical techniques available. Throughout, examples drawn from the work of EH's own metric survey team, such as the eighteenth-century town house, Danson House, Bexleyheath, were used to illustrate CoBRA in practice. Although CoBRA has never really made it into the common parlance of buildings' archaeologists, its principles have become widely accepted. Other useful published examples include Acton Court, Burlington House, and Stowe. In Spring 2009, an entire edition of EH's *Conservation Bulletin* provided examples of "Conservation Principles in Practice," and Heaton (2007) and Neale (2010) provide a similarly useful surveys of case studies in which attitudes to the "restoration" of historic buildings have been transformed by initiatives such as *Conservation Principles*. At the time of writing, major changes are occurring in the UK's system of planning policy and guidance which are already having an impact on the role of building recording in the heritage and conservation process (Morrice 2011; Heaton 2012).

The Practice of Building Recording: Guidelines and Principles

Early reactions against the idea of total and objective recording methodologies in the UK gradually informed the development of principles and guidelines governing a "selective" approach to recording. This was enhanced by the increasing recognition that archaeological projects needed to justify a level of recording appropriate not only to the significance of the building but also the practical and financial constraints imposed by the commercial sector. Buildings archaeology in the UK tends to draw on two main guidance documents. EH's (2006) *Understanding Historic Buildings*: *A Guide to Good Practice* provides "clear practical guidance on the ways in which the wealth of historical evidence embodied in buildings can be gathered and disseminated for the lasting benefit and enjoyment of all." At the heart of the guidance is the definition of four "levels of recording" (where 1 is the most basic and 4 the most complex form of record) described in relation to three forms of record: written, drawn, and photographic. A table within the guidance maps the "circumstance" and "principle need" of recording against the four levels and forms of record. Similar, but subtly different, commercial priorities can be seen in the professional guidance of the UK's Institute of Field Archaeologists' *Standard and Guidance for the*

Archaeological Investigation and Recording of Standing Buildings or Structures (2008). Once again, the need for archaeological building investigation and recording to be driven by a written specification or project design, in which appropriate levels of survey, accuracy, and the forms of reports are identified, is emphasized.

Understanding Historic Buildings emphasizes that its guidance is not intended to be prescriptive or definitive and acknowledges that different levels of recording may be required by different user groups, while different levels might be adopted within a single project or across a single site. Nevertheless, they provide a standard which is widely used by those commissioning and delivering building recording in the UK. Although neither of these documents provide explicit guidance on recording or interpretative methods, they do acknowledge technological advances are reflected in both documents, with sections on digital photography and digital archiving. However, both also emphasize the importance of historical research and the use of documentary sources, maps, and pictorial sources in researching and interpreting buildings. This contrasts with the methodology of buildings' archaeology outlined in the UK's principle textbook on the subject, where the use of documentary sources is relegated deliberately to Chap. 12 on the grounds that "The archaeology of buildings is really about the study of the evidence of the buildings themselves" and that undertaking documentary research prior to survey and interpretation can, "at the risk of sounding priggish, affect the purity of the purely archaeological analysis" (Morriss 2000: 165)!

Guidance on the practice of recording buildings can be found in a variety of sources. Morriss' (2000) volume provides basic guidance on hand survey, but one of the most useful step-by-step guides to historic building survey methods is that of Swallow et al.'s (2004). The volume provides a factual description of different survey methods but also reflects critically on their potential and limitations. It also provides a series of case studies which reflect on the interrelationship of selective recording principles and the choice of particular recording methods. This "toolbox" approach to guiding practitioners through choices of survey methods and case studies is also evident in EH's (2003) *Measured and Drawn* and in the second volume of Letellier and The Getty Institute's (2012) recent publication, with which English Heritage were closely involved. Useful individual articles on particular techniques can also be found on the building conservation directory website: http://www.buildingconservation.com/articles/.

As well as guidance on survey methods, UK buildings' archaeology has also sought to establish standardized conventions relating to the visual outputs of building survey methods. Early guidance on the artistic conventions and production of standardized plans, sections, and elevations was also provided by the Association of Archaeological Illustrators and Surveyors (1995). Specific guidance on the use of CAD has also been produced (English Heritage 1998 and the Archaeology Data Service's 'CAD Guide to Good Practice': (http://ads.ahds.ac.uk/project/goodguides/cad/)).

Currently, there is considerable debate within buildings' archaeology in the UK about the relationship between the increasingly technological aspects of building survey, such as laser scanning and the analysis and interpretation of buildings. Some practitioners have argued that laser scanning offers a new, more objective, and "total" method of recording historic buildings. However, interestingly, projects such as Heritage3D (http://www.heritage3d.org/) have also recognized the current limitations of such technologies and emphasized the need for laser scanning to be selected on the same grounds as alternative recording techniques, namely, its ability and suitability to answer the research questions, or problems being posed.

Another current debate concerns visualization and the use of virtual reality models. Projects such as the historical theater modeling project, Theatron (www.theatron.co.uk), have demonstrated the potential of virtual reality technologies to generate visually pleasing computer graphics designed to evoke the visual experience of now-lost buildings. However, they have also raised questions about the extent to which "a" virtual model can inadvertently close down alternative and multiple interpretations of the same evidence. Heritage technologies can not only mask the process of recording but also "gap" between recording and subsequent scholarly interpretation. Increasingly, digital heritage practitioners have called for the development of a more critical approach to the use of computer reconstructions. This has resulted in the development in the UK of the "London Charter for the Computer-Based Visualisation of Cultural Heritage" initiative (www.thelondoncharter.org; Beacham et al. 2006). The London Charter encourages greater "transparency" in the creation and use of models through the publication of the "paradata" on which they are based.

Example 3

The Guild Chapel, Stratford-upon-Avon (Warwickshire), is a recent example of an integrated buildings' archaeology and virtual modeling research project (Giles et al. 2012). The chapel is an internationally significant late fifteenth-century building built by the Guild of the Holy Cross and Hugh Clopton, a guild member, merchant, and former Lord Mayor of London. The project sought to use a virtual model to reconstruct the chapel's original decorative scheme of wall paintings, which were partially destroyed at the Reformation but which came to light during restoration works in the nineteenth and twentieth centuries, when they were drawn by a series of Antiquarians. A metric survey of the chapel was used as a basis for a digital model. However, rather than seeking to reconstruct "the" appearance of the Guild Chapel, the model and its accompanying text was used explicitly to present the "paradata" of the wall paintings by layering different Antiquarian drawings and descriptions of the same images over each other, so that their similarities and differences can be compared directly by the user him/herself. In this way, the project seeks to remind the user of the "gaps" between the reality of the past and the interpretative processes of recording and representation discussed above.

One issue that greatly dominated the emergence of UK buildings' archaeology, but which no longer seems current, is the use of stratigraphic analysis in the interpretation of historic buildings (Grenville & Morris 1992: 301). Early buildings archaeologists maintained that stratigraphic recording provided a more systematic and reliable form of record than the fluid and partial records made by other disciplines. From the outset, however, it was acknowledged that there were profound differences between the unconsolidated contexts of below-ground archaeology and the consolidated structures encountered within buildings, particularly with regard to the principle of superimposition and the definition of stratigraphic contexts.

Example 4

The most cogent discussion of these issues to date has been by Jones (2000), analysis of the ceiling over and partitioning of a medieval "Cruck Cottage," Cuppenham (Hampshire). Jones argues that stratigraphic units must be defined by the investigator in relation to the purpose and level of the record. At Cruck Cottage, context numbers were given not only to individual roof timbers but also to evidence of human activity such as "smoke blackening" to illuminate the process of "closure" in vernacular buildings. Jones' work also demonstrates how the systematic use of stratigraphic terms such as "cut" and "fill" or "abutment" provides a much clearer way of describing relationships within and between contexts than the traditionally ambiguous concept of the "building break" used more commonly in architectural history.

Early enthusiasm for the application of stratigraphic analysis to buildings encouraged the development within organizations such as the Central Archaeology Service at English Heritage of "recording manuals" and pro formas for the recording of "built structures" and "timber structures." However, skeptics of the stratigraphic approach have tended to question the value of such time-consuming recording methods, which, in presenting all information as being of equal value, "fail to guide the user to that which is significant." In Morriss' (2000: 154-5) volume, while the importance of the principle of analyzing the relationship between contexts is acknowledged, it is argued that the use of colored phase drawings is far easier and more effective method of interpretation than the creation of context sheets and Harris matrices. Over the past ten years, the detailed application of stratigraphic analysis to standing buildings, the use of pro formas and production of site matrices, seems to have become less common in both academic and commercial practice. However, rather than representing its abandonment of stratigraphic analysis, it can be argued that this represents the maturity of the discipline. The key significance of stratigraphic analysis for buildings' archaeology was that it represents "an intellectual framework which can be used to organize the different sources of evidence used to interpret a building." While the *principles* and *terminology* of stratigraphic analysis have been widely adopted and used in buildings' archaeology, it appears that they have been combined highly effectively with conventional and traditional ways of communicating and presenting such analysis – in the form of written descriptions, phased drawings, and reconstructions.

Theory and Buildings Archaeology

Alongside its function within the cultural heritage process, buildings' archaeology has also continued to explore theoretical approaches to the research and interpretation of historic buildings (Hicks & Horning 2006). Although early approaches to the interpretation of vernacular and industrial buildings tended to be very descriptive and functionalist, gradually buildings' archaeologists began to embrace structuralist and contextualist approaches such as the idea of "generative grammars," borrowed from historical archaeology in the US, and spatial analysis techniques such as space syntax and "isovist" or viewshed analysis (Locock 1994). As postmodern, or "post-processual," theoretical approaches began to impact the discipline, and buildings' archaeologists began to eschew the kinds of totalising narratives which these studies often produced and to focus rather on the complexity of the material evidence and the diversity of historical interpretations which could emerge from detailed building analysis (see Reynolds 2009). Current studies are particularly interested in the potential of applying "biographical" approaches to the study both of the individual occupants of buildings and the material biographies or histories of buildings themselves and of developing more phenomenological or experiential approaches to the theoretical interpretation of buildings. More broadly, UK archaeologists have extended their remit to include the study of buildings across the historical period, including polite houses and gardens, institutional architecture, industrial buildings, and contemporary buildings.

International Perspectives and Future Directions

In 2012, the role of building recording, documentation and information management as being at the heart of cultural heritage and resource management appears to be recognized internationally. It is embedded in the charters and policies of ICOMOS and in European and US legislation and practice. The value of research-informed conservation for understanding and conserving high-profile, internationally significant buildings and much humbler, regionally and nationally significant structures is also acknowledged. The potential of building recording methodologies to be extended to wider cultural landscapes, and to inform structural and condition surveys, has also been demonstrated and recognized. The gradual acceptance of the methodology across the heritage profession has resulted in dialogue and information exchange, rather than the interdisciplinary hostility and protectionism which characterized its early days. New technologies are also being harnessed to enhance the presentation and interpretation of research. As building recording is gradually embedded in academic curricula, a new generation of professionals is emerging internationally, with a greater understanding of its benefits and potential to enhancing understanding and inform conservation.

The greatest threat to the future development of the field is the economic crisis currently affecting most of Europe and North America. The loss of conservation professionals at both local, regional, and national level due to budget cuts, and the absence of dialogue between practitioners, is a major source for concern in the UK. The desire to boost the construction industry by removing or waiving existing legislation and policy also threatens the role of recording in the planning and development process in many countries, regions, and localities. Commercial units are under greater pressure than ever to deliver rapid results for minimum cost. Moreover, leading organizations, such as English Heritage in the UK and Parks Canada in North America, have experienced drastic budget cuts to units involved not only in recording but also in setting standards and monitoring their application within the profession. Only time will tell how the discipline emerges from this latest challenge, but it seems likely that academics and professionals will need to collaborate more than ever if we are to ensure that building recording continues to inform the understanding, conservation, and management of historic buildings and places into the twenty-first century.

Cross-References

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- ▶ Historic Building Conservation: Current Approaches
- ▶ Historic Site and Historic Building Preservation: Overview
- ▶ Households and Domesticity: Historical Archaeology
- ▶ Post-Medieval Archaeology
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Buildings, Archaeological Study of

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Introduction

The study of buildings has always formed a significant part of archaeological endeavor. In Britain, research, illustration, and publication began to mount through the first half of the nineteenth century, not least through the national work of John Britton and Robert Willis and their regional contemporaries. These early students of historic buildings applied archaeological standards of draftsmanship and subsequent dissection, phasing, and analyses that permitted logical insights about dating, periodization, and typology. Indeed, Willis used the term "archaeology" to describe his recording techniques and their application at several English cathedrals. He knew the value of demonstrating structural and dating arguments through making proper records, and his work remains as valid today as it ever was. Of course, succeeding generations would set new standards and devise new procedural models, but Willis stands close to the start of the archaeological tradition that requires accurate measurement and drawing before an analysis is undertaken.

Key Issues/Current Debates/Future Directions/Examples

Research and Understanding

For Willis, and the subsequent researchers that he inspired, it was enough to demonstrate the academic benefits that accrued from the study of buildings. The notion of "pure" research for its own sake, simply to find out, may be unfashionable these days, but it is still alive. In this age of public accountability, however, academic curiosity and challenge may not be enough to secure the necessary financial or legislative support. Other benefits, such as opportunities for innovation and community engagement, must be demonstrated. Today, the study of buildings needs to be set within a wider intellectual context, and the archaeologist must ensure that research programs are carefully considered and coordinated with others in similar fields before work begins.

In recent years, the role of the archaeologist and the application of modern archaeological practice have been extended to inform the conservation and management of historic buildings. This is based on the firm belief that it is not possible to conserve or manage a building without first understanding its history. There is a need to know how and why a building was constructed, how the spaces within a building and between buildings were altered and used through time, what survives of the building and what has been lost, as well as any association with individuals and events. In this way, the study of buildings is inevitably drawn down the path of research – albeit research directed toward a practical outcome. This understanding is documented through the process of making analytical records.

The ultimate aim of understanding buildings is to define their *significance*, so that the historical asset may be retained and enhanced. In particular, it is essential to recognize those aspects that make buildings important enough to justify the necessary conservation time and effort. It is impossible to say, for example, whether or not a particular roof structure should undergo extensive repair or be renewed until it is known what date that roof structure is and how important it is relative to comparable roof structures elsewhere. To put it in a single word, the importance of a building or group of buildings will need to be "*characterized*" and to gain credibility that characterization must be well documented.

Having characterized a building, the knowledge gained can then be used to address any sensitive management problems. This may lead to more intensive study to inform particular conservation or development proposals. Clearly not all buildings need to be studied in the same detail: different circumstances will demand different responses. The scope and level of documentation need to be economically tailored to particular conditions and will be dependent on a number of factors, such as the type and complexity of the building and the nature and scale of proposed works. Consideration should carefully be given to the appropriate kinds of analytical recording in each case. For instance, further research will be especially important for elaborate works programs on multiphase buildings where a greater understanding of the structural and material performance of the fabric is required to avoid damage and allow for appropriate preservation. Where, for example, it is necessary to deconstruct the timber frame of a building to repair decay, or where partial demolition of its masonry to remove rusting metal cramps cannot be avoided, it will be important to prepare precise records. For the dismantling of buildings for re-erection elsewhere, for example, in a museum, very detailed three-dimensional recording and numbering of all components will be required,

Buildings, Archaeological Study of, Fig. 1 The major repair project at Ightham Mote, Kent (UK), undertaken on behalf of the National Trust, had the benefit throughout of an archaeologist working alongside the architect and contractor to inform the process and record what was discovered (Photo: Jason Wood)

in order to recreate the disposition and assembly of as much of the original fabric as practicable.

In such situations, the role of the archaeologist, often working in close partnerships with other disciplines, needs to be properly integrated with the project direction and monitoring team, usually under the leadership of the project architect. The most satisfactory projects will be those which, from the earliest possible stage, work with and take into account the skills and experience of a wide variety of specialists. As well as archaeologists, these may include architectural historians, structural engineers, materials specialists, and others (Fig. 1).

It should be noted that as a part of an historic building conservation or development project, the work of an archaeologist differs significantly from that associated with conventional archaeological fieldwork, in that the data can form a vital part of the subsequent works specification. Scaled drawings and photographs often provide the essential basis for detailed works proposals and consent applications. Such records may also be used for issuing instructions to building contractors. The need for accuracy and legibility are therefore paramount.

Techniques for Studying Buildings

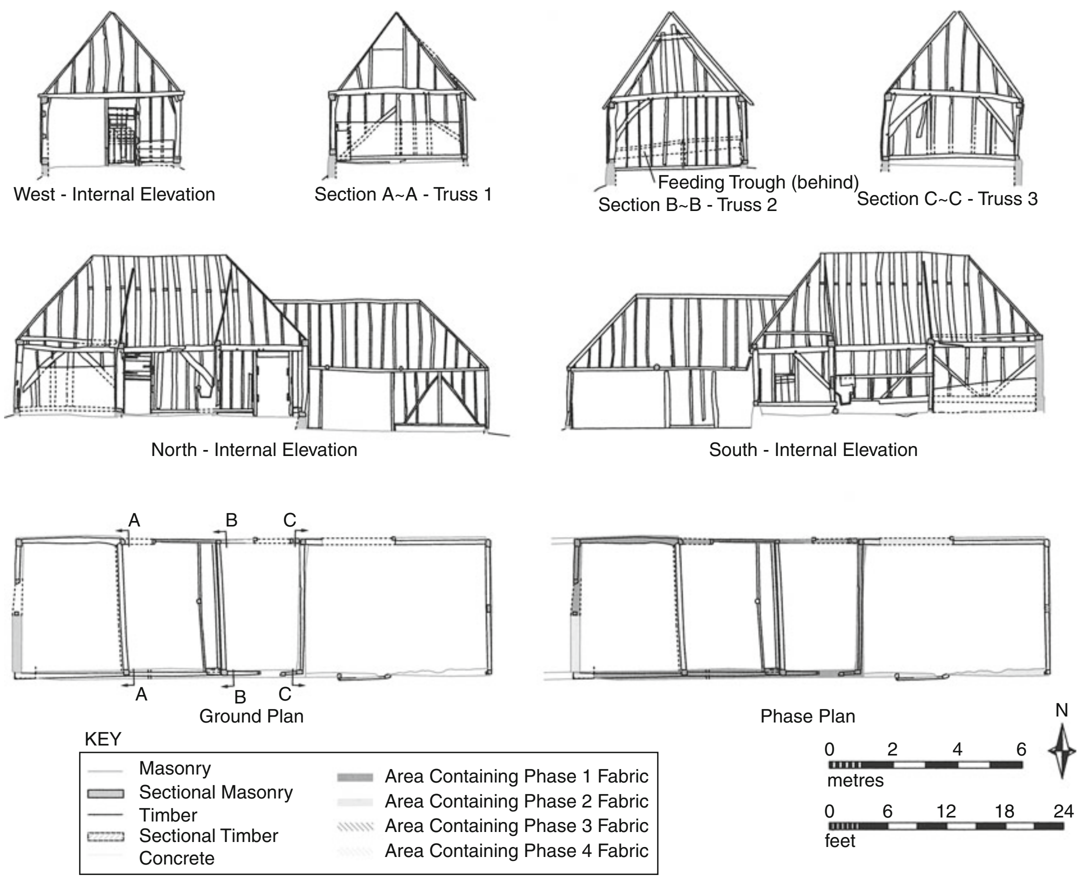
Documentary research is important to establish the architectural and historical interest of a building and to elucidate the evidence for its history and development. This can be achieved in a number of ways. Most research should start with the obvious sources – the relevant statutory designation, a survey of standard reference works and existing secondary sources on both the individual building and of that class of building in general. Local authority record systems and record offices are often a good source of information, as well as national records and specialist archives. It is advisable not to restrict research to locally available material, as in many cases, crucial information will lie in national collections and may have been overlooked in the past.

In general, work should concentrate initially on the sources most likely to reveal evidence for the history of the fabric of the building, such as maps, plans, photographs, and other historic images. Most studies will benefit from a map regression exercise. This involves gathering copies of all relevant maps, starting with the most recent and working back through the whole sequence of every period. Topographical or other drawings, published views, and photographs are especially useful. Their collation can be time consuming, but the effort is not often wasted as these images frequently shed light on the original context and tell much about a building's function and pattern of alterations.

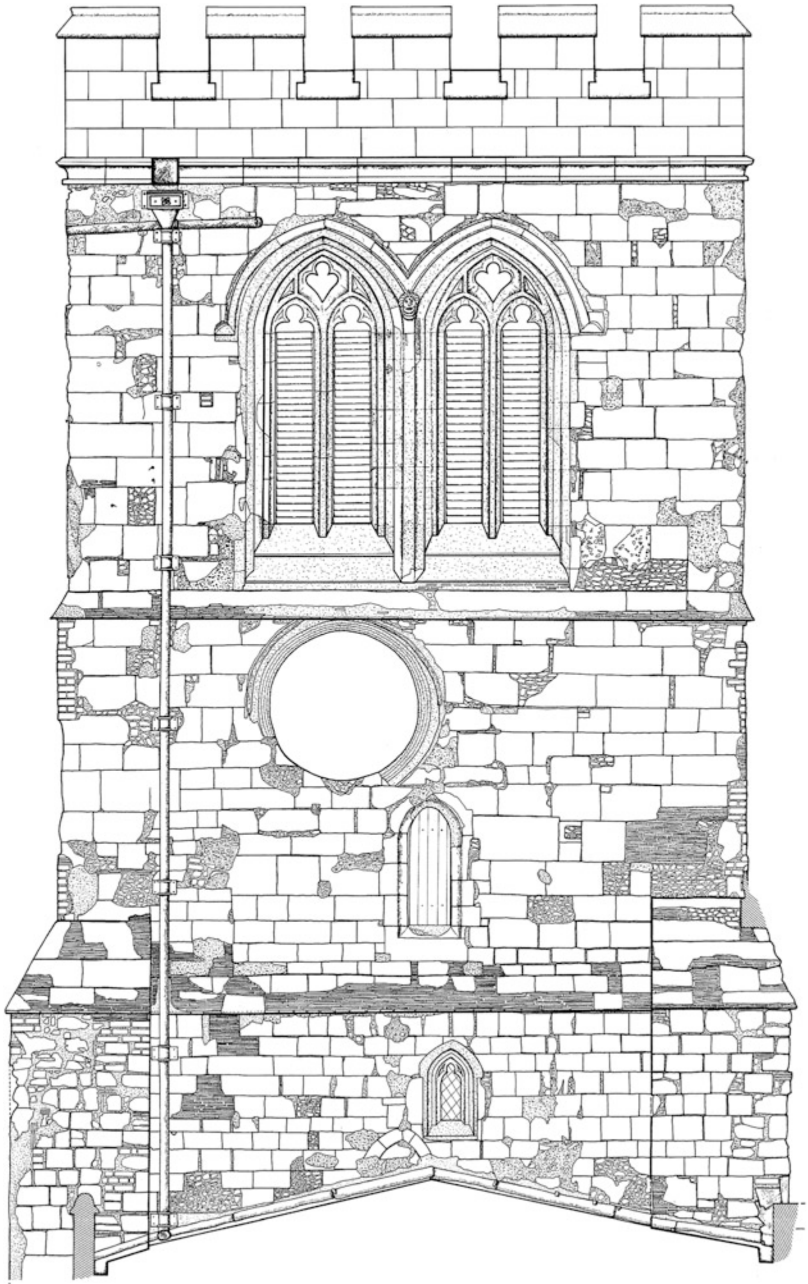
Buildings, Archaeological Study of, Fig. 2 Laser scanning carried out by the University of Birmingham at Chedworth Roman Villa, Gloucestershire (UK), on behalf of the National Trust (Photo: Jason Wood)

Beyond these sources is a whole range of information including title deeds, taxation lists, and rate books, which can all be helpful to construct a simple chronology of ownership and tenancy.

Oral history has an important role to play in the study of buildings. People who have direct experience of a building's use and adaptation in the recent past may present opportunities to gather supporting evidence for changes in form or function. For example, the redevelopment of industrial buildings can benefit from contact with former employees resulting in a greater understanding of any surviving plant and its significance, informing decisions on retention or disposal. Defining significance is now



Buildings, Archaeological Study of, Fig. 3 Plans, elevations, and sections of the timber-framed stable block at Abbey Farmstead, Faversham, Kent (UK), recorded in advance of repair and refurbishment works (Drawing: Lancaster University Archaeological Unit; courtesy of Oxford Archaeology and Swale Borough Council)



Buildings, Archaeological Study of, Fig. 4 An elevation drawing of the church tower of St. George of England, Toddington, Bedfordshire (UK). Recording and analysis provided accurate base level information about the nature and historical development of the fabric to inform the repair program (Drawing: Network Archaeology Ltd; courtesy of Toddington PCC)

a process that increasingly goes beyond expert values to encompass the wider community and to embrace public history. Capturing peoples' views and attitudes about buildings that are significant to them can be illuminating. A crucial aim must be to encourage people to tell their own stories, to share their personal and often "unofficial" history, and to explore further the forces that link these memories to specific buildings.

Fabric Survey and Analysis

Historical research alone is not sufficient: there must always be some degree of engagement with

Buildings, Archaeological Study of, Fig. 5 An annotated ground plan showing suggested periods and phases of part of Whalley Abbey, Lancashire (UK) (Drawing: Lloyd Evans Prichard)

the fabric of the building. Drawings are an indispensable part of studying buildings. These can be produced using a variety of different survey methodologies, equipment, and related software packages:

Hand-measured survey involves the use of tape measures, plumb bobs, frames, and surveyor's levels.

Instrument-based survey involves the use of total station theodolite control, consisting of a closed-traverse run around and through a building, followed by trigonometric intersection of suitably observed points on a façade, or electronic distance meter tacheometry utilizing microprisms for cross sections through complex enclosed structures.

Photographic-based survey (often used in conjunction with hand-measured and instrument-based control) includes

Rectified photography, consisting of single photographs or a mosaic of overlapping photographs taken using large- or medium-format cameras aligned square to the object

Photogrammetry, based on stereophotography taken using metric cameras

Laser-based survey using terrestrial laser scanners. These record three-dimensional positions at a predetermined resolution over a chosen area, generating thousands of high-accuracy coordinates. The coordinates are stored as a series of XYZ measurements which visually constitute a point cloud that represents the geometric form of the building being scanned in three dimensions. Laser scanners also operate in complete darkness and are therefore unaffected by varying light levels, unlike more traditional recording methods (Fig. 2).

The resulting drawings are usually provided as a set of scaled plans, sections, elevations, and details (Fig. 3):

Plans: The requirement may include basement, ground and upper level floor plans, including

Buildings, Archaeological Study of, Fig. 6 A cutaway reconstruction drawing of the church at Furness Abbey, Cumbria (UK) (Drawing: David P Cooper)

plans of ceilings, vaults, and roof structures, showing relevant external and internal detail and features. The location of all sections and elevations should be identified. Plans are the fundamental product to which all other material can be related.

Sections: The requirement may include sections corresponding to the bay divisions or axes through the relevant parts of a building. These should normally define the principal wall plane and also include detail through adjacent openings and voids such as windows, doors, passageways, and smaller features such as putlog holes and beam sockets, as well as roof and floor detail. The height locations of all plans should be identified.

Elevations: The requirement may include external and internal elevations of the relevant parts of a building, depicting architectural features with associated detail (Fig. 4). Walls adjoining elevations should be depicted in section. The height locations of all plans should be identified.

Details: The requirement may include separate plans, sections, and elevations of representative openings and architectural features, with exploded views to supplement the two-dimensional record where appropriate (for example, carpentry joints), and representative architectural, decorative, and ornamental details, both loose and in situ (molding profiles, inscriptions, setting-out lines, tooling, nail positions, masons' and carpenters' marks, graffiti, etc.).

It is not possible, however, to understand an historic building on the basis of record drawings alone. Close analysis of the fabric will be required to establish the relative chronology of the building and its structural phases:

Analytical records: The requirement may include annotating the plans, sections, and elevations to depict boundaries between different types of building material (stone, brick, tile, wood, metal, glass, etc.); surface finishes (mortar, render, plaster, daub, paint, industrial lining, etc.); building periods, phases of construction and repair; constructional detail (wall alignments and thicknesses, bonding patterns, blockings, putlog holes, beam sockets, chase scars, butt joints, building lifts, work-gang breaks, fittings, etc.); occupational detail (wear marks, blackened timbers, industrial residues, etc.); and evidence for abandonment or demolition (robbing, salvaging, fire damage, etc.).

Interpretation records: The requirement may include plans, sections, and elevations depicting outline reconstruction of the principal elements and features, for each of the periods identified. Output may be presented as an annotated plane (Fig. 5) or three-dimensional or cutaway projection (Fig. 6).

Intervention records: "As-built" records, showing the extent of conservation or development works, should depict areas of rebuilding, rebedding, repointing, grouting, new fabric insertions, etc. "As-built" records are particularly important where a component or structure is dismantled, repaired, and then reassembled.

General photographic recording of the external and internal appearance of the significant parts of the building should be undertaken. Close-up photography will also often be required for architectural details.

Finally, detailed physical or chemical analysis of certain building materials, surface finishes, or residues can often provide essential corroborative information including technological and supplementary dating evidence.

Cross-References

► Buildings Archaeology
► Historic Site and Historic Building Preservation: Overview

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Burial Archaeology and the Soviet Era

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> "Also the dead remain silent – until it is time for them to speak."
>
> Stanislaw Jerzy Lec

Introduction

There is something paradoxical in the fact that in 1943, the representatives of one totalitarian dictatorship, the Germans, began the excavation of the graves of the victims of another totalitarian dictatorship, i.e., the Soviet Union. The location was the site of the mass murder of Polish officers, NCOs, and officials at Katyn in Russia (e.g., Drazkowska 2010; Johansson 2010). The Stalinist terror (e.g., Conquest 1992) applied not only to the citizens of the Soviet Union but also to segments of the population regarded as politically dangerous in the areas conquered and occupied by the Soviets. It must also be mentioned that the archaeological profession suffered heavily from the terror (e.g., Klein 1997; Formozov 2006; Platonova 2010: 184-8).

After the collapse of the Soviet Union, the search for the remains of the victims of the terror and their exhumation has become a new area of work for archaeologists. Numerous mass graves have been discovered, but there have also been systematic searches for them. The reasons for this have been above all human, humanitarian, and political. The work of locating these grave sites outside the Russian Federation has been carried out actively in the Baltic republics, Poland, and the Ukraine (Tamm et al. 2008). In human terms, the need for archaeological and physical-anthropological exhumation is obvious and needs no explanation. The nations, ethnic groups, families, and individuals that experienced the terror have finally been given a chance to know the fate of their lost members and loved ones and their possible places of burial and to complete the process of individual and collective grieving (on the commemoration of the terror in present-day Russia, see Etkind 2009). According to Zoe Crossland (2011: 286 and cited literature), this involves "the increasingly pressing question of the memory and commemoration of recent conflict."

Apart from the human aspect, the reasons for investigating the material remains of the Soviet terror can be summarized as three main considerations (see, e.g., Zemitis 2005): (1) the legal aspect with research for the purposes of establishing historical truth and possible crimes against humanity (e.g., Kalbarczuk 2008), (2) the preservation and cherishing of the memory of the dead, and (3) to generate interest in history. The goals of national unity have also been in the background, and the present administration seeking reforms has reinforced its own legitimacy by revealing the victims of the old system of government (Paperno 2001: 89-90).

Since these investigations, however, are due more to human, humanitarian, and political reasons than the actual needs of research, their nature cannot always be merged with archaeological or forensic procedures in completely unproblematic ways (Crossland 2011). The Estonian, Latvian, and Lithuanian research teams, however, involve a prominent archaeological, physical-anthropological, and medical contribution. They have also made use of expertise from beyond their own national borders (e.g., Lõugas 1991: 83). Lithuanian experts, in particular, have been employed in the other Baltic countries. The origins of Lithuanian forensic anthropology date from the 1960s, one of its roots being the exhumation of mass graves of the Holocaust (Garmus & Jankauskas 1999). Thus, the Soviet system provided the necessary training for later exhumation work.

Key Issues/Current Debates/Future Directions/Examples

Investigations have been organized in the Baltic countries by the institutes of archaeology of the national academies of science, the departments of archaeology, medicine and anthropology of the universities, and antiquarian societies (Tamm et al. 2008). This work has also involved large numbers of volunteers, various state and municipal bodies, and organizations including the successors of the state security organizations.

While the investigations have primarily concerned mass graves, execution sites of officers and other ranks of national armies and places where resistance fighters of the long period of occupation were killed have also been excavated. A separate area of work consists of locating the graves of heads of the state and other dignitaries and the identification of their remains (Jankauskas et al. 2008). The grave and remains of Konstantin Päts, the last president of the first Estonian Republic, for example, were located, and the remains were reinterred in a solemn state ceremony in Tallinn (Lõugas 1991; Verdery 1999;

Puustak 2008), while the body of Karlis Ulmanis, the last pre-Soviet president of Latvia, has not been found (Zemitis 2005: 2). The remains of Prime Minister Imre Nagy of Hungary have also been exhumed (Tallai & Keve Kund 2008).

There was, in fact, interest in the Soviet Union in the remains of dignitaries and especially of Tsar Nicholas II and his family. There was a secret search for them already in the late 1970s, and investigations were officially resumed in 1991, leading to the scientific identification of the remains, their reburial, and canonization (Rousselet 2011). In Russia, however, the main focus has been on investigating the burial sites of victims of mass murders. The main organization involved in this work is Memorial (http://www.memo.ru), which also operates in Ukraine, Kazakhstan, Latvia, Georgia, and Italy, in addition to Russia. One of Memorial's main objectives has been "the awakening and preservation of societal memory of the severe political persecution in the recent past of the Soviet Union." In fact, the perpetuation of the memory of the victims was the very idea around which Memorial was formed. These activities have involved the preparation of "Books of Memory," special publications listing victims of Soviet repression (e.g., Gil'di & Braudze 2010).

The main part of the work of Memorial has been the search for the burial sites of victims of the terror and related exhumation. The Soviet terror particularly concerned ethnic minorities, and some examples and results from their territories can be presented. Large numbers of mass graves have been found in Russian Karelia, including Sandarmokh in the District of Medvezh'egorsk (Karhumäki), the largest known burial site of victims of the Stalin terror of 1937–1938 in Northwestern Russia, which was discovered in 1997 (Etkind 2009: 182-4). The 9,000 executed victims at Sandarmokh represent approximately 60 different nationalities (on burial sites in Karelia, see, e.g., Trubin 1989; Korablev n.d.).

In the Republic of Mari El in Central Russia, research was launched during the period of *perestroika*, and as early as by 1991, at least 12,000 bodies had been found in 200 identified mass graves (Patrushev 1991) within a 13-km radius of Joskar-Ola, the capital of the republic. The purges were particularly aimed at liquidating the intelligentsia of the Mari people. By way of comparison, it should be noted that under Stalin the republic had a population of approximately 600,000.

The work of the association of children of the victims of the repression of the Mari is an example of how searches were carried out for the graves. Firstly, people with knowledge of the executions were sought and interviewed. Eye-witness accounts were supported by aerial photographs of forested areas from 1955 with the notable detail of depressions on the surface of the ground where no trees grew. The investigations involved the local authorities and students of history at the Mari University under the direction of an archaeologist. The excavations revealed details of execution methods, and artifacts ranging from the headwear of members of the national intelligentsia to officers' sword belts pointed to ethnic and professional groups. The artifacts indicate the wide social spectrum of the victims. The process also included the erection of monuments at the burial sites (Patrushev 1991).

The research conducted in Mari El is a good example of the investigation of graves. The results include the surveying of burial sites based on archive materials, interviews, and aerial photographs, establishing the numbers of victims and their ethnic and social backgrounds, the reconstruction of methods of execution, and remembrance. For the time being, compilations of this area of archaeological work have not appeared in the former area of the Soviet Union. Katyn and other execution sites of Poles were not the only mass graves excavated and studied by the Nazis. Paradoxically, the results concerning the mass graves at Vinnytsia, issued in 1944 by the publishing house of the National Socialist Party, are still the most thorough forensic studies of mass graves from the area of the former Soviet Union (Paperno 2001 and literature therein).

In some cases, excavations have left unverified the wildest assumptions concerning grave sites. There is also, e.g., a rumor in Minsk that the local porcelain factory tried to improve its wares by adding powdered bone of human skeletons collected for this purpose. No one has yet been able to prove this claim, but people familiar with the period believe that it may well be true (Lõugas 1991: 80).

As Lõugas (1991: 84) writes: "Every East European archaeologist is familiar with the Early Iron Age "kosti" of Glayadenevo Baskiria, 25 km from the city of Ufa. It is a mountain of bones, containing the remains of thousands of animals. This site is a well-known point of departure and comparison for the study of similar sites and antiquities of smaller scale. Perhaps a chronological starting point for future archaeologists will be the 'East European and Siberian layer of bones' from the second quarter of the 20th century."

Military graves in the former Soviet Union must also be mentioned in connection with Soviet-era burials. Interest has now arisen in Russia in keeping and maintaining them. The Red Army usually left its dead unburied in the field. Now the remains have begun to be collected into military cemeteries, the care of which has begun.

An additional theme here consists of the burial sites and remains of lost soldiers of former enemy nationals in the present area of the Russian Federation. An example is the situation involving Finland and the Soviet Union/Russia. Finns have shown interest in the Finnish war dead of the areas ceded to the Soviet Union and the repatriation of their remains. This work was launched by the Finnish Ministry of Education, and it has led to a Finnish-Russian agreement on keeping the memory of both Finnish soldiers who died in Russia and Russian (Soviet) soldiers fallen in Finland, and an official statute on its implementation. These activities are of a bilateral nature. Finns assist Russians in their search for remains of soldiers in Finland, provide information on finds of this nature, and participate in keeping and maintaining the grave sites.

There are also results from Finland. The Association for Cherishing the Memory of the Dead of the War (http://www.sotavainajat.net/perussivut/sivut/english.htm; see also Blinnikka 2004) continues the work previously carried out by the Ministry of Education. This work and its results are cited below as described by the Association.

In practice, the work involves searching for and bringing back remains of Finnish soldiers from the battlefields of the wars of 1939–1945 that are currently located in Russia. During the wars between 1939 and 1945, approximately 13,000 Finnish soldiers were either lost on the battlefields or reported missing. The identification of the dead and their burial in their home areas is the main goal of the work. The remains of almost 1,100 Finnish soldiers have been found so far. Of these, the identities of some 300 soldiers have been established. The majority of the c. 90,000 killed were evacuated and buried in the home graveyards.

Another field of activity is the restoration and maintenance of seven field graveyards in the ceded territory. These were established during the war and are today a final resting place for nearly 900 Finnish soldiers. Later, monuments have been raised at each of these graveyards.

During the wars of 1939–1945, around 4,000 Finnish soldiers were captured as prisoners of war. Of them, a little more than 2,100 were able to return to Finland after the war. It has been confirmed that 760 soldiers perished during their captivity. The fate of the others is still unknown. Five monuments have been raised in the locations of the former prisoner of war camps for those who perished there.

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▶ Forensic Anthropology: Definition
▶ Forensic and Archaeological Analyses: Similarities and Differences
▶ Human Remains Recovery: Archaeological and Forensic Perspectives

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Burial Excavation, Anglo-Saxon

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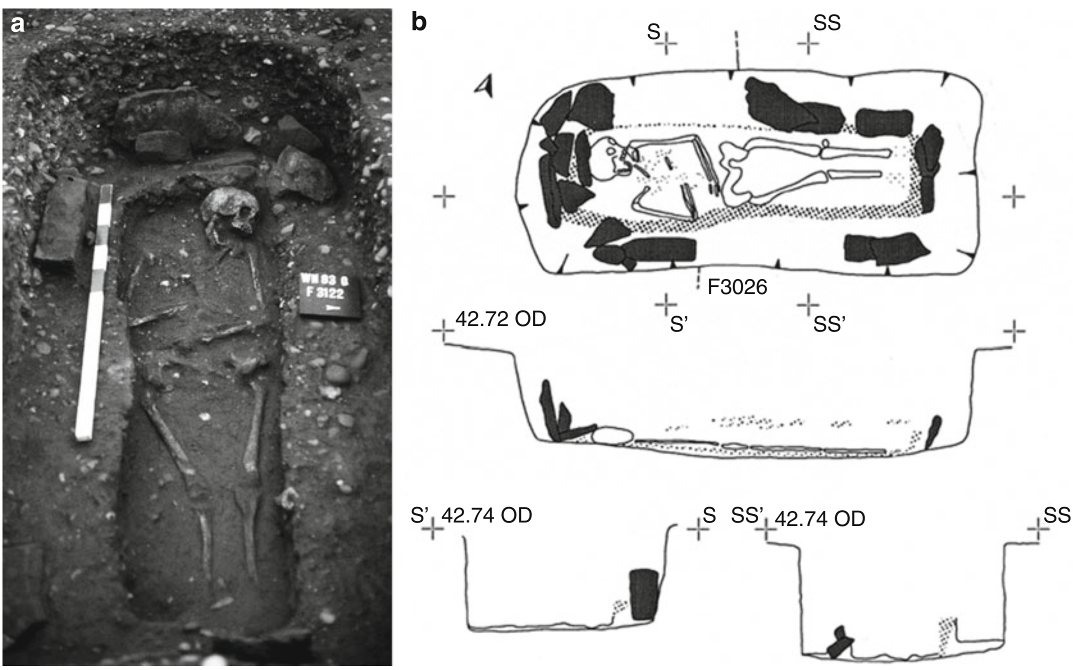
Brief Definition of the Topic

Human burials constitute a major source of evidence for human history. Burials excavated by archaeologists may report on both the individual commemorated and on society more broadly. Human remains may be encountered as burnt bone in containers or in pits (*cremations*), or as skeletons in graves (*inhumations*), or as mixed collections of bones, created by communal deposition (as in European Neolithic long barrows), or by reburial (*charnel*). The state of the remains (and their potential for further research) is dependent on the local terrain and consequent degree of decay (see ► Site and Artifact Preservation: Natural and Cultural Formation Processes; that associated with human remains is termed *taphonomy*). In general, acid soils (e.g., sands and gravels) attack bones, while more alkaline soils (chalk) tend to preserve them better. Anaerobic conditions (excluding air) can preserve the

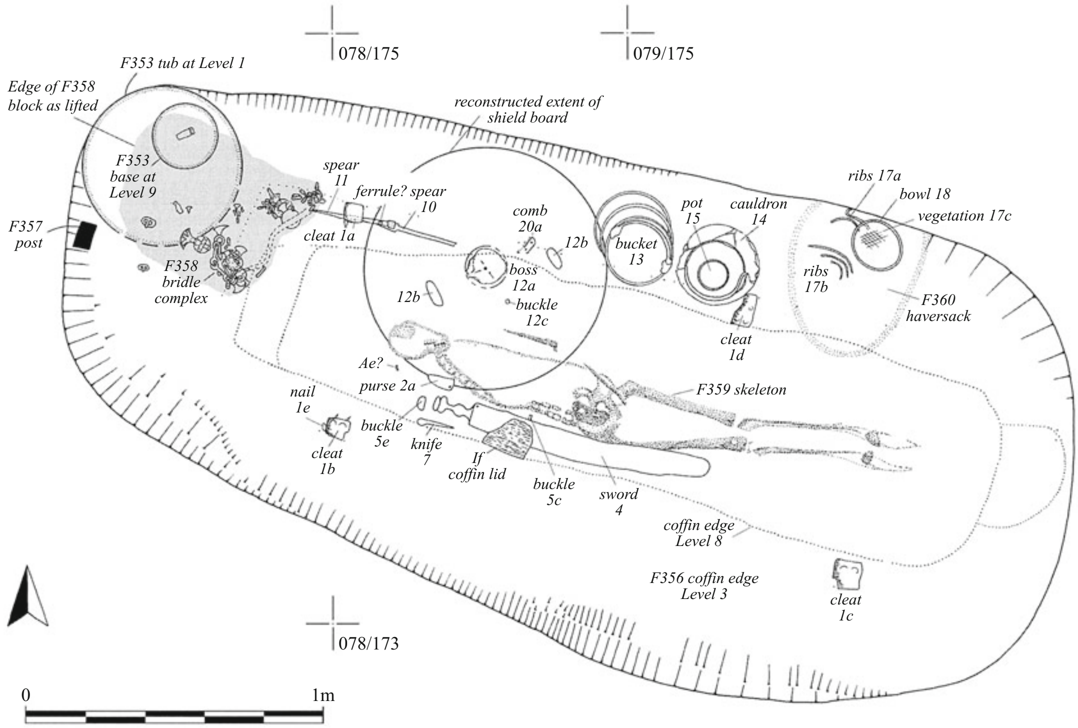
Burial Excavation, Anglo-Saxon, Fig. 1 A cremation urn

soft tissues. Thus *bog burials* (seen in the Scandinavian Iron Age) have preserved skin and inner organs and even the last meal of the deceased, but the acid solution of the bog has nevertheless dissolved the bone (Glob 1969).

The purpose of excavating cemeteries is to gain an insight into the population and thinking of an ancient community and generally involves two lines of inquiry: the study of the burial rites and the study of the skeletal material. The *burial rites* include the form of the grave, its orientation, and the disposition and character of the objects placed in the grave – the *grave goods*. In burial rites, variat ions in space imply different ranks or families; variations through time may relate to changes in religious or political thinking. *Skeletal material* reveals evidence for basic demography through a study of anatomy: This gives age at death, sex, major diseases, and injuries. The carbon contained in the collagen in the bone (including cremated bone) can be extracted and *radiocarbon*-dated, using the



Burial Excavation, Anglo-Saxon, Fig. 2 An inhumation with typically poor bone preservation. The stones are part of the burial rite



Burial Excavation, Anglo-Saxon, Fig. 3 Plan of a furnished inhumation (from Sutton Hoo, Mound 17)

proportions of carbon isotopes. Carbon and nitrogen isotopes present in the bone are also used to assess the emphasis of diet (it will show whether the diet of an individual had a strong or weak marine intake, i.e., fish). Oxygen and strontium isotopes trapped in teeth indicate the character of the groundwater where a person grew up. *Ancient DNA* (aDNA) can now be recognized in skeletal material.

The excavation of Anglo-Saxon burials (fifth to seventh century), used here as an example, has generated a notable range of techniques (Williams 2006; Carver 2009: 131-8). The pits containing cremations are exposed on the surface by troweling, and the pot exposed and removed, intact wherever possible, for excavation indoors (Fig. 1). The contents of the pot are removed in very small spits to document the association of the fragments of burnt bone with each other and with the fragments of grave goods. The objective is to discover which humans, animals, and grave goods had originally been on the funeral pyre.

Inhumations accompanied by grave goods are commonly encountered in Anglo-Saxon cemeteries (Fig. 2). The graves are revealed on the surface by troweling, and the grave fill is then removed in 5- or 10-cm spits against the long axis: This will provide a profile through the grave. The skeleton and all the grave goods (e.g., sword, shield, brooch) are photographed and plotted individually on a grave plan (Fig. 3).

An example of a research project at an Anglo-Saxon cemetery is given by Sutton Hoo. A ship burial discovered by chance at the site in 1939 drew attention to its potential. The site was

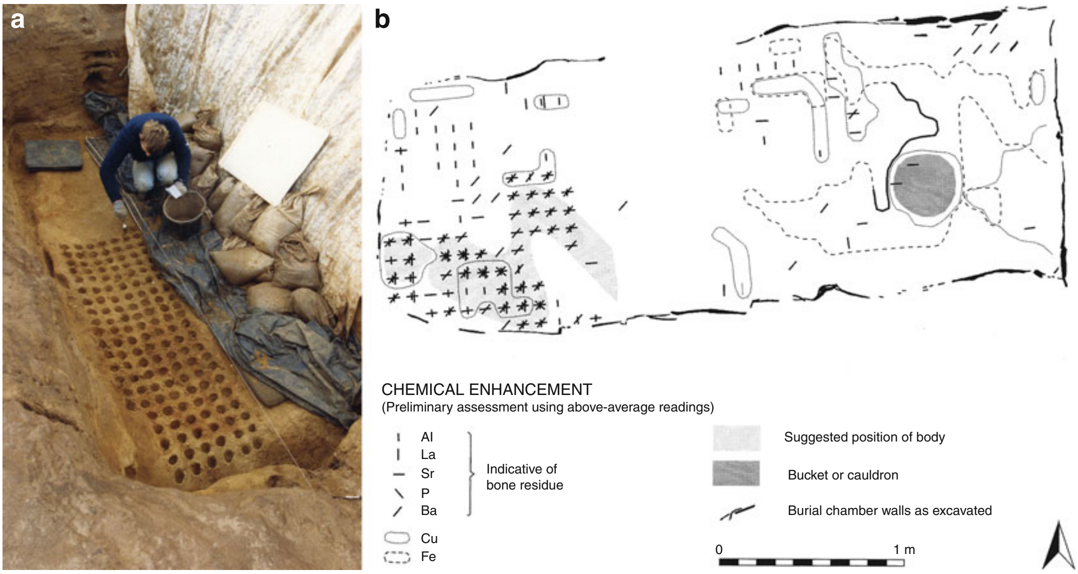
Burial Excavation, Anglo-Saxon, Fig. 4 The burial under Mound 17 being excavated from a cradle

Burial Excavation, Anglo-Saxon, Fig. 5 A 'sandman' burial' where the form of the body is preserved (but less so the bone)

subjected to a 2-year evaluation in the 1980s, with a view to determining what had survived the effects of taphonomy, plowing, and treasure hunting, and a project design was then published. In addition to regional surveys, this design proposed the excavation of 1 ha of the 4 ha site, encompassing five of the 18 known burial mounds (and the spaces in between). Several of the mounds contained cremations, two had contained ships, and one contained a young man buried in a coffin (Fig. 4). His horse was buried in a separate pit adjacent. In the later Saxon period (eight to eleventh century), this high-ranking pagan cemetery became a place of execution.

The ground conditions at Sutton Hoo were hostile, and although fragments of bone were sometimes present, human bodies had decayed markedly in the acid sand, creating "sand fossils" rather than skeletons. The majority of burials, still marked by mounds, had been severely pillaged, scattering bone and objects. The medieval use of the mounds as rabbit warrens had further dispersed the burials.

Nevertheless, the horse and rider burial was undisturbed and could be excavated in precise detail. The execution burials (sand fossils) proved susceptible to excavation in three dimensions, and their shapes were sufficient to show examples that had been killed by hanging or beheading (Fig. 5). The chamber in a pillaged mound, Mound 2, was surveyed by intensive chemical mapping, which showed the location of the now vanished body, a copper alloy cauldron, and other grave goods (Fig. 6). In spite of the evident battering the cemetery



Burial Excavation, Anglo-Saxon, Fig. 6 Chemical mapping of the floor of a robbed chamber

has suffered through the ages, there was sufficient bone to radiocarbon-date the whole sequence, from 580 to 1,050, and align it with the typological dates of the rich grave goods from the famous ship burial.

Cross-References

► Excavation Methods in Archaeology

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Burial Mound Dissection in Sweden

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Introduction

In 1949, it was decided to excavate the first of the four Migration Period large mounds in Högom at a cemetery a few kilometers west of Sundsvall in the county of Medelpad, North Sweden. Concentrations of large mounds (>20 m in diameter) in Scandinavia are known at Old Uppsala in Uppland, Bertnem in Trøndelag, and Borre and Snartemo. Often arranged in rows, these are high status burials representing generations of regional leadership. The four mounds in Högom ("mounds") Medelpad north Sweden clearly belonged to this exclusive group. When investigations began in 1949, the site had been largely forgotten and was encumbered by houses, barns and cellars, driveways and threshing places. The National Heritage Board decided to purchase the area, remove the buildings, and restore a cultural landscape around the cemetery. But before restoration, it was decided to investigate the most damaged of the burial mounds (No. 2). The project was one of exceptional innovation.

Key Issues/Current Debates/Future Directions/Examples

The mound was 40-m across and at least 4-m high, and in accordance with the excavation methods of the late 1940s, it was initially investigated with a trench. This was placed on the NE side of the mound on the site of a demolished building. Beneath the topsoil, the excavators encountered a stone cairn, which was then exposed in its entirety (Fig. 1). It proved to be 20 m across, and seen from a tower was clearly no random heap, but the stones had been deliberately sorted by size. To record this information, the whole cairn was carefully planned, stone by stone.

While the stones were being removed, it became apparent that there was a central burial chamber measuring 5 × 2 m in plan that had been constructed in timber. It had been compressed by the weight of the mound into a compact layer 10-cm thick containing all the wood, the body, and the objects, some of which showed through the matt surface of the compressed wooden roof (Fig. 2). Attempts to excavate the chamber in situ were frustrated by the hardness of the wooden layer; more forceful digging threatened to destroy the objects.

Inspired by the successful lifting of a whale jawbone during the excavation of a Stone Age settlement in Bohuslän (western Sweden) in 1935, it was decided to try and lift the whole chamber in order to excavate it in the laboratory. This much more challenging project was achieved by engineers from the construction firm, Hallström & Nisses of Sundsvall. To provide access, a wide and deep trench was dug around the chamber, making an archaeological record of the layers disturbed. The chamber

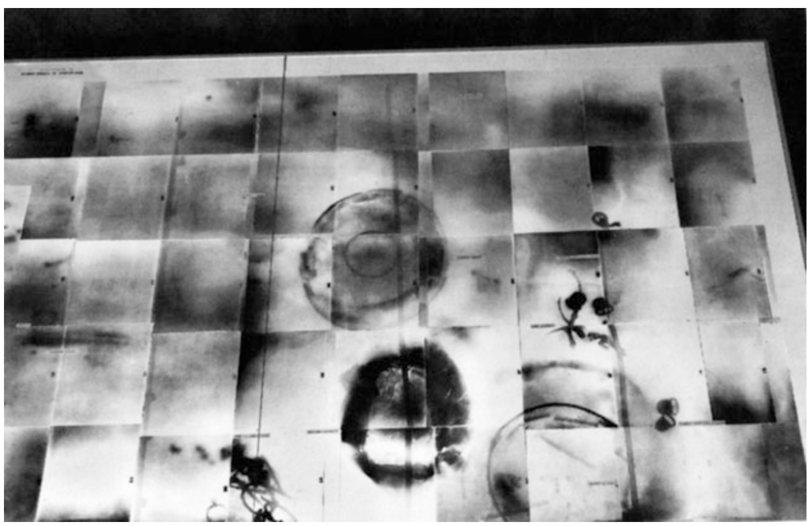
Burial Mound Dissection in Sweden, Fig. 1 Dagmar Selling, excavator (with Sverker Janson) of Högom Mound 2, working on the central cairn (Ramqvist 1992, Fig 17a)

Burial Mound Dissection in Sweden, Fig. 2 Metal buttons on the leggings of the buried person showing in the compressed roof of the chamber (Ramqvist 1992, Fig 24)

Burial Mound Dissection in Sweden, Fig. 3 Metal plates being driven beneath the chamber with jacks (Ramqvist 1992, Fig 25)

proved to be resting on silty deposits without a wooden floor. The engineers then built a wooden box around the chamber and drove steel pipes beneath it, with horizontal steel plates jacked into position above them to create a base for the chamber deposit (Fig. 3). The wooden box was infilled with plaster to prevent movement of the deposit and the whole encased in a steel frame. It was then lifted and transported to the National Historical Museum in Stockholm.

Burial Mound Dissection in Sweden, Fig. 4 The encased burial chamber is unloaded outside the laboratory in Stockholm



Burial Mound Dissection in Sweden, Fig. 5 The set of X-ray plates from the eastern part of the chamber showing the bridle and cauldron in position in the laboratory (Ramqvist 1992, Fig 28b).

When unloading the box in Stockholm (Fig. 4), it was turned completely upside-down, so that the continuing investigation could take place "from below," with the impenetrable roof now as the base. Before excavation in the laboratory, the entire deposit was X-rayed, producing a set of plates at 1:1 which proved to be an invaluable guide to the indoor excavators (Fig. 5). The burial was excavated in minute detail. Dating to c. 500 CE, it is known as one of the richest and best excavated in the Baltic area.

In 1984, the site was surveyed in detail and the previously unexcavated perimeter around the cairn was examined, revealing large postholes of a building erected before the mound, probably a three-aisled long house. The whole site was eventually published by Ramqvist (1992).

Cross-References

- ► Archaeological Record
- ► Excavation Methods in Archaeology
- ► Scandinavia/Northern Europe: Historical Archaeology
- ► Scandinavia: Field Methods
- ► Trade and Transport in the Ancient Mediterranean

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Burial Practices and Tombs in the Roman World

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Introduction

Understanding the rituals associated with death and burial can help reveal a past society's attitudes toward death and beliefs about the afterlife. Information concerning burial practices and commemoration in the Roman world is derived from ancient literary sources written by elite male members of Roman society, often about the funerary practices of aristocrats from the city of Rome. The archaeological record also provides invaluable information on burial practices, but only a small percentage of burials have survived intact from the Roman period and are overrepresented by monumental tombs that belonged to a small elite segment of Roman society. Through the integration of different lines of evidence, general patterns can be discerned, but it is important to emphasize that there was not one universal "Roman" way of burying the dead throughout the Roman world and that these practices varied both geographically and temporally.

Definition

The term "burial" refers to the act of placing the deceased in the ground and can also indicate the location where the deceased is interred, which is often used interchangeably with "grave." "Burial practices" refer to the activities surrounding the preparation of the deceased for burial and deposition of the remains in the ground or in some type of burial structure. A "tomb" can be used to refer to the general location where the deceased is buried, but more commonly it is used to describe a freestanding architectural structure that is used to house the dead.

Key Issues

Death Pollution

A number of factors influenced the treatment and burial of the dead in ancient Rome. The widespread belief in death pollution, both spiritual and physical, meant that rituals were required to separate the deceased from the living and to cleanse the survivors of any contamination associated with death (Toynbee 1971; Lindsay 2000). Attitudes toward the dead were also influenced by the belief that some part of the individual continued to exist after death and could have an impact on the living, so appropriate burial practices were required to guarantee a smooth transition into the afterlife. A "proper" burial ensured that the deceased made this transition successfully, made certain that deceased spirits were not restless, and helped to reintegrate the survivors back into society (Hope 2000).

The period of mourning, known as the *feriae denicales*, began with the death of the individual and ended after the ninth day. Pine or cypress branches were placed outside the front door of the house to advise other members of the community that a death had occurred (Lindsay 2000). Once the body was washed and prepared for burial, either by family members or by hired professionals for more affluent members of society, the body was then laid out for exposition in the home. For wealthier members of society, the display of the deceased and the funeral procession may have been an elaborate affair involving professional mourners and actors hired to wear the wax masks (*imagines*) of the deceased's ancestors and public eulogies in honor of the deceased in the forum (Flower 1996; Lindsay 2000). For a description of a Roman elite funeral procession, see Polybius (*Histories* 6.53–54). For the majority of people in the Roman world, however, the funeral procession from the home of the deceased to the grave or tomb was likely a more modest affair taken care of by the family.

The association of death with pollution and contagion also had an impact on the location of burials and tombs. Roman law dictated that burial had to occur outside the sacred boundary of the city (the *pomerium*), with the exception of a small number of elite members of Roman society who were buried within the walls of the city (Patterson 2000; Retief & Cilliers 2006). The tombs of aristocrats and their household members often lined the main roads leading into the city, such as those found along the Via Appia outside Rome and the Street of the Tombs outside Pompeii. Less wealthy members of society were buried in a variety of structures in cemeteries outside the city (see "Burials and Tombs," below), but these cemeteries were often not clearly defined (Hope 2000).

After the funeral ceremony, the participants consumed a meal, the *silicernium*, at the site of interment or cremation, and food and drink were also offered to the deceased. Food was an essential part of the transition of the deceased from the world of the living to the afterlife, and the ritual of feasting with the dead continued through annual festivals to commemorate the dead. After returning from the funeral, family members and other mourners had to be cleansed of the pollution associated with death with water and fire (the *suffitio*), and the house of the deceased had to be purified to once again reintegrate the survivors back into society. At the end of the 9 days, another meal (the *cena novendialis*) was held to mark the end of the mourning period and the reintegration of the mourners back into society. Some ancient texts also refer to the practice of sacrificing a sow to the goddess Ceres at the grave site so that the burial was legally considered a grave (Lindsay 1998; Erasmo 2008).

Inhumation

Inhumation involved placing the wrapped body either directly into the ground or inside a coffin for burial. If communal tombs were used, the individual might be placed inside a freestanding sarcophagus, interred in spaces along the walls, or placed in pits in the floor of the tomb. In order to have a proper burial, it was important for soil to be scattered over the deceased; otherwise, the spirit was trapped between the worlds of the living and the dead and would remain restless (Hope 2000; Graham 2006). Disturbing a burial or damaging a tomb was a criminal offense.

The burial or tomb was viewed as the house of the deceased, consistent with the belief in the afterlife and that the spirits of the deceased still required sustenance through regular offerings of food and wine, and a permanent place to reside (Patterson 2000; Wallace-Hadrill 2008). The deceased was typically buried with personal items or grave goods that would be of use in the afterlife, such as pottery vessels and oil lamps, although the quantity and quality of the objects would vary according to the gender, age, and status of the individual. The presence, absence, quality, or quantity of grave goods must be interpreted with caution, as changing patterns in burial contents may also be related to shifting attitudes toward the inclusion of grave goods on the part of those responsible for burial (e.g., asceticism). Literary sources from the fifth century BCE to the second century CE also describe the common practice of placing a coin in the mouth of the deceased to pay the ferryman, Charon, for transport across the river Styx to the underworld. The archaeological evidence, however, does not support the ubiquitous use of coins in burials or the consistent placement of coins in the mouth of the deceased when present (Hope 2009). Coins are not found in all Roman burials, and when present, they are found in association with other areas of the body. Thus, the prescribed ideals for Roman burial ritual could be adapted or ignored depending on local customs and individual choice.

Cremation

Cremation of the dead involved transporting the deceased to the cemetery and burning the body in the location of the burial (*bustum*) or cremating the body in an area of the cemetery reserved for this process (*ustrinum*). In *bustum* burials, the individual was placed on a wooden pyre above the grave, and as the cremation progressed, the burnt remains and ashes would fall into the burial along with any grave goods that were placed with the body. The presence of *bustum* burials can be recognized archaeologically by the presence of cremated remains interspersed with ash and traces of carbonized wood (Fig. 1). These funerary pyres did not produce enough heat to fully incinerate the bones of the deceased, so carbonized bone fragments are typically present. Once the pyre had cooled, the remains were sprinkled with wine and the grave would be filled in by soil and/or covered by a more permanent tomb structure.

After the deceased was cremated in an *ustrinum*, the remains were sprinkled with wine and soil and then placed in a container that would eventually be interred in a columbarium or family tomb (see "Burials and Tombs," below). Remains of *ustrina* from the Roman period have been found associated with the mausoleum of Augustus in the Campus Martius and along the Via Appia outside Rome. The preparation and tending of the funerary pyre likely required specialized knowledge in order to ensure that the remains would be properly cremated and required the skills of a professional pyre burner (*ustor*) (Noy 2000; Graham 2006). An incomplete or partial cremation was considered an insult to the deceased and was potentially dangerous to the living because the deceased had not been properly laid to rest (Noy 2000). The ancient authors

Burial Practices and Tombs in the Roman World, Fig. 1 In situ cremation burial (*bustum*) showing carbonized wood and ash. Cremated bone is distributed throughout the burial and grave goods are in the foreground

Cicero and Varro describe the practice of removing a fragment of the body (*os resectum*) prior to cremation for later reburial, which is attributed to the requirement of symbolically burying the deceased to ensure a proper burial (Retief & Cilliers 2006). This ritual is often described in the literature on Roman burial practices, although obtaining archaeological evidence for this practice is unlikely due to the fragmentary nature of cremated remains and the uncertainty concerning where the body part, usually described as a finger bone, would later be deposited (Hope 2009). It has also been suggested that the body fragment would be placed in the urn along with the ashes (*ossilegium*) (Erasmo 2008).

Changing Patterns of Cremation and Inhumation in the Roman World

Ancient texts indicate that inhumation was the standard method of disposal of the dead in pre-Roman Italy and that the practice of cremation slowly gained popularity between the fourth and first centuries BCE (Graham 2006). This burial custom was not universally adopted throughout Roman Italy and there is archaeological evidence that inhumation remained the predominant practice among local populations in southern Italy, possibly linked to the influence of Greek colonial inhumation practices in the region (Davies 1977). The persistence of inhumation may also have been related to the retention of indigenous cultural practices in response to Roman expansion, or it may simply have been due to financial considerations and the reportedly lower cost of inhumation. Cremation remained the predominant custom in urban centers such as Rome from the first century BCE through the second century CE, but beginning in the second century CE, inhumation regained popularity and became widespread across the Roman Empire (Graham 2006; Hope 2009). Recent explanations for the shift from cremation to inhumation after the second century CE have discounted the idea that this was linked to the spread of Christianity and was more likely the result of changing patterns in burial display and commemoration (Morris 1992; Graham 2006; Bodel 2008).

The Burial of Infants and Children

Writers from the Roman period advised parents to be stoic about the loss of very young infants since they were not yet fully integrated into Roman society. Infants less than 40 days old were to be buried in or around domestic buildings and those under the age of six months could not be cremated, although the assertion that Romans did not provide young infants with proper burials has recently been challenged by Carroll (2011). Archaeological and epigraphic evidence indicate that infants under one year of age are underrepresented in cemeteries from the Roman period, but this does not necessarily reflect a lack of concern or grief over the loss of a child (Hope 2009; Carroll 2011). Preservation of infant remains and the ability to recognize and recover the bones of young children, may also contribute to the underrepresentation of infants in the archaeological record (Norman 2010; Carroll 2011). It has also been suggested that the funerals of children were held at night, in part due to the association with death pollution and due to their marginal status in society (Hope 2009). Infants were sometimes buried in broken amphorae, interpreted as symbolic of the infant's return to the womb (Norman 2010). Older children were cremated or buried in a similar manner to adults and there are proportionally more funerary epitaphs to children over the age of one year, reflecting the increased emotional investment of the parents in older children and the public expression of grief at the loss (Hope 2009).

Maintaining Relationships with the Dead

The relationship between the living and the dead did not end after the burial rituals. There was an ongoing relationship between the living and the dead, consistent with the belief that the spirits of the dead could affect the living and the responsibility of surviving family members to maintain the burial or tomb. Regular visits to the grave would occur throughout the year to commemorate birthdays and the anniversary of the day the person died. The Roman festival of *Parentalia* (13th–21st of February) was held annually to honor the deceased members of the family. Food and wine (libations) would be offered at the grave site to share with the deceased, often through the presence of libation tubes inserted in the ground above the burial (Fig. 2), or food could be left on potsherds or at small altars at the grave site (Dolansky 2011). The consumption of food at the grave site is further attested archaeologically by the presence of dining benches inside or outside communal tombs, such as those found at the necropolis of Isola Sacra near the Roman port city of Ostia (Fig. 3). The festival of *Lemuria* took place on the 9th, 11th, and 13th of May each year when restless spirits returned to their homes and rituals had to be performed by the patron of the house to make the spirits leave. Burial was also a means of commemoration, and so tombs were not only for the dead but were also competitive expressions of status for the living to witness as they passed by.

Burial Practices and Tombs in the Roman World, Fig. 2 Libation burial with two curved imbrices inserted vertically in the soil above the burial cover

Burial Practices and Tombs in the Roman World, Fig. 3 House tomb with two benches (*biclinia*) for funerary banquets flanking the main door

Burials and Tombs

Single Burials

Simple inhumations – Poorer members of society were likely buried in simple pits in the ground or in a burial container like a wooden coffin or sarcophagus. The location of these burials may have been unmarked or indicated with a grave marker that could vary in size and permanence. Sometimes stone *stelae* marked the location of the burial, or more elaborate funerary altars were placed over the burials that were designed to resemble a sacrificial altar (Hope 2009). Fragmentary amphorae were sometimes reused in burial contexts to mark the location of a burial in a cemetery and also to act as libation tubes, such as those found outside the monumental tombs at the necropolis of Isola Sacra near Rome (Fig. 4).

Cappuccina burials – This was a common burial structure found throughout the Roman world in which the deceased would be placed in a simple pit or laid out on a series of large flat roof tiles (*tegulae*). The deceased was then covered by

Burial Practices and Tombs in the Roman World, Fig. 4 Amphora burial from the Roman necropolis of Isola Sacra

a series of paired *tegulae* inclined over the body in an inverted "V" shape, with the narrowest part of the burial at the top (Fig. 5). The ridge formed by each pair of tiles would sometimes be capped with curved tiles (*imbrices*) or fragments of pipe. The burial would then be partially or completely covered with soil.

Libation burials – Not all burials possessed libation tubes, but when present, they were simple pit burials, sometimes covered with a series of horizontal *tegulae*, and a terracotta tube or two *imbrices* were inserted vertically in the soil above the burial (Fig. 2). Cappuccina burials could also have libation tubes inserted into the soil above the grave.

Sarcophagi – Stone boxes with flat or gabled lids that were often elaborately carved with biographical scenes of the deceased, mythological scenes, hunting scenes, or representations of military conquests on the exterior, but the interior was usually left undecorated. This type of burial container gained popularity among wealthier members of society with the shift from cremation to inhumation in the second century CE and was usually placed inside larger monumental tombs (Morris 1992).

Burial Practices and Tombs in the Roman World, Fig. 5 Cappuccina burial from the Roman cemetery at Vagnari

Burial Practices and Tombs in the Roman World, Fig. 6 Interior wall of a tomb at Isola Sacra showing a series of niches for cremation urns

Cassone – Barrel-vaulted brick structures built directly above single inhumation or cremation burials, examples of which are found in the necropolis of Isola Sacra and the Vatican necropolis in Rome (Graham 2006).

Multiple Burials

Puticuli ("little pits") – There are a small number of references in ancient texts to the existence of mass graves outside the Esquiline gates in Rome that were used for the disposal of slaves and poorer members of society. Excavations in Rome by Rodolfo Lanciani in the nineteenth century reportedly revealed the presence of "hundreds" of these pits containing human and animal remains, although the archaeological evidence for these estimates has been called into question (Graham 2006). A critical examination of the archaeological and literary evidence reveals that the Esquiline pits were only used for a short period of time (i.e., between the third and second centuries BCE) and were likely not used as a normal mode of disposal for the poor in the city of Rome, but rather may have been associated with epidemics or other catastrophic events (Patterson 1992; Graham 2006). Horace refers to the presence of a graveyard scattered with bones on the Esquiline hill, which was eventually covered over by gardens in the first century BCE and may have been a cemetery for poorer members of society (Morris 1992; Bodel 2000). It has been suggested that cremation in public crematoria became the common mode of disposal of the urban poor during the Imperial period (Bodel 2000; Patterson 2000).

Columbaria – Communal tombs containing a series of niches intended to hold cremation urns (*cineraria*) that gained popularity in the first century BCE and staying in fashion through the second century CE (Morris 1992; Bodel 2008). *Columbaria* varied in size, from small family tombs (Fig. 6) to larger structures that contained hundreds of niches, and could be built above or below ground. These communal tombs could contain members of the patron's extended family, along with household members including slaves, freedmen, and their descendants (Patterson 2000). Funerary societies, called *collegia*, also existed to provide less wealthy members of society a means to ensure a proper funeral through regular payments to the society and guaranteed that members would be interred in communal *columbaria* (Toynbee 1971). These funerary clubs did not, however, replace the role of the family in the proper disposal of the dead but acted in cooperation with the family to guarantee a proper funeral and final resting place (Patterson 2000; Bodel 2008).

Catacombs – A form of subterranean collective burial in ancient Rome that gained popularity in the second century CE, following the gradual shift in burial practice from cremation to inhumation. This period also coincides with the emergence and spread of Christianity in the Roman world, but catacombs were not originally a Christian phenomenon and likely developed from earlier forms of subterranean burial chambers called *hypogea* (Morris 1992; Bodel 2008). The catacombs discovered outside the city of Rome are characterized by complex subterranean tunnels carved into the volcanic rock with niches lining the walls (*loculi*) for individual interments and the presence of larger chambers (*cubicula*). According to Bodel (2008), the criteria for identifying catacombs are independent entrances at ground level, space for large numbers of inhumations, and the capacity for extension of existing galleries to accommodate further burials.

Monumental tombs – The size and structure of monumental tombs varied according to the tastes and wealth of the owners, the competitive expression of social status, and changing fashions in commemoration. Masonry-built tombs varied in appearance from simple open-air tomb enclosures to a wide variety of tomb structures including houses, towers, temples, and pyramids (Toynbee 1971; Hope 2009). From the first century BCE through the second century CE, these communal tombs were in fashion, and the tombs of elite members of society often lined the main roads outside the city. Tombs from the Republican period were mainly constructed for members of the immediate family, but in the Imperial period they included members of the extended family, their slaves, and freedmen (Patterson 2000).

House tombs, like those found at the necropolis of Isola Sacra near Ostia, are rectangular roofed structures with doorways, windows, internal decoration (e.g., mosaics and frescoes), and some with benches for funerary banquets (Hope 1997). Earlier tombs contained small niches for funerary urns, consistent with the preference for cremation up to the second century CE, while later tombs also contained spaces in the walls for inhumations (*arcosolia*) and others contained spaces underneath the floors (*formae*) for additional burials.

According to Toynbee (1971), circular tombs found in Roman Italy likely developed from the Etruscan tumuli found near Rome. The most famous example of a circular tomb is the mausoleum of Augustus located in the Campus Martius in Rome, characterized by a series of concentric walls surrounding a central chamber. The structure was covered by an earthen mound and a statue of Augustus was on the top of the mound (Toynbee 1971; Hope 2009). Other famous examples of circular tombs include the tomb of Caecilia Metella, the *tomba rotunda* of Lucilius Peto, and the mausoleum of the emperor Hadrian, more commonly known as Castel Sant'Angelo.

International Perspectives

Systematic and comprehensive excavation of urban and rural cemeteries found on Roman period sites will help to identify variability in patterns of burial and commemoration. In addition, better integration is needed between epigraphic evidence (when present), the analysis of burials and their contents, and the osteological analysis of the people buried within. Excavation and analysis of burials should be undertaken by archaeologists and/or bioarchaeologists who are trained in the identification of human remains, particularly the recognition of small, delicate infant remains, so that the maximum amount of information can be obtained from each burial. This will help to provide a more nuanced understanding of differences in burial treatment and attitudes toward the dead based on variables such as age, gender, and health (e.g. Gowland & Redfern 2010; Prowse 2011).

Future Directions

Much of what we know about the burial practices and tombs in the Roman world comes from literary evidence and monumental tombs associated with large urban centers like Rome and Pompeii. What ultimately happened to the enslaved and poor after death is not fully resolved, particularly with respect to the existence and role of *puticuli*, and what we know about these mass graves is cited mainly from one nineteenth century source. Continued research on the burial treatment of traditionally underrepresented members of Roman society (i.e., women, children, and slaves) will contribute to a greater understanding of burial practices and commemoration of different segments of ancient Roman society.

Cross-References

- ▶ Bioarchaeology in the Roman Empire
- ▶ Cremation in Archaeological Contexts
- ▶ Demography of the Ancient Roman World
- ▶ Ethics and Human Remains
- ▶ Human Remains Recovery: Archaeological and Forensic Perspectives
- ▶ Religion, Italo-Roman, Archaeology of
- ▶ Tombs, Etruscan
- ▶ Tombs, Greek (Iron Age)

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Burke, Heather

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Burke, Heather, Fig. 1 Heather Burke

Basic Biographical Information

Heather Burke (Fig. 1) received her Bachelor of Arts with First Class Honours from the University of New England, Australia, in 1987. She studied for her Ph.D. under the supervision of Iain Davidson and Graham Connah and was awarded the Doctor of Philosophy (Archaeology) from the University of New England in 1997.

In 1988, Dr. Burke started her practicing archaeological career as the Acting Yengo Archaeologist for the NSW National Parks and Wildlife Service. After that she became a tutor with the Department of Archaeology and Paleoanthropology at her alma mater, the University of New England, from 1988 to 1991. She worked throughout New South Wales, the Northern Territory, and Queensland, serving as an Assistant Regional Archaeologist for the NSW National Parks and Wildlife Service (1990–1991), a private archaeological consultant (1991–2000), and a senior archaeologist for Gordon Grimwade & Associates, Yungaburra (2000–2002). Dr. Burke joined the Department of Archaeology at Flinders University in South Australia in 2002. Currently, she is an Associate Professor and the Graduate Program Coordinator.

Dr. Burke's research interests range from European constructs of cultural landscapes to women in historical archaeology and the archaeology of World War II. She has also conducted long-term fieldwork with Claire Smith in the Barunga region of the Northern Territory. Dr. Burke's professional and community engagement projects show her passion for these research interests and have included excavations at the Repatriation General Hospital in Adelaide and at historical sites in Penola and Mallala, South Australia. Her excavations have provided communities with valuable information about their local history and archaeology and numerous students with meaningful learning experiences.

Dr. Burke's commitment to her students and their future careers is a shining light in the Department of Archaeology at Flinders University. Her dedication to her teaching profession has been recognized in several awards, most notably the Flinders University Vice Chancellor's Award for Teaching, Flinders University, Team Category, with Claire Smith, and the national Carrick Award for Teaching Excellence, Team Teaching.

Major Accomplishments

Dr. Burke's accomplishments in archaeology lie in three areas: in her research as a theoretically sophisticated and community-oriented historical archaeologist; in service to her profession through administrative roles, such as editing and conference convening, that have allowed peers and young scholars to flourish; and in her contributions as an outstanding teacher, who has developed world-leading graduate programs in professional archaeology (Fig. 2).

Dr. Burke's research publications on the links between style, class, and identity have made major theoretical contributions to underrepresented and under-theorized areas of historical archaeology. Her authored book *Meaning and Ideology in Historical Archaeology* (Burke 1999) undertook landmark investigations of the construction and maintenance of capitalist ideologies in rural Australia:

> The theoretical sophistication of the study is admirable, and it should serve as a model for research in other parts of the world . . . The study of capitalism challenges archaeologists and thus it is impressive when a scholar successfully rises to this challenge. Meaning and Ideology in Historical Archaeology meets this challenge and should be read by any scholar interested in understanding capitalism (McGuire 2001: 172-73).

Dr. Burke also publishes in the areas of Indigenous contact and social archaeology. The edited volume *Kennewick Man: Perspectives on the Ancient One* (Burke et al. 2008) redressed a lack of Indigenous views on one of the most contentious topics in modern archaeology in the United States. This book canvassed a range of responses from Indigenous and non-Indigenous archaeologists, judges, anthropologists, tribal elders, students, and specialists over the landmark legal struggle for control

Burke, Heather, Fig. 2 Heather Burke working with children at Barunga School, Northern Territory, Australia over one of the oldest skeletons in the US Pacific Northwest.

Dr. Burke's contributions to her profession are evident in the administrative and organizational roles she has held within her career. These roles can be roughly divided into conference organization and editorship. Dr. Burke's conference organization includes being Program Chair for the Fifth World Archaeological Congress (WAC-5), held in Washington, DC, in 2003; the 1997 Fulbright Symposium ("Indigenous Cultures in an Interconnected World"), at the Museum and Art Gallery of the Northern Territory, Darwin; the "Women in Archaeology" conference at the University of New England, NSW, Australia; and the World Archaeological Congress symposium "Cultural Heritage and Intellectual Property Rights," held in Burra, South Australia. Her editorial service to the profession includes being coeditor of *Australian Archaeology*, the journal of the Australian Archaeological Association, and series editor for two international book series: the *Global Cultural Heritage Handbooks*, published by Springer, and *Worlds of Archaeology*, published by Alta Mira Press.

Dr. Burke's teaching is characterized by intelligent innovation. Her teaching innovations include the development by undergraduate classes of online and community accessible databases that provide a unique source of primary information for the wider community that exists nowhere else and experiential learning through role-playing as archaeological theorists (see Smith & Burke 2005) and elegant Victorian-era tea parties. Dr. Burke's major publication in relation to teaching innovation is the edited volume *Archaeology to Delight and Instruct* (Burke & Smith 2007). This volume was an attempt to take Horace's philosophy that the purpose of literature is to "delight and instruct" and apply it to the teaching of archaeology at a tertiary level. The contents explore ways to integrate the formal process of teaching archaeological theory with the potential to have fun in a university classroom.

Dr. Burke's commitment to ensuring standards of excellence in the field practice of archaeology has manifested in two principal ways. The first way is through her publications, notably the *Archaeologist's Field Handbook* (Burke & Smith 2004), which provided the first comprehensive field manual for archaeologists in Australia in almost 20 years, and *Digging It Up Down Under: A Practical Guide to Doing Archaeology in Australia* (Smith & Burke 2007), written to make the processes of doing archaeology in Australia transparent and to engage archaeologists in cross-cultural discussion of their roles as heritage managers. The *Archaeologist's Field Handbook* won the White Bequest Award from the Australian Academy of the Humanities. The success of this manual was furthered in an international context through regionally specific editions, published for the United States (Burke et al. 2009) and Spain (Domingo Sanz et al. 2007). The second way in which Dr. Burke has engendered excellent standards in the field archaeology has been in her role as Head of the Department of Archaeology at Flinders University in the development of a Master of Archaeology and a Master of Cultural Heritage Management. These programs are embedded with industry partners and have provided unprecedented industry-engaged training for cultural heritage practitioners. They have become the premier graduate training programs in Australia.

Dr. Burke is a community archaeologist with a serious commitment to engaging the academy with industry and community groups so that the advantages of a university system can also benefit wider society. Her success in archaeology, commitment to her students, and contributions to the field of archaeological education in Australia are inspiration to her students at Flinders University and to the communities in which she has been involved during her archaeological career.

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Burned Remains in Forensic Contexts

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Introduction

Burned human remains may be found in a variety of contexts (Fairgrieve 2008, 2010; Schmidt & Symes 2008). Such remains recovered from a "forensic context" have relevance to a legal inquiry as do cases where a death is suspicious must be investigated. In many countries, legislation is in place which states that any death that is not attended by a physician must be investigated (e.g., in the Province of Ontario, Canada, see the Coroner's Act; RSO 1990 c. C.37, s.31). Under such an investigation the investigative authorities attempt to answer the following five questions:

1. Who the deceased was?
2. How the deceased came to his or her death?
3. When the deceased came to his or her death?
4. Where the deceased came to his or her death?
5. By what means the deceased came to his or her death?

Burned skeletal remains may be difficult to locate, recover, analyze, and interpret. For example, remains associated with mass disasters, such as plane crashes, train derailments, domestic fires, and even automotive collisions, are often highly fragmentary, and commingled with other individuals and other items at the scene. The recovery, documentation, and identification of these remains may provide further evidence of the cause of death and have serious implications for the interpretation of the scene. A multidisciplinary approach to the processing of these scenes is without question the best practice.

Burned remains may be found in clandestine contexts. The use of fire to dispose of remains is not a new concept. It has been practiced in a variety of cultures over thousands of years (Fairgrieve 2008). Given enough fuel and time, a perpetrator may eliminate all of the soft tissue leaving only bones and teeth. This material may be intentionally broken and crushed in order to fragment the remains further. These remains may be subsequently moved to another location or buried.

The discovery and recognition of burned human bone is clearly a challenge, regardless of the context. There are many issues when it comes to processing such scenes. It is necessary for the forensic anthropologist to have a clear understanding of how bodies burn and how various soft and hard tissues are altered by fire. Hence, precautions regarding the recovery, documentation, and understanding the limits of an analysis are outlined below.

Key Issues

Burning of Soft and Hard Tissues

Fire consists of heat and light that is generated by an oxidation reaction (DeHaan 2002). This process, known as flaming combustion, is the gaseous combination of a fuel (tissues of the body) and an oxidizer (oxygen). Although the full mechanics of how fuel, heat, air (oxygen), and an uninhibited exothermic chemical chain reaction all combine to result in a sustained combustion reaction is beyond the scope of this entry, it is sufficient to note that there is a chemical breakdown (pyrolysis) of the molecular structures of a fuel that results in the production of vapor, gases, and a residual solid (char). The heat converts the mass of the fuel into a form that can be ignited and a sustained combination may ensue if appropriate proportions of oxygen are present.

The combustion of a human body is not an even process. A body consists of soft tissues of varying thickness and densities over bone. Therefore, some areas with bones closer to the surface, such as the neurocranium, will have the soft tissue eliminated prior to that of the abdominopelvic cavity. In general, the tissues of a body pass through the clinically defined degrees of burning (e.g., 1st through to 5th degree burns). When the burning process has proceeded to the point at which bone is being burned directly, such burns are said to be either fourth degree or fifth degree (DeHaan 2002). Prior to this state the superficial layers of the skin initially blister (a separation of the epidermis from the underlying dermis). The layers of skin contract due to the dehydrating action of the fire. Large fissures open in the skin, exposing the fatty hypodermis. With the consumption of fat, muscle is then directly charred and burned. The heating of the muscle tissues causes a contraction, and the larger flexor muscles overpower the typically smaller extensor muscles resulting in the flexion of various joints of the body, particularly in the appendages and the posterior of the neck. The bending of the arms and the fingers of the hands are said to mimic the stance of a boxer, referred to as the "pugilistic pose."

The clinical scale for degrees of burning is not sufficient for describing the state of burned human remains in forensic contexts. The Crow-Glassman Scale (CGS) remedies this situation and reflects a systematic pattern of burning (Glassman & Crow 1996) (see Table 1 below for the full scale).

The differing levels of the CGS also serve to describe the inherent difficulties in processing scenes with burned human remains. These range from the recognition of the remains to the collection of bones and teeth when a body has reached CGS 5. The CGS also reflects the fact that the body does not burn evenly. The head and the appendages will burn and eventually fall away from the body after having assumed the pugilistic pose. Meanwhile, depending on the amount of subcutaneous fat, and the presence of clothing, the torso of the body will burn starting with the ribs and the spinous processes of the vertebrae. The body position and location, in relation to other objects, may hinder the burning of the body. This is why the context of the body is of such importance.

The time that it takes to burn a body to CGS 5 is variable. There is a distinct difference between a body burning in a confined space (a house) and an open space (an outdoor fire pit). House fires can easily expose a body to temperatures between 670°C and 810°C and after approximately 10 min and may exhibit the "pugilistic pose" (Bohnert et al. 1998). At 20 min, the vault of the skull is free of soft tissue and the outer table may have fissures. At 30 min, the body cavities are visible and a further 10 min of exposure results in shrunken internal organs. At approximately 50 min, the extremities have been rendered to bone and fallen away from the body and may be difficult to discern from the related debris around the body. Beyond this, the remaining torso of the body is further consumed down to calcined bone. The entire process, at the stated temperature range, may take 2–3 h.

Microstructural and Ultrastructural Alterations

Once the soft tissue is eliminated, the exposed bone will also undergo heat-induced alterations.

Burned Remains in Forensic Contexts, Table 1 The Crow-Glassman Scale (CGS) of burn injury to human remains (Glassman & Crow 1996)

CGS level	Description
1	Burn injuries characteristic of typical smoke death. The body may exhibit blistering of the epidermis and singeing of the head and facial hair. Recovery of the body is similar to that for other victims not involving burn injury. The body is recognizable for identification at this level
2	The body may be recognizable, but most often it exhibits varying degrees of charring. Further destruction of the body is limited to the absence of elements of the hands and/or feet, and possibly, the genitalia and ears. Additional search near the body is warranted for recovery of the disarticulated elements. Identification is made, most often by the collaboration of the medical examiner and a forensic odontologist
3	Further destruction of the body is demonstrated by missing major portions of the arms and/or legs. The head is present at this level, although identity is not evident. The search area for associated disarticulated remains should be widened. A forensic anthropologist should be included to facilitate successful search and recovery procedures at the death scene. Identification is coordinated by a medical examiner, who may require the aid of a forensic odontologist. If needed, a forensic anthropologist may be called on to determine sex, age, race, etc., from the skeleton
4	The skull has fragmented and is absent from the body. Some portions of the arms and/or legs may still remain articulated to the charred body. Search and recovery should be aided by a forensic anthropologist, using systematic bioarchaeological methods, including screening procedures to locate small body fragments and dental elements. Identification is coordinated by a medical examiner using a forensic anthropologist and an odontologist as consultants as needed
5	The body has been cremated and little or no tissue is present. The remains are highly fragmentary, scattered, and incomplete. A forensic anthropologist should be an on-site consultant for the identification and recovery of cremains. Personal identification is most difficult at this level, and a forensic anthropologist may be best trained to interpret cremains for identifying physical attributes of the deceased. Recovery of dental elements will require the expertise of a forensic odontologist. As with all fire deaths, a medical examiner is, most likely, the designate to coordinate consultant activities

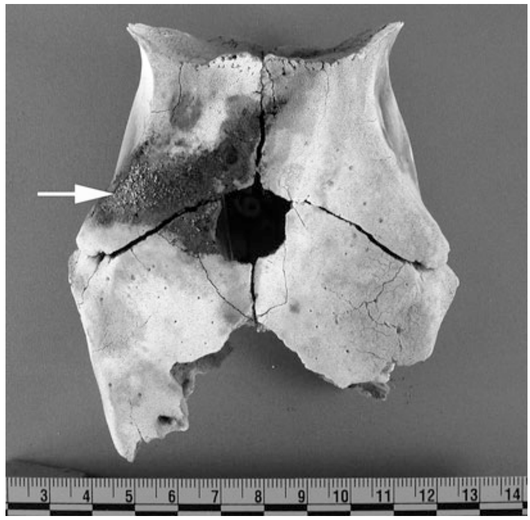
Again, the burning process of bone dehydrates the bone tissue and consumes the organic portion of the bone and even alters the microstructure of the hard matrix. This can result in a color change, splitting, and warping. The color of burned bone may be interpreted in a variety of ways (Fairgrieve 2008: Table 3.5). However, a range of colors exhibited on the same burned bone may be the result of the fuel load, oxygen availability, and contact with other substances, such as metals. The range of color exhibited by burned bone will depend on the temperature reached by the bone, and the duration of time at that temperature. Initially, the bone is a light amber color. The organic components of the bone remain (Fairgrieve 2010). As the process continues, the bone will begin to blacken; the periosteum is burned away and the organic constituents of the bone, including the marrow begin to be consumed. The black color of the bone indicates that the bone has reached a temperature of approximately 300°C and the lamellar microstructure of the bone persists (for a review see Holden et al. 1995).

A gray color is attained once the bone temperature reaches at least 600°C. The organic portion of the bone has leached out at this stage. Microscopic spherical-type crystals are formed (Holden et al. 1995). With further exposure to the heat, these crystals change their shape and size. The organizational structure of lamellar bone is broken down. However, bone collagen has been found in bone reaching temperatures of 600°C (Walker et al. 2008). With further heating, the bone will transition to a blue-gray appearance that may ultimately yield to a final white color. This occurs when the bone has attained a temperature of at least 800°C. The crystals are now hexagonal, and there is no discernible lamellar pattern (Holden et al. 1995).

Along with these microstructural changes there are associated ultrastructural changes beyond the color changes. With the consumption of the organic portion of bone there is a concomitant reduction in the bone's dimensions (length and caliber). Such changes will affect any metrical analysis of skeletal elements. Therefore, it is generally not recommended to take metrics of burned bones if they are to be used in aging and sexing. However, in order to interpret the presence of any pre-incineration fractures, it is essential that heat-induced fractures be clearly understood.

Heat-induced fractures can be broken down into five general types. *Patina* fractures occur on the surface of a bone. The intersecting surface fractures do not penetrate to the medullary cavity. *Longitudinal* fractures follow the long axis of a long bone and may penetrate the medullary cavity. Such fractures follow the longitudinal orientation of the collagen fibers parallel to the cylindrical osteons. *Curvilinear (or curved transverse)* fractures extend around the bone from one side to the other. *Transverse* fractures are perpendicular to the longitudinal axis of the bone and tend to penetrate through the medullary cavity and may even divide the bone into proximal and distal portions. *Delamination* fractures appear as a superficial peeling or flaking of bone from a deeper layer of cortical or cancellous bone.

To distinguish the aforementioned heat-induced fractures from peri-mortem trauma, it is necessary to reassemble the pieces and observe the overall fracture pattern. This way heat-induced fractures may be distinguished from tension, compression, and shearing fractures (Mayne 1990). The color of the fracture margins, relative to those that are heat-induced, may assist in the analysis. Additionally, pre-incineration, penetrating trauma, to the cranial vault, will result in the venting and burning of fluid that is forced out of the vault at that location. This discoloration also indicates the orientation of the head during the burning process (see Fig. 1).



Burned Remains in Forensic Contexts, Fig. 1 The *arrow* indicates charred residue of material that is the result of venting at the time of burning of a pig (*Sus scrofa*) skull (posterior at *top*). In this case, the presence of venting is evidence of a pre-incineration opening in the skull. The pig was lying on its right side

Recovery Issues

In forensic contexts, the issues that pertain to burned human remains are similar to those found in archaeological contexts. These issues include the detection, recording, collection, analysis, and interpretation of the remains. Ultimately this process leads to producing a report that meets the needs of investigators and the courts.

The detection of burned remains may be quite simple. Burned human remains may be obvious as a darkened mass within the debris being observed. However, in cases that have remains buried under large amounts of debris, a systematic approach to searching the scene, such as superimposing a grid and proceeding square by square through each level of the debris, will yield the best results.

In certain instances, the use of alternate light sources may be used. Bones and teeth will fluoresce when exposed to light at the violet-blue-green region of the spectrum and viewed through an orange barrier filter (Craig & Vezaro 1998). Calcined bone is not likely to fluoresce with any combination of light and barrier filters, however, burned bones have been found to appear dark purple when exposed to a light of 450 nm (nm = nanometers) when viewed with a yellow barrier filter (Mavin 2001). This may be helpful as the body will burn unevenly and may be at intermediate stages depending on the duration of the burn. Other items in the debris may also fluoresce.

The use of human remains detection (cadaver) dogs is a common practice. Such dogs may be valuable in detecting burned human remains. However, the use of dogs is no substitute for a systematic search as dogs have been known to give false positive indications as to the presence of remains. In all cases, confirmation of positive indications is essential (Fairgrieve 2010).

The documentation of the location and position of burned bone will be more productive if one recalls that the bones of the victim will be found in relative anatomical order unless they have been moved. The position of the remains must be considered in both the vertical and horizontal planes. Remains found in direct contact with the basement floor with debris on top indicate that the victim was in the basement at the time of the burning. Whereas, a victim's remains positioned between debris indicate that their original position was on an upper floor of the house. It is ideal to use computerized survey equipment during the recovery of remains at most scenes. This evidence may refute or corroborate witness and suspect statements.

Burned remains that have been moved out of relative anatomical position may have been subjected to taphonomic forces (Haglund & Sorg 1997). Natural phenomena, such as gravity, can cause the remains to fall through the superstructure of the house, altering their position. However, a perpetrator may have dismembered a body and then burned the remains. Another artificially induced change may come from the recovery process itself. Careful examination of the remains to explain all marks is necessary for a successful analysis.

Analytical Issues

Analytical questions are no different than those of unburned remains. The obvious difficulty is with the fragmentary state of the remains and the friable nature of the bones. This means that the analysis has the potential to be highly limited. However, cataloging all identifiable skeletal elements can yield a minimum number of individuals, as can an overall weight of the remains recovered.

The repair and reconstruction of fragments is done to facilitate the analysis of fracture patterns. The margins of fractures may have been degraded to the point where a physical mend is not possible. However, all mended bones must be photographed both individually and collectively. An overall photograph of the mended bones in relative anatomical order can be a useful visual aid in court. This will also aid in the analysis of fracture patterns and burn patterns.

Age, sex, ancestry, and even stature may be possible to discern from burned remains. However, as fire alters the dimensions of a bone, this must be considered when applying metrics to an analysis (Thompson 2004). As a result, the reliability of analytical methodologies may be called into question.

The analytical goal is to lead to a positive identification of the victim. The remains may be complete enough to use in a comparison of antemortem and postmortem radiographs. DNA may be recovered from burned tissues, in order to arrive at an identity (e.g., Williams et al. 2004). Burned dental remains, such as tooth roots and crowns, may be very helpful in establishing a positive identification (Hardy 2007).

The identification of trauma is a central issue in the analysis of burned skeletal remains. As noted above, the analyst must differentiate heat-induced fractures from traumatic fractures that have occurred antemortem, perimortem, and even postmortem. Fractures without healing are usually classified as perimortem. However, when a non-burned bone is broken after the soft tissue has decomposed, and the bone is dry, there is a color difference between the break and the surface. This can be discerned in burned bone if it is broken after the fire, and the color of the inner bone tissue differs from the exterior. In the case of a bone exhibiting differential burning, the variation of the color of the bone must be considered carefully in order to interpret the nature of the fracture. Generally, fracture margins that are the same color as the adjacent surface usually indicate that the fracture was present at the time of burning. Bones burned to a calcined (white) state tend to be highly fragmented and uniform in color. Hence, determining the relative timing of the fracture may not be possible.

Future Directions

The recognition and analysis of burned human remains in forensic contexts pose various challenges. Knowledge of the uneven burning of a body can assist in the documentation, recovery, and interpretation of the remains. Standard osteobiographical analysis may be limited depending on the state of the burned remains. However, it may be possible to derive the age, sex, and ancestry with such remains. Additionally, a positive identification from the remains, including dental remains, may not be precluded in such cases. The successful outcome of an analysis is dependent upon the documentation and recovery at the scene. Understanding how a body burns is essential to the interpretation of the state of the remains.

Future research directions tend to be in the area defining criteria for the diagnosis of trauma from burned remains. Such new studies include attempts at examining the effects of fire on dental tissues. By defining criteria for the diagnosis of trauma from burned skeletal remains, the analysis will conform to the standards that are currently being demanded by the courts.

Cross-References

- ▶ Age Estimation
- ▶ Ancestry Assessment
- ▶ Bone, Trauma in
- ▶ Cremation in Archaeological Contexts
- ▶ Dental Anthropology
- ▶ DNA and Skeletal Analysis in Bioarchaeology and Human Osteology
- ▶ Human Remains Recovery: Archaeological and Forensic Perspectives
- ▶ Sex Assessment
- ▶ Stature Estimation
- ▶ Taphonomy in Bioarchaeology and Human Osteology

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Burra Charter: The Australia ICOMOS Charter for Places of Cultural Significance (1999)

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Introduction

The Australia ICOMOS *Burra Charter* was first adopted in 1979, in the historic mining town of Burra Burra in South Australia. Since then – with amendments – the Charter has provided guidelines for cultural heritage management in Australia to ICOMOS members, heritage agencies at all levels of government, and planning bodies. ICOMOS, the International Council on Monuments and Sites, is the international non-government professional organization primarily concerned with the philosophy, terminology, methodology, and techniques of conservation for places of cultural significance. ICOMOS is also an advisor on the UNESCO World Heritage and Intangible Cultural Heritage Conventions and has 100 national committees and 27 specialist committees (see www.icomos.org). Australia ICOMOS is a national committee founded in 1976, now with some 500 members.

The *Burra Charter* reflects an Australian understanding of heritage place conservation practice, and amendments to the Charter over time have incorporated a widened and deepened professional understanding of heritage issues. Widely regarded as best practice, the Charter has been endorsed and accepted by all levels of government in Australia. The *Burra Charter* has also been adopted, adapted, and applied in other countries in all continents. This entry provides an outline of the Charter, its principles and processes, and changes to it over time.

Definition

The Burra Charter: The Australia ICOMOS Charter for Places of Cultural Significance provides guidance for the conservation and management of places of cultural significance. The full text of the Charter is online at http://australia.icomos.org/wp-content/uploads/BURRA_CHARTER.pdf. The *Burra Charter* provides a series of principles and a conservation management process setting a standard for practice for those working in cultural heritage management – primarily heritage places – and related objects, with both tangible and intangible values.

The *Burra Charter* includes definitions, conservation principles and process, and practice (Articles). The Conservation Principles (Articles 2–13) form the basis for the process to be undertaken when making decisions about heritage places as shown in the chart below (Australia ICOMOS 2000: 10). A key principle in the Charter is that the cultural significance of a place is the basis for decisions on managing the place (Article 6.2). Cultural significance is interpreted as having key values for past, present, or future generations (Article 1: 2), namely, *aesthetic*, *historic*, *scientific*, and *social*, with *spiritual* added in 1999. These values are explained further in the guidelines to the Burra Charter: Cultural Significance (Australia ICOMOS 2000: 11–3). The Charter insists that such values may be held by different groups in societies and may conflict, yet should be recognized and respected (Article 13).

A core principle when making decisions about a place assessed as having cultural heritage significance is to take a cautious approach: "changing as much as necessary but as little as possible" (Article 3). Other key principles inherent to the *Burra Charter* are found in Articles 2–13, as summarized by Walker (1996):

> *There are places worth keeping because they enrich our lives – by helping us understand the past; by contributing to the richness of the present environment; and because we expect them to be of value to future generations.*

The cultural significance of a place is embodied in its physical material (fabric), its setting and its contents; in its use; in the associated documents; and in its meaning to people through their use and associations with the place.

The cultural significance of a place, and other issues affecting its future, are best understood by a methodical process of collecting and analysing information before making decisions.

Keeping accurate records about decisions and changes to the place helps in its care, management and interpretation.

The Burra Charter's section on the conservation process (Articles 14–25) refers to more than physical conservation, but the entire range of decisions made including retention of reintroduction of use to reconstruction, adaptation, and interpretation (Article 14). Associations between people and place are to be respected, and opportunities taken for the meanings of place be not only maintained but revived where possible (Article 24). Following the Charter's conservation process in undertaking the relevant research and assessments can better guarantee that decisions about the heritage place are well informed and guided by heritage significance. The following chart demonstrates the *Burra Charter* Conservation Process (Fig. 1):

The *Burra Charter's* section on conservation practice (Articles 26–34) provides some practical guidelines for the hands-on process once cultural significance is established, physical conservation issues identified, and external factors such as planning, zoning, and other statutory considerations. Matters such as dealing with disturbing or removing physical elements and recording all decisions and changes are important when affecting any change to a heritage place. In doing so, key definitions in the Charter enhance understanding and decisions regarding what actions are appropriate for each individual heritage place, particularly in Article 1:

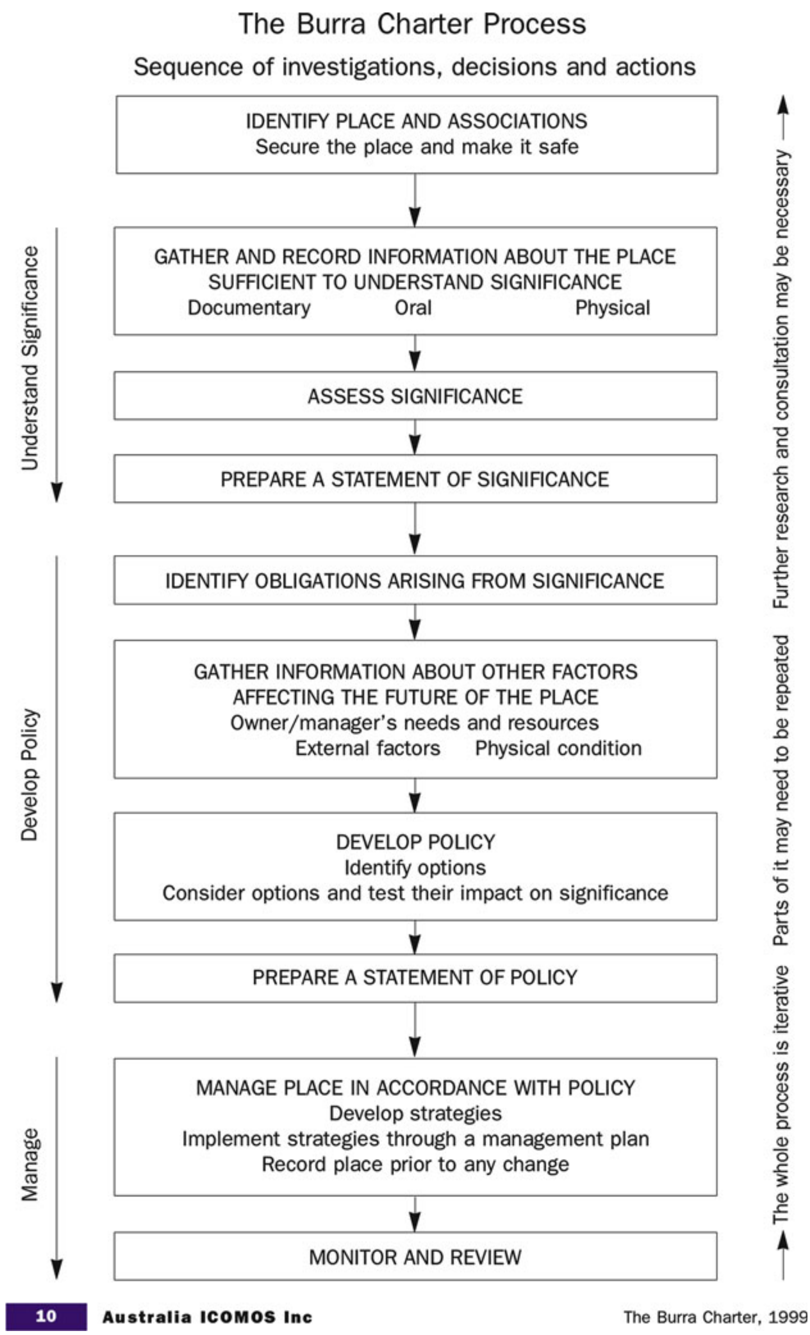
1.4 *Conservation* means all the processes of looking after a place so as to retain its cultural significance.
1.5 *Maintenance* means the continuous protective care of the fabric and setting of a place, and is to be distinguished from repair. Repair involves restoration or reconstruction.
1.6 *Preservation* means maintaining the fabric of a place in its existing state and retarding deterioration.
1.7 *Restoration* means returning the existing fabric of a place to a known earlier state by removing accretions or by reassembling existing components without the introduction of new material.
1.8 *Reconstruction* means returning a place to a known earlier state and is distinguished from restoration by the introduction of new material into the fabric.

These definitions clarify the different decisions that can be made and when they are applicable given the potential impacts on the cultural significance on the place, depending on the nature of the heritage values found. Potentially a place where the fabric is of little significance compared to its use and association with the community may be rebuilt as a new structure yet maintain a continued use; whereas another place's significance may reside in its architectural style, therefore to be retained, yet possibly with a quite different use.

Exemplars of best cultural heritage conservation practice have been presented in *The Illustrated Burra Charter*, both in 1992 updated after the 1999 changes to the Charter (Marquis-Kyle & Walker 1992; Walker & Marquis-Kyle 2004). They provide a useful array of situations and issues in heritage management and how such can be resolved by applying the Burra Charter principles and processes. These publications are not available online, but can be purchased from Australia ICOMOS.

Current Debates and Future Directions

Conservation of Places of Cultural Significance, although generally referred to as the "Burra Charter." In 1999 not only were several amendments



Burra Charter: The Australia ICOMOS Charter for Places of Cultural Significance (1999), Fig. 1 The conservation process (Australia ICOMOS 2000: 10)

passed, but a name change was also adopted: *The Burra Charter: The Australia ICOMOS Charter for Places of Cultural Significance*. This is not merely a semantic change but reflects a widened as well as deepened comprehension of heritage places, their values, and associated conservation management issues. While previous amendments in 1982, 1984, and1989 had been relatively minor (these can be found at http://australia.icomos.org/publications/charters/), those adopted in 1999 after five years of member consultation show a greater shift. The name change reflects a move from a focus on purely physical conservation to a broader engagement to sustaining cultural heritage places for all their values, whether expressed in their physical structure or intangibly.

The 1999 amendments resulted in the greatest shifts to its text. The key changes (beyond the change of title) related to the following (see Truscott & Young 2000 for more information):

- A broadening of the understanding of what is cultural significance, not only fabric of a place but its use, associations, and meanings, particularly to relevant community groups (Articles 1.2, 12, 26.3).
- The coexistence of values, particularly perhaps in a multicultural society such as Australia; this also reflects the Australia ICOMOS Code on the Ethics of Co-existence in Conserving Significant Places, adopted in 1998 (Australia ICOMOS 2000: 20–1).
- Reference to interpretation, that the previous Charter had been silent on; it was recognized that interpretation is important and also that restoration and reconstruction are acts of interpretation (Articles 1.17, 25).
- An expanded preamble to make the document more approachable, with a statement about a rationale about "why conserve?"
- Changes to Article 2 to provide an obligation to conserve and a recognition that conservation is an integral part of good management, arguing that only when conservation is included in other aspects of managing a place will there be satisfactory outcomes.

The review of the Burra Charter that led to the 1999 amendments was in some ways fraught, showing up differences in perceptions of the charter. Some members and heritage practitioners tended to apply the Charter to the letter, in its literal content, others in terms of its intent or spirit. A major conflict occurred in the proposed adoption of the changes in 1997, and the working group went back to a greater consultative process that resulted in an almost unanimous adoption of the amendments at its meeting in 1999 (Truscott & Young 2000).

Australia ICOMOS has a commitment to ongoing review and update to reflect changes in heritage practice. This is unlike the ICOMOS *Venice Charter* (the International Charter for the Conservation and Restoration of Monuments and Sites, see www.international.icomos.org/charters/venice_e.pdf). The Venice Charter has not been changed and in 2004 ICOMOS decided to keep it as an original doctrinal text (see Pécs Declaration: www.icomos.org/venicecharter2004/pecsdeclaration.pdf).

Currently, the Burra Charter is again being reviewed, with proposed amendments expected to be submitted to the membership for comment later in 2013. The guidelines that were not updated in the 1999 amendments are also being updated (Australia ICOMOS 2000: 11–9). Over a decade after the 1999 *Burra Charter* was adopted, the amendments are expected again to reflect changes in perceptions of heritage and practice in its conservation. The amendments will hopefully provide guidance as to how to practice heritage conservation in a way to ensure those changes are incorporated. It is likely that they will include a greater inclusion of community interests and how to balance these with best physical conservation; an appreciation that "experts" and community members have different perceptions of what is important; and a more integrated approach to place, landscape, and the wider environment.

Cross-References

▶ International Council on Monuments and Sites (ICOMOS) (Ethics)
▶ International Council on Monuments and Sites (ICOMOS): Scientific Committees and Relationship to UNESCO

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Burrup Peninsula

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Introduction

The Burrup is a region of Northwest Western Australia known for its petroglyphs, stone arrangements, stone quarries, shell middens, and other archaeological sites (Bird & Hallam 2006). In an area of about 100 km^2, it has been estimated that there are between 0.5 million and 1 million petroglyphs, some of extraordinary beauty (e.g., Fig. 1), carved on natural blocks of hard granophyre and gabbro. The area is on the Australian National Heritage List (McDonald & Veth 2009), and the case has been made for World Heritage nomination.

Definition

The Burrup is the name given to that part of the Dampier Archipelago which was formerly called Dampier Island. Large concentrations of petroglyphs have been found in many islands of the archipelago. The name change was a consequence of the establishment of several heavy industries in the region (against growing opposition from rock art specialists). The establishment of a salt industry replaced the wetlands that had separated Dampier Island from the mainland and established it as a peninsula – the Burrup.

Key Issues/Current Debates/Future Directions/Examples

History of Industry Impacts on the Cultural Heritage

Aboriginal people generally avoid the peninsula because of the history of massacre in the nineteenth century, but historically, they continued to use it for ceremony, for sheep pastoral activities because of the good water, and as a base for collecting shells. During these activities, elders explained the images to their young people. As a result, present-day Aboriginal people of the Ngarluma (including the Wong-goo-tt-oo, the Coastal Ngarluma), Yindjibarndi, Mardudhunera, and Yaburara recognize the importance of the images which were made by the *Marga* ancestors (Palmer 1975), including ongoing connections to rock art traditions further inland.

Since the 1960s, Western Australian Governments (of all political leanings) have encouraged the development of heavy industry in the region. Before the Western Australian Government (W.A.Govt.) passed the Aboriginal Heritage Act 1974 (AHA) (which offers the possibility of slight protection for heritage), there was a search for a port site in the region for shipping iron ore. This survey suggested that Dampier Island was a better option than Depuch Island, 100 km east of Dampier where petroglyphs had been known since the visit of HMS Beagle in 1840 (Wickham 1842), because a cursory survey had concluded (erroneously) that the petroglyphs on Dampier Island "do not form such a rich display" (Ride et al. 1964). According to anecdotes, when the port was established, there was substantial destruction of petroglyphs without documentation. Further, recent scientific studies of the threats from

Burrup Peninsula, Fig. 1 Four Ibis from Gum Tree Valley (Photo: Iain Davidson)

industry (Sinclair Knight Merz 2009) to the petroglyphs have shown that there is little threat, but the continuing presence of the port has left the petroglyphs vulnerable to ongoing damage from the presence of particulate iron ore dust in the atmosphere. Chemical concentrations in the atmosphere were all low, lower than those recorded in Karratha, where they are probably due to urban activities rather than the effects of industry.

In the late 1970s, approval was given for a Joint Venture, led by Woodside Energy Limited, to establish a plant for processing liquefied natural gas subject to certain conditions resulting from the application of the AHA. This led to detailed and prolonged field study of the petroglyphs by teams led by Patricia Vinnicombe, Ken Mulvaney and Jim Rhoads (Vinnicombe 2002). Most of this work did not include local Aboriginal participation, although Aboriginal staff from the Western Australian Museum did participate. Many petroglyphs were documented, some were salvaged with the intention of relocating them after the establishment of the gas plant, and others were documented before being destroyed. Those that were salvaged have not yet been relocated (Fig. 2), causing ongoing friction between Aboriginal and other stakeholders in rock art and government and industry. An audit of the petroglyphs on Joint Venture leases in 2007 showed that in many cases where approval had been given for removal or destruction, the petroglyphs are still present in the lease.

Burrup Peninsula, Fig. 2 Outline kangaroo in Salvage Yard (Photo: Iain Davidson)

In 2003, in advance of a determination on Native Title, the W.A. Govt. established industrial zones on the Burrup and obtained Aboriginal consent through the Burrup and Maitland Industrial Estate Agreement (BMIEA). There is a perception that the W.A. Govt. did not deliver the agreed benefits in return. Approvals under the

AHA subsequent to this have followed Aboriginal involvement in surveys, but industries (including another gas plant) have been established against Aboriginal wishes.

Results of Cultural Heritage Work on the Burrup

Attempts have been made, under existing legislation, to mitigate the direct impact of industry in some cases, but government deemed the cumulative impact on sites in the region, and the broader impact on the sites in the landscape less important than the development of industry.

A major conveyor carries salt through the rocky part of southwest Dampier Island (Virili 1977), and Michel Lorblanchet undertook archaeological work (funded by the Australian Institute of Aboriginal Studies, as it then was) in the adjacent Gum Tree Valley and Skew Valley from the early 1970s (Lorblanchet 1992). This work has produced the only secure dates for the production of petroglyphs. These dates come from excavation of shell middens at the entrance of Skew Valley which revealed images produced more than 4,200 years ago. In addition, among the engraved blocks in Gum Tree Valley, Lorblanchet found a trumpet shell which was dated to about 22 thousand years ago. This shell does not definitely date the art but shows that people were present in the region at the period of maximum cold of the last glacial when sea levels were much lower: the shore was 100 km or more distant, and the islands of the archipelago were the tops of hills in the Dampier range. Radiocarbon dates from shell middens on Rosemary Island confirm that the island was used between 9.5 thousand and 7.2 thousand years ago, corresponding to the interval in which the rising sea reached the hill, and then isolated it (Bradshaw 1995). The petroglyphs on the island do not show the full range of images found on the mainland, suggesting that the older ones (including faces called "archaic") predate the earliest shell middens and the latest ones (including many turtles) (Fig. 3) could be later depending on when water crossings became possible.

The petroglyphs were made by removing some of the weathered outer surfaces of the blocks, revealing a lighter-colored surface below (Donaldson 2009). Both Lorblanchet and more recently Ken Mulvaney (2013) have documented that there are several stages of weathering after the images were made, allowing the construction of a sequence of relative ages for the images. Some image classes show several stages of weathering. Considering only those that have only one stage, in the oldest class were very small images of birds and quadrupeds and in the next oldest some of the large tracks of birds and macropods as well as large outline images of them. In the second youngest class, there were lines of people dancing (Fig. 4), and, in general, images of fish, turtles (Gunn & Mulvaney 2008), and other

Burrup Peninsula, Fig. 3 Turtles from Rosemary Island (Photo: Iain Davidson)

Burrup Peninsula, Fig. 4 Line of dancing people, Dugong Heights (Photo: Iain Davidson)

Burrup Peninsula, Fig. 5 "Archaic face" at Picnic Creek, showing Joint Venture Plant in background (Photo: Iain Davidson)

marine species are the least weathered. Some of the "archaic faces," particularly those with concentric framing (Fig. 5), occurred in the oldest weathering stage (Dix 1977).

Finally, there are many images of the carnivore, *Thylacinus* (Wright 1972), which became extinct on mainland Australia about 3 thousand years ago. These animals were represented at many different times, including some in the oldest weathering stage. They are never in the youngest weathering stage.

Cross-References

▶ Australian Institute of Aboriginal and Torres Strait Islander Studies (AIATSIS): Its Role in Australian Archaeology
▶ Australian Paleoart
▶ Australia's Archaeological Heritage
▶ Cultural Heritage and Communities
▶ Cultural Heritage Objects and Their Contexts
▶ Cultural Heritage Site Damage Assessment
▶ Cultural Landscapes: Conservation and Preservation
▶ Dampier Archipelago Petroglyphs
▶ Heritage and Archaeology
▶ Heritage Ethics, Cultural Base of
▶ Heritage Landscapes
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▶ Heritage, Changing Views of: A Legal Perspective
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Basic Biographical Information

Robyn Bushell holds a doctorate from the University of Sydney. She is an Associate Professor in the Institute for Culture and Society at the University of Western Sydney. In addition to her interests in cultural heritage research, Dr. Bushell has worked for many years with natural heritage, sustainable tourism planning, and community development across the Asia Pacific region.

Major Accomplishments

Her teaching and researching is located at the interface of critical heritage studies and community well-being, focusing on the values underpinning everyday life, sustainable development and heritage management, and the entangled relationships between the local and global, between conservation and development, in heritage places in both developed and developing countries, particularly in SE Asia. While "heritage" has become an effective means for protecting landscapes, rituals, materiality, and values of place, it has emerged as a valuable resource for achieving wider goals such as poverty alleviation. Heritage worldwide faces unprecedented threats. Her current work focuses on policy frameworks and theories of social entanglement and the efficacy of international instruments including the World Heritage Convention and the Convention for Biological Diversity, with particular interest to Indigenous and developing nation peoples.

A successful collaborative researcher on funded grants around tourism, community well-being, heritage management, and sustainability. Prof. Bushell has over 44 refereed edited books, book chapters and journal articles, and commissioned reports. In addition she has contributed to a number of international policy documents – for the IUCN, UNESCO-World Heritage Centre, UN-World Tourism Organization, the World Health Organization, and ASEAN Secretariat. These include a report to the 34th meeting of the World Heritage Committee as part of the review of the Operational Guidelines for the World Heritage Convention with the development of Principles for World Heritage and Sustainable Tourism practices, which was a joint initiative of UNESCO-World Heritage Committee, IUCN, ICOMOS, and ICROM. Her latest book *Heritage Tourism: Place, Encounter & Engagement* in the Routledge Series *Key Issues in Cultural*

Heritage is coedited with Russell Staiff and Steve Watson (Staiff et al. 2012).

Prof. Bushell initiated led the European Union – Australian Gov't funded: Post Graduate Training Scheme "*Sharing Our Heritage*"*: Master Classes In Cultural & Natural Heritage Management* with in-kind support from UNESCO-WHC and Parks Australia, 2005–2007. The project involved four universities in Australia and four in Europe. She also supervises doctoral scholars engaged in research around a range of topics related to heritage management and community development issues.

Dr. Bushell works with a range of national and international heritage governance bodies and academic institutions. She is a member of Forum-UNESCO; the Australian Department of Environment and Heritage World Heritage Reference Group (2009–2012); IUCN representative on Steering Committee World Heritage and Tourism (2009–2011), Blue Mountains World Heritage Advisory Committee; ICOM-Australian chapter; Ministerial Appointment, Booderee National Park Board of Management, comanaged with the Wreck Bay Indigenous community (2003–present); Ministerial Appointment to the NSW NPWS Regional Advisory Council for Blue Mountains National Park, Executive Ctee for the Oceania Regional Steering Committee of the World Commission for Protected Areas (WCPA) of the International Union for the Conservation of Nature, IUCN (1998–present); Vice Chair, International Specialist group on Tourism, WCPA–IUCN (1998–present); and IUCN "Healthy People Healthy Parks" Steering Committee (2011–). She was a member of the Expert Liaison Committee for Protected Areas to develop input to the SBSTTA 9 for the Convention on Biological Diversity (1998) and member of the UN-World Tourism Organization Expert Advisory Group on Indicators of Sustainable Tourism.

Cross-References

▶ Cultural Heritage and Communities
▶ Cultural Heritage and the Public
▶ Cultural Heritage Management: International Practice and Regional Applications
▶ Heritage Theory
▶ Heritage Tourism and the Marketplace
▶ Stakeholders and Community Participation
▶ Sustainability and Cultural Heritage
▶ Sustainable Cultural Tourism Policies: Overview

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Basic Biographical Information

Karl W. Butzer (1934–) is an American geographer, geoarchaeologist, cultural ecologist, and environmental archaeologist. Much of his research has focused on the relationships between the environment and prehistoric people and more recent societies. He has collaborated with many paleoanthropologists and archaeologists, working at both larger, regional scales and at the site-specific microlevel.

He was born in Germany and emigrated to England and then Canada as a child. He attended McGill University, where he received a B.Sc. in Mathematics (1954) and an M.Sc. in Meteorology and Geography (1955). With the support of an Exchange Fellowship, he went on to the University of Bonn (Germany), where he received a Doctor of Science (Dr. rer. nat.) in Physical Geography and Ancient History (1957).

After two years as a research associate at the German Academy of Sciences and Literature, he was appointed Assistant and then Associate

Professor at the University of Wisconsin-Madison (1959–1966). In 1966 he took a position as Professor of Anthropology and Geography at the University of Chicago and in 1980 was named the Henry Schultz Professor of Environmental Archaeology. During 1981–1982, he was Chair Professor of Human Geography at the ETH (Swiss Federal Institute of Technology), Zurich, but returned to Chicago. During his tenure at Chicago, he was elected to various subdepartmental units, including the Committee on African Studies, Committee on Evolutionary Biology, and Committee on Archaeological Studies (Humanities). He also served as Professor in the Oriental Institute.

In 1984 he joined the faculty of the Department of Geography and the Environment at the University of Texas, Austin, where he is today, and was named the Raymond Dickson Centennial Professor of Liberal Arts. In 1995 he was Cecil and Ida Green Visiting Professor at the University of British Columbia.

Major Accomplishments

During the early part of his career, his research focused on two general topics: the geomorphology, geoarchaeology, and Quaternary climates of Egypt (especially Nubia) and the paleoecology and geochronology of early hominins. His dissertation, *Quaternary Stratigraphy and Climate in the Near East*, was largely based on his field research in Egypt and was published in 1958 and reprinted in 1969. As a member of the Yale Prehistoric Nubia Expedition of 1962–1963, he spent seven months in the field studying late Quaternary landscape evolution and the prehistoric archaeological record in Egypt's southern Nile Valley. His early research on Egypt was coalesced in two major works: *Desert and River in Nubia*: *Geomorphology and Prehistoric Environments at the Aswan Dam* (1968) and *Early Hydraulic Civilization in Egypt*: *A Study in Cultural Ecology* (1976). The latter was the first effective attempt to isolate, understand, and synthesize the critical factors involved in the rise of an "irrigation civilization."

In the late 1960s and early 1970s, he turned his attention to the paleoecology and geochronology of early hominins. He participated in the University of Chicago Omo Expedition in southwestern Ethiopia (1967–1969), which involved collaboration with Richard Leakey, and in 1971 and 1973 he worked independently at Axum, Ethiopia. He was especially interested in the paleoecology of the African australopithecines and *Homo erectus*, Neanderthal spatial behavior, and the first appearance of anatomically modern humans. His argument that both archaic and modern *Homo sapiens* coexisted 135,000–65,000 years ago is supported by the results of recent biomolecular research.

The early part of his career also included research in Spain and South Africa. He was involved with the University of Chicago's excavation of Acheulian sites at Torralba and Ambrona in central Spain (1961–1963, 1967, 1980–1981), and he directed the Sierra de Espadan Project in anthropology, historical archaeology, and environmental history (1980–1987). Also, he conducted independent research in Mallorca and Catalonia, Spain (1969–1971). Between 1969 and 1983, he spent 9 field seasons investigating the geoarchaeology of some 30 sites, including Taung and Swartkrans, in South Africa.

During the second half of his career, he focused on the more recent prehistoric and historic periods in order to obtain and interpret high-resolution records, including written accounts, of human impacts on the environment. The skills of his wife, Elisabeth Butzer, in archival research and interviewing have been key factors in facilitating this change of direction. For example, as director of the University of Texas Laguna Project (1995–2000), he considered the recent environmental history of northern Mexico. This project led to a series of papers with Elisabeth, all heavily based on archival sources, addressing the impact of livestock grazing on Colonial Mexico. In a similar study, he evaluated the environmental impact of livestock introduction to New South Wales, Australia (with David Helgren, 1999, 2003). He also has investigated the recent history of French coastal reclamation in Nova

Scotia (1999), the environmental history and geoarchaeology of Cyprus (2004), and the geoarchaeology of Celtic hillforts in northern Portugal (2010–2011).

He is author or editor of 15 books and monographs and author or coauthor of some 275 refereed, scientific papers or book chapters. His seminal book, *Environment and Archeology*: *An Introduction to Pleistocene Geography*, was first published in 1964; a new and expanded edition, with the subtitle *An Ecological Approach to Prehistory*, appeared in 1971. This work served to shift "environmental archaeology" from a technical to a synthetic and processual overview of world prehistory. He characterized Pleistocene geography as "environmental reconstruction as applied to an understanding of ecological setting and prehistory" and took issue with Gordon Willey and Philip Phillips' (1958) acclamation that "archaeology is anthropology or it is nothing," pointing out that "Archaeology…has been equally dependent on geology, biology, and geography…during its development [and] is heavily dependent on the natural sciences."

His book *Archaeology as Human Ecology* (1982) represents another major contribution to the archaeological community. In that work he stressed the significance of "contextual archaeology," whereby archaeological sites are placed in their cultural, biological, climatic, and landscape context. This approach is now standard in archaeological investigations.

He has received many awards and honors in recognition of his contributions to archaeology, geoarchaeology, and geography, including a Guggenheim Fellowship (1976), the Royal Geographical Society's Busk Medal (1979), the Society for American Archaeology's Fryxell Award for Interdisciplinary Research (1981), the Geologists' Association of London's Henry Stopes Medal (1982), the Geological Society of America's Rip Rapp Archaeological Geology Award (1985), and the Archaeological Institute of America's Pomerance Medal (1991). He was elected a Fellow of the American Academy of Arts and Sciences in 1984 and a Fellow of the National Academy of Sciences in 1996.

During the course of his career, Karl Butzer has been at the forefront of geoarchaeology, cultural ecology, and environmental archaeology. He is often described as one of the "fathers" of geoarchaeology, and he remains deeply engaged with interdisciplinary environmental archaeology and history.

Cross-References

▶ Geoarchaeology

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