21 Archaeology as an Interdisciplinary Science at the Cross-Roads of Physical, Chemical, Biological, and Social Sciences: New Perspectives and Research

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> *When Willard F. Libby first discovered radiocarbon dating in 1947, archaeologists, and especially Egyptologists, ignored it. They questioned its reliability, as it did not coincide with the "known" historical dates of the artifacts being tested. David Wilson, author of The New Archaeology, wrote, "Some archaeologists refused to accept radiocarbon dating. The attitude of the majority, probably, in the early days of the new technique was summed up by Professor Jo Brew, Director of the Peabody Museum at Harvard. 'If a C14 date supports our theories, we put it in the main text. If it does not entirely contradict them, we put it in a footnote. And if it is completely out-of-date we just drop it.*
>
> Christopher Dunn

Summary

This chapter will focus on new research in archaeology, interdisciplinary science that uses various physical, chemical, biological, and social sciences. Such studies, also known as archaeological sciences, are generally referred to as archaeometry. Information kept hidden by an artifact from the past can be learned with the help of archaeological sciences. Archaeology is, as an interdisciplinary field of science, fundamentally considered to be a social

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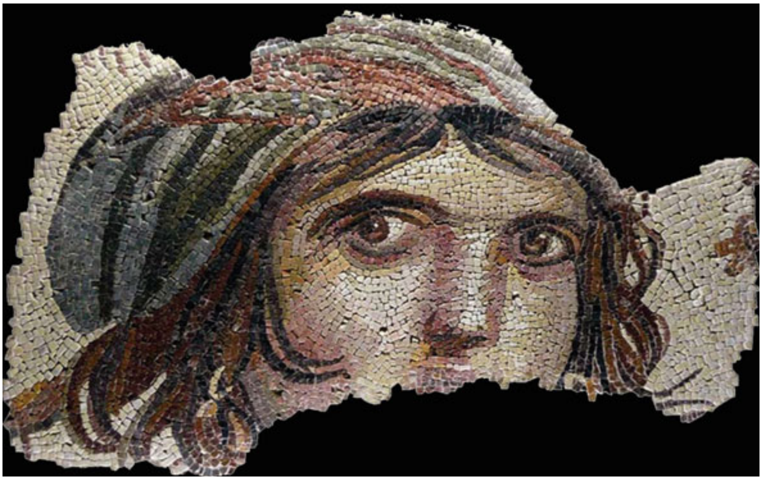
science. However, it is an interdisciplinary science because various basic hard sciences such as physics, chemistry, biology, statistics, maths, and social sciences such as economics and sociology occur in archaeological research. Firstly, the relationship between natural sciences and archaeology and then the relationship between social sciences and archaeology are addressed in the light of new studies. Lastly, the approach of society and archaeology is considered. The number of joint studies and analyses of the natural sciences is increasing every day. For 60 years, the archaeological sciences and archaeology have produced important results with integrated studies in human history. Archaeology uses current methods that are constantly renewed thanks to archaeological science. This allows the integration of any other science in an archaeological study. For instance, computer science's frequent application in archaeological science in recent years is a crucial development. New methods and discoveries in the integrated sciences make the future of archaeology exciting. Thanks to the scientific cooperation in question and with the help of analyses, the distant past will be closer to us and more comprehensible.



"Gypsy Girl" mosaic Gaziantep Zeugma Excavation (Adapted with permission from the archives of Zeugma Excavation).

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1 Introduction

Archaeology is an interdisciplinary science since the information used in research methods in excavations and obtained in excavations and research is related to other sciences. Archaeology is a word derived from the words "*arkheos*" (ancient) and "*logos*" (path, method, science) and means "*Science of the Past.*" It provides information about the various disciplines of science and also scientific discoveries. Such leads to the development of civilization's history, humanity, and specific ancient cultures while providing insights into human creativity elements. It also includes information about the development of art, trends in art, human relationships with nature, etc.

Archaeology and archaeometry have become inseparable today. The archaeology sciences can help manage it to reach the maximum level of knowledge from an archaeological excavation project. While this precisely answers many questions, it also provides a new perspective illuminating the past's unknowns. Archaeology takes place between experimental sciences and observational sciences. Is archaeology a social science? In its shortest known definition, archaeology studying humans, society, and cultures in the past is also a social science. In this context, it uses various methods and techniques of the social sciences. Today's archaeological projects no longer include only archaeologists and photographers. Archaeological sciences experts participate in archaeological site work and research their subjects personally. This has led to an increase in archaeology's importance in recent years. Accordingly, archaeological site work becomes combined with the fundamental issues of archaeological sciences. Many archaeologists feel the need to analyze archaeological sciences such as geology, chemistry, physics, or biology after unearthing and interpreting an artifact. Thus, an archaeologist can better trace the past than ever by evaluating archaeological science results with site results. The archaeological sciences' methods and techniques are being used together, ranking archaeology first among the interdisciplinary sciences. Indeed, techniques that the archaeological sciences use consist of basic techniques and methods. It primarily borrows the background on basic principles and phenomena of physics of the natural sciences, chemistry, geology, geophysics, astronomy, maths, and information science (Fig. 1) [1].

2 Natural Sciences and Archaeology

For an archaeologist, archaeometry studies are priceless in terms of showing the unseen. For instance, the metal composition of a metal dagger can be identified by the analysis. If there is fabric preserved on the metal, archaeometry studies can be performed for this fabric, and it can provide a better understanding. Analyses applicable to the fabric, for example, are Schweitzer's reagent for cellulose fiber to determine the fiber type and whether it is linen or cotton, Loew reagent to see whether it is natural silk, XRD analysis for mineralized remains, and examination by scanning electron microscope (SEM) to understand their fiber structure in detail [2]. The examination of various remains obtained by sifting soil at the base of a house will provide more information about the house. Archaeological excavations oblige many disciplines to work together. In this context, it has a renewed cycle of methods and theories continuously [3]. While the archaeometric examination of

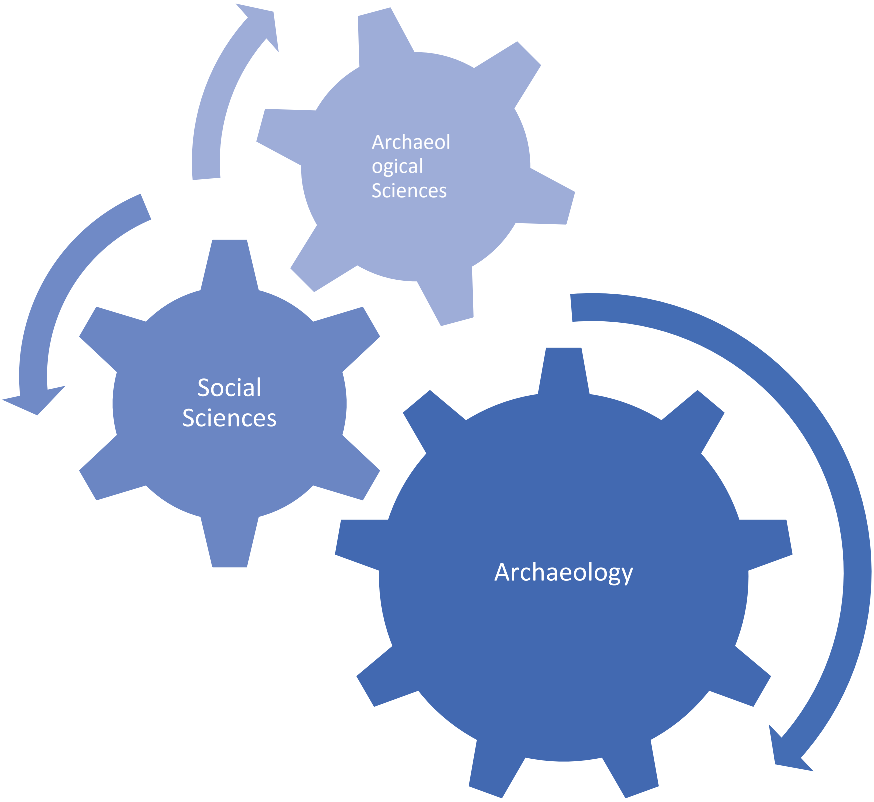

Fig. 1 Archaeometry and other scientific fields. A simple schema shows the relations between archaeology, archaeological sciences, and social sciences

certain artifacts starts directly in the laboratory, for instance, some remains such as skeletons unearthed by anthropologists during excavation, anthropological methods and theories should also be used at the site. Some information obtained from archaeometric studies has illuminating results for today. For example, the glaze analysis concluded that Roman glazed drinking vessels contained lead, and Roman soldiers might have died due to poisoning. Therefore, lead glazing in ceramic technology was prohibited [3].

Archaeometry can apply physics, chemistry, geology, and engineering sciences to analyze various archaeological materials. The term archaeometry comprises the Greek words *archaeos* (ancient) and *metron* (measurement). With the discovery of radiocarbon in the 1950s, modern archaeometry came to exist. Dating an archaeological material using the C 14 method led to a breakthrough in that period's archaeology. It contributed to the development of chronology across the globe. Modern archaeometry was first used as a science and a term in the late 1950s by C.F.C. Hawkes of Oxford University [1, 4]. Since then, archaeometry has always offered new methods and analyses and is continually updating itself. Today, it is also referred to as the archaeological sciences.

The use of natural sciences in archaeology, the determination of the amount of carbon or carbon-14 (14C) in organic materials (wood coal, bones, shells, decayed wood, plant material, etc.), were invented by American W. Libby in the mid-1950s at the Institute of Nuclear Science in Chicago. He was awarded the Nobel Prize in chemistry in 1960 [1]. However, some analyses performed with methods of specific positive sciences date back to the 1930s. Some archaeological studies carried out in the Near East offered pioneering archaeometric analyses. For instance, the Alishar Höyük excavation in Yozgat, Turkey, was one of the most important excavations of the University of Chicago in those years. However, in the 1930s, archaeometric analyses of human and animal bones, seashells, obsidian, wood, ceramics, grains, the fabric remains, and metals were carried out. The publication of the Americans' Alishar Höyük excavation reports supported with archaeometric analyses was a first for Anatolian archaeology [5]. The publication in question is also one of the pioneering studies, including archaeometric analyses in world archaeology.

The use of developments in the positive sciences by their adaptation to archaeology leads to new studies. The network of relations between archaeology and archaeometry varies day by day, and the number of disciplines in this field is increasing. An interaction network between the archaeological sciences occurs when analyzing various materials from an archaeological area based on humans, society, and the environment [1].

Archaeometry offers the opportunity to evaluate archaeological materials for various purposes. There are nine different groups most commonly used. Among them, dating methods with physical and chemical techniques determine the raw material of archaeological material with chemical or physical processes, examine remains under the ground with geophysical methods, and establish a connection between celestial bodies and monuments in terms of astronomy. Moreover, conservation sciences are essential in preserving and restoring monuments with physical and chemical methods. It is valuable determining past environments in terms of fauna, flora, and climate with archaeological science methods in environmental archaeology. Digital archaeology is a new archaeometry area that transfers the past information of an object digitally to the future by allowing this object to be completed thanks to the computer sciences using cyber-archaeology. Digital mapping is also integrated into the evaluation of ancient settlements with all types of mapping using geomatic engineering techniques. These are based on various sub-branches such as lithic analysis, palynology, osteoarchaeology, zooarchaeology, palaeoethnobotany, archaeometallurgy, archeogeophysics, chemistry, bioarchaeology, archaeobotany, meta-archaeology (philosophy of archaeology), conservation and restoration sciences, archaeometallurgy, pathology, ancient DNA, and geomatics and artifact studies (Table 1) [1]. A new method emerging in the sciences mentioned above, archaeometry, is updated continuously by enabling new evaluations. In this sense, archaeometry methods have a continually expanding range. This is a real reflection; the more science progresses, it illuminates the past to the same degree. For instance, archaeological samples' examination has increased in parallel with technological improvements in DNA archaeology within the last 12 years. Mobile DNA labs are on the agenda. In this way, it will be possible to examine samples at the site during excavation or research. According to the results of current studies, ancient DNA studies have clearly shown the determinations

Table 1 Archaeology and integrated science of physical, chemical, biological, and social sciences

Archaeology	
Archaeological sciences	Social sciences
Chemistry (Diffusion, reactions, melting, affinities, archaeometallurgy, obsidian source determination, mineral ore source determination, clay source determination in ceramics and XRF (X-Ray Fluorescence), NAA (Neutron Activation Analysis), ICP-MS (Inductive Coupled Plasma-Mass Spectrometry) FTIR (Fourier Transform-Infrared Spectroscopy) and Raman Spectroscopy)	*Philosophy* (Meta-archaeology)
Physics (Radioactivity, C14 Dating, dendrachronology, luminescence methods, electricity and magnetism, atomic theory, electromagnetic ration)	*Museology* (Exhibition, education)
Biology (aDNA, isotopic analysis, paleogenomics, osteoarchaeology, bioarchaeology, zooarchaeology, palaeoethnobotany, ancient diet and botany)	*Geography* (Human geography, ancient climate, ancient landscape, paleogeography, GIS)
Geology (Geomorphology, geoarchaeology, pedimentology, petrology, paleopathology, archaeoenvironment)	*Sociology* (Social organization, society, social relation, social systems)
Geophysics (Paleoclimate, geomagnetic field, atmosphere, ground penetrating radar (GPR), electrical resistance prospection and magnetic prospection-magnetic susceptibility)	*Economics* (Ancient economy, commerce network, trade)
Mathematical Sciences (Algorithms, statistics, geometry, mathematical modelling)	*Ethnography* (Ethnoarchaeology)
Astronomy (Archaeoastronomy, Solar system, celestial mechanics, sun, moon, symbol)	*Anthropology* (Paleoanthropology, social anthropology, phycical anthropology)
Cyber-archaeology/information science (Information and communication Technology (ICT), software engineering, computer sciences, photography digital archive, virtual Reality, 3D modelling)	*Philology* (Ancient linguistics)
Conservation sciences (Reconstruction, restoration, conservation, architecture)	*History* (Period system, revolution, event, phenomenon)

of human interactions, migrations, and ethnic identities across broad geographies [6, 7].

2.1 Dating Methods in Archaeology

The oldest and most used techniques in archaeology are undoubtedly dating methods. Carbon 14 can reveal the approximate history of artifacts along with dendrochronology and luminescence methods. Thermoluminescence reveals the date of the last heating of a ceramic object. It is possible to date most ceramics, clay objects, some rocks, flints, megalith structures, and even cave paintings [1, 8]. Thermoluminescence dating was first applied to a ceramic vessel fragment in the 1960s. A new method introduced in 2020 has enabled ceramics to be dated with Carbon 14 [9]. Archaeologists generally date ceramics stratigraphically and relatively. However, learning the exact date of certain questionable pieces will help to solve some problems. The obsidian hydration dating method developed in the 1960s is an aging analysis based on the measurement of water absorbed in obsidians, volcanic rocks. The Infrared-Photoacoustic Spectroscopy (IR-PAS) method has higher precision, correlating the water peak's height with rim width. Secondary Ion Mass Spectroscopy (SIMS) is the most accurate measurement with ± 0.005 µm error. Currently, the obsidian hydration dating method (SIMS-SS) introduced by scientists suggests the use of SIMS for the measurement of diffused water's profile in the outer surface layers of an obsidian tool [10]. Thus, it is used today as an exact dating method compatible with archaeological data [1, 11]. Another exact dating method is radioactive dating applied to bone and cave deposits [5].

2.2 Origin Determination and Characterization Studies

These studies aim to determine population mobility and commercial networks by identifying the source region of materials from various sources in close or remote regions. The materials analyzed in this context are both inorganic (faience, stone, ceramic, glass, sediment, pigment, metals, fossils) and organic (bone, skin, wood, textile, plant remains) [1]. These include obsidian source determination, mineral ore source determination, clay source determination in ceramics, and XRF (X-Ray Fluorescence), NAA (Neutron Activation Analysis), ICP-MS (Inductive Coupled Plasma-Mass Spectrometry), FTIR (Fourier Transform-Infrared Spectroscopy), and Raman Spectroscopy. The first important study on obsidian resource determination and dating emerged in the 1960s. Cann and Renfrew's *"The Characterization of Obsidian and Its Application to the Mediterranean Region"* (1964) and Friedman and Smith's *"A New Dating Method Using Obsidian"* (1960) marked a new era. To date, many methods have been added to various problems. Thus, regional syntheses and databases began to emerge.

Recently developed applications of ion mass spectroscopy and infrared-photoacoustic spectroscopy bring new methods for obsidian dating. Today, some archaeologists are still skeptical about obsidian hydration, but this will change with new technological advances [12]. A common use for the geological petrology technique is the examination of ceramic fabric under a microscope. The determination of rocks and minerals in additives to the fabric offers a comparison with specific geological sources in the region. This examination of fabric groups of ceramics can also be a reference for future studies by establishing a regional database. Also, it contributes to the determination of local or imported ceramics. Various periods have witnessed a detailed analysis of changes in ceramic production [13]. Lead isotope analysis (LIA) has been used in geological source determination of certain archaeological materials for more than 50 years. The determination of ore sources, particularly metal artifacts, as a result of chemical analyses is difficult due to the sources' similar geological features. A new study on this issue examines the change in Pb isotopic oxide and sulfide ore minerals. It correlates them with the geological histories that ore formation has in each region. In the areas where ore deposits are mostly similar in terms of geological ages, such as in the Andes Mountains, Europe, and the Mediterranean; it is inherently challenging to perform provenance analysis for Pb isotopes with similar isotopic ratios in sources of distant geographical origin.

Conversely, the regions with many ore formation periods, such as South Africa, are seen as quite promising for future studies done with Pb isotopes. As a result, resource analysis studies could produce better results in specific world regions. The number of analyses has increased following the introduction of MC-ICPMS in the late 1990s. This method works faster, cheaper, and more precisely than TIMS to measure Pb isotopic archaeological LIA ratios [14]. These studies have prompted research on determining archaeological materials and ore sources' chemical composition in recent years. Archaeometallurgy will continue to offer archaeologists a new perspective and evidence on the use of different resources and metal trade determination.

2.3 Archaeo-geophysical Methods

They are essential for determining artifacts or structures preserved under the ground using archaeo-geophysics before excavation. From the second half of the twentieth century, geophysical methods became widespread in archaeology. There are various scanning methods for this work. These include Ground Penetrating Radar (GPR), Electrical Resistance Prospection, and Magnetic Prospection-Magnetic Susceptibility [1, 15]. Accurate analysis of measurements using various scanning methods can provide important information about what is under the ground without any excavation. For instance, it is possible to identify an area with an architectural structure and its walls before excavation [15]. Geophysical studies can help determine the structure's depth, location, and shape without harming any buried structure is carried out in 3D. This is crucial in obtaining preliminary information about where to start excavation and the depth of buried structures [16]. It is even possible to scan the whole of an archaeological site with this method. A current study is the GPR and magnetometer survey study carried out in Falerii Novi, a Roman city in Italy. This study has uncovered the architectural plan of a Roman city without excavation. Archaeological excavation has provided detailed information about the city plan spread over a wide area and obtained over many years. Therefore, the concept of Roman city planning has generally been understood. The Roman city plan reflected a different architectural plan by contrast with more familiar towns such as Pompeii. In this study, computer-aided geophysical methods, which are not yet advanced, have been included.

Along with such new analytical methods, future studies will fundamentally change our knowledge, such as that not all Roman cities were designed like Pompeii, are expected [17]. Nowadays, different high-resolution remote sensing techniques serve to integrate into studies of landscape archaeology. They mostly comprise of a satellite (optical and radar data), air (photographic, infrared, and Lidar data obtained from aircraft and unmanned aerial vehicles), and land acquisition (different geophysical techniques, field walking, and differential GPS topographic research). These studies offer new approaches that have emerged in the last decade in geoarchaeology research [18]. Even though geophysical studies offer limited information to archaeologists, it is possible to achieve better results thanks to new scanning techniques emerging with each passing day. Today, it is not always possible to carry out scanning with geophysical methods for various reasons such as rough and mountainous terrain and conductive soil types. It is important to use the right method for the terrain conditions. New methods that are suitable for all types of land conditions are expected to emerge in the future. It is possible to compare results using more than one method before an archaeological excavation. Furthermore, the accuracy of data previously obtained with archaeological excavation is proven. Thus, one can expect a developing relationship between archaeology and geophysical sciences to positively influencing each other. Geophysics, helping archaeologists show what is unseen under the ground without any excavation, is the most vital aid to save time and budget by showing the right place to excavate. It is, therefore, among the indispensable instruments for archaeological field research. In the future, the geophysical methods will undoubtedly maintain their importance in archaeological studies.

2.4 Archaeoastronomy

Another archaeometry branch becoming increasingly important is archaeoastronomy. Prehistoric people determined some religious ceremonies, harvest seasons, calendars, and certain structures' locations by observing the sky and stars. It is a science that examines based on ancient astronomical observations in an archaeological structure or culture [1]. So, how did they manage to observe the sky? As a result of a long-term study of the sky with the naked eye, they determined that the moon, the sun, and stars moved at regular intervals. Even there were small stars invisible to the naked eye noted in Ancient Egypt. Archaeoastronomical studies determined that successful astronomical observations occurred mainly in Mesopotamia, Egypt, and the Maya. They used these observations in dividing time, determining seasons, and the location of various structures. Some Stone Age monuments in England, such as Stonehenge, are thought to have been built due to sky observations. It is still a mystery about how advanced ancient people were in sky observation. Future studies will help to develop new perspectives. The ancient Egyptian civilization applied knowledge of astronomy, mathematics, and geometry, especially for architectural structures. For example, a recent study tracked the application of geometry to a still earlier date in the Göbekli Tepe structures, approximately 11.000 BC. This study has solved one of the mysteries of constructing one of the oldest temples throughout human history. Surprisingly, it has revealed that geometry knowledge was in work as reflected in buildings constructed by planning (Fig. 2) [19]. This study shows surprising aspects of the distant past by understanding archaeological discoveries better with the positive sciences' support.

Fig. 2 General view from Göbekli Tepe (*Photo by Soner Atesogullari*)

2.5 DNA Archaeology

In 1985, archaeology began to examine biological remains. Bimolecular archaeology research helps archaeology obtain ancient DNA or aDNA (Paleogenomics) from skeletons and determine nutritional data (Isotopic Analysis). In recent years, DNA studies have revealed the origins of people who created cultures and the unknowns about migrations [20]. aDNA is based on separating the samples' DNA from archaeological bones, teeth, or mummified tissues by a special method. Today, the introduction of whole-genome sequencing methods from the cell nucleus has started to produce better results. An aDNA study examining the genetic structure of South-eastern Europe has revealed significant results. The origin of the farming that first appeared in Europe in the mid-seventh millennium BC is through immigrants settled in southeast Anatolia before moving to Europe. Understanding this process's dynamics was the objective behind the analysis of aDNA data of 225 people living in South-eastern Europe and surrounding regions between 12,000 and 500 BC. Previously, it was possible to identify the vast majority of European ancestry from three separate sources. The first one is ancestors associated with Mesolithic hunter-gatherer groups. The second is related to Neolithic farmers of North-western Anatolia and "North-Western-Anatolia-Neolithic-related" ancestry strongly associated with agriculture. The third is the ancestry emerging during Late Neolithic-Bronze Age in western Europe and associated with the "steppe" derived from Yamnaya steppe pastoralists. There is a reference to the steppe-related ancestry that involves a mixture of Upper Palaeolithic hunter-gatherers of Caucasia and the first farmers of northern Iran [7, 21]. However, there are still some questions that archaeologists cannot answer. When FOXP2 genes were discovered, this was assumed to be the genetic key for the difference between Neanderthals and humans. However, the main point of this study is not to understand human evolution. Reich and many researchers are skeptical that we can reveal biological or behavioral differences between our ancestors and us by comparing ancient and contemporary DNA. aDNA studies are expected to answer unknown questions about the origins of humanity. For instance, the determination of global human migration can give us information on many issues. Various developments are needed to produce the revolutionary ancient DNA evidence for archaeology promoted by Reich. S. M. Downes characterizes these in three categories: extraction methods, the quantity of sequenced genomes, and genetic analysis methods [22]. David Reich's contributions to aDNA studies are undeniable. The future of aDNA studies is quite exciting. With the help of developing new methods, Archaeologists can manage to answer new questions. aDNA has become one of the branches of science that helps archaeology today and will allow us to enthusiastically follow past evidence, such as tracing our ancestors' footsteps.

2.6 Conservation Sciences

It involves preserving and/or restoring artifacts or architecture by archaeological excavations. Cultural heritage management is one of the essential elements of archaeological excavation. It has two main functions, which are to present visuals for community archaeology and preserve archaeological materials. In a sense, the restoration and conservation of unearthed archaeological artifacts, especially architecture, help reduce excavation damage. The better preservation of architecture will undoubtedly allow visitors to an archaeological settlement to understand the settlement much more quickly. Restoration sciences that would enable visitors to complete restored walls with their imagination are significant for archaeology. The application of measures, such as preserving any archaeological finds in situ or moving them to a museum to implement preservation in a laboratory, is possible with restoration sciences. In conservation studies, the object should be documented before and after conservation by photography or video so that researchers and restoration scientists can follow the records [1, 13]. Architectural restoration and conservation in archaeological sites have provided the opportunity for archaeological site management and open-air museums.

For example, Turkey offers a unique open-air space in terms of archaeology. The open-air museum is necessary, especially whether monumental artifacts are as large as to be unmoved to a museum. Since the beginning of the last century, the preservation of artifacts in situ provided open-air museums' development. During the excavations started in 1946 at the site of Karatepe in the district of Kadirli in Osmaniye province in Turkey, in 1958, the "Karatepe-Aslantaş National Park" was declared under the direction of Halet Çambel and the "Karatepe Open Air Museum" was established [23]. The first open-air museum of Turkey was one of the pioneers in this field (Fig. 3). The restoration sciences are the most crucial help for archaeologists in raising a city from a small archaeological artifact. Innovations in chemical products and new methods and techniques can maintain cultural heritage conservation by allowing the restoration sciences to carry out more effective work.

2.7 Geoarchaeology

It emerged in the early 1970s that covers ancient environment and climate research with geology, geography, and environmental sciences. Modern archaeology integrates into a wider field of the natural sciences instead of being a branch of the arts and humanities by using geological methods [1]. Nowadays, geoarchaeology has become a multidisciplinary science that uses earth sciences in determining the human and physical environment in prehistoric times. One of the most important paleogeography studies in this field proves that today Troy's city was situated on the sea-coast during the Bronze Age in northwestern Anatolia. Sedimentological data obtained by drillings on the alluvial plains at the Troy have provided evidence to illuminate changes in the ancient environment. The shoreline's continuous change due to alluvial deposition of Karamenderes (Scamander) river deltaic

Fig. 3 "Karatepe-Aslantaş National Park" and "Karatepe Open Air Museum" at Kadirli town in the city of Osmaniye-Turkey (*Photo by Adem Yildiz*)

progradation greatly affected Troy city. After Bronze Age, Troy lost its location, harbor, and shore side. At present, Troy is situated on the Karamenderes plain nearly 7 km inside the seashore [24]. This study has shown how important it is to consider an archaeological site by assuming its environment. Paleo-environment tries to determine the environment at the time the archaeological site was in use. It is a multidisciplinary science that determines environmental conditions in the past by examining the physical environment, climate, land and sea conditions, soil structure, vegetation, and animals around the site together.

2.8 Cyber-Archaeology

It appeared as a discipline in archaeology in the early 2000s. It aims to animate archaeological data with virtual reality thanks to various computer graphics, such as digital simulations and 3D modeling. It is possible to make many different animations of the past by making wide use of computer science [25]. For instance, it is possible to raise a structure, including its all finds, in 3D. With new advances in the computer sciences and software engineering, cyber-archaeology applications are becoming more various every day. Modern computer software enables the use of statistical analyses that are complicated for archaeologists. The results obtained are only as good as the evidence from which they come from and the suitability of the testing methods used. A primary goal of statistical tests should be to provide shelter for archaeologists to collect and analyze data more accurately and precisely. The awareness of probability and correlation that will develop in time will undoubtedly offer a better understanding of sampling [13]. Information and Communication Technology (ICT) that has just started to apply for archaeology can store and use information. Currently, archaeology is developing research methods and techniques using ICT, the Internet, and Industry 4.0 information technologies.

2.9 Statistics

It is one of the sciences that help archaeology by solving specific problems with various analyses. These sciences help archaeology analyze the past using multiple data. Weaving statistics help us get information about the thread's thickness and woven fabrics' sizes. Thus, the production potential of hundreds of textile tools obtained in most sites can be calculated [26]. This has increased the amount of textile research in archaeology over the last two decades. The use of experimental archaeological methods in weaving has allowed many unknowns of archaeological textile production to be understood. Today, studies for developing new textile analyses and new methods continue. A recent study using statistics has tried to determine the spread of culture with histograms. The spread of the Neolithic to Europe has been a debated topic for many years. The spread of a culture can be revealed using mathematical modeling as a new archaeometric approach. It is possible to determine the cultural and demographic spread. For instance, a model was developed with histograms in a study carried out about the Neolithic spread to Europe. The spread rate, how much area it influenced, and points of finds were shown with graphs. This study indicates that statistics and mathematics can make raw archaeological information more understandable by presenting it graphically [27]. There is no doubt that mathematical modeling in immigration and culture spread will present important results in the future. The use of statistics and mathematics, especially with computer sciences, may allow new approaches and analyses to evaluate many archaeology data in the near future.

Archaeology, as integrated with natural sciences, includes:

- Archaeology is an interdisciplinary science that uses some methods of the natural sciences; and
- Natural science, whose methodologies ultimately involve many sciences (biochemistry, biology, chemistry, geography, geology, materials science, medicine, and physics), strongly correlates with archaeology.

Accordingly, when a new technique is discovered in the natural sciences, archaeological science can be quickly integrated into archaeological studies. For example, currently, aDNA analysis supplies new approaches to ancient human populations and migration theories.

3 Social Sciences and Archaeology

For the last 20 years, archaeology has benefited from economics, ethnography, history, sociology, philology, geography, philosophy, and anthropology to analyze a community in an archaeological site and the sociocultural adaptation strategies to the natural environment (Table 1). While archaeological finds and their analysis provide much information and are quite popular, research on the community structure has always been more limited. As a social science, archaeology can reveal past communities' social organization by using social sciences methods. For instance, archaeological and social sciences in Finland determined Neolithic hunter's social organization, gatherer fishers. The second phase focused on reanimating social networks' social structure and determination within and outside the household. Social organization analysis can determine the size, the number, and total population of settlements, what kind of a culture or community it was, how and why it changed, and what kind of natural and social relations existed between the culture/community and its environment. An analysis of the community can consider a limited amount of archaeological data [28]. New methods and theories in this field will do joint research in archaeology and the social sciences more common in the future. It is possible to obtain information about people and their environment thanks to analyses done using social science methods.

Ceramics, architecture, and stone tools are the main sources of archaeological data. At first glance, this may not seem ideal for analyzing social systems, economy/trade, or political dynamics. However, analytical methods and physical and chemical applications increasingly offer precise information on raw material sources and production. New computer analyses allow meta-analysis of these data. This allows the social sciences to contribute to archaeology. Social studies such as anthropology, economy, and trade encourage the study, especially for determining social structure and economic development and commerce networks [29]. Interdisciplinary studies of social, biological, and natural sciences play a very critical role. The social sciences and environmental sciences' joint studies determine human communities' nature and environment landscapes in a settlement through the ages [29]. Moreover, studies of daily life based on archaeological evidence can be analyzed using various social science methods.

It may be possible to establish a relationship between the social sciences, physical-engineering sciences, and archaeology in terms of archaeometry with meta-archaeology. Lester Embree considers archaeological study as a sub-discipline of the philosophy of science. He defines this as a conceptualization field with critical reflection rooted in archaeologists' dialogs, whom we can define as historians, art historians, museum scientists, restorers, etc. There are two basic dimensions in this field: while one of them is rational, historical, sociological, and economical, the other one can be evaluated in the framework of schools of thought increasing in the West, for instance, empiricist, evolutionist, feminist, historical materialist, neo-Marxist, technological, determinist, etc. [3]. The re-evaluation of material cultural remains along with the philosophy of archaeology, adds new dimensions in terms of interpretation. Evaluation of archaeometric results and archaeological knowledge is possible by evaluating the issue from a broad perspective from the philosophical point of view, in a meta-archaeological way [3].

Ethnography, perhaps one of the most important sciences to which archaeologists frequently refer, for them, is living prehistory. It is a multilayered science, just like archaeology. The ethnographic values alive today also include knowledge, techniques, or methods from the past. At this point, the examination of historical architecture, an oven, or a production technique allows a better understanding of archaeological finds. Ethnoarchaeology is a major, though it is not always the best way to provide operationally important analogy in explaining the archaeological records. Ethnoarchaeological data can also be exactly experienced through experimental archaeology. For instance, archaeologists can observe numerous details in the production phase of archaeological material. However, experimental archaeology cannot fully provide ethnoarchaeology's perspective due to its narrowness and lack of a cultural context [30]. Ethnoarchaeological data may give the best retrospective reconstruction for archaeologists. Sometimes people in the same region unwittingly use the same traditions and techniques for centuries. Therefore, ethnography carrying traces of the past to the present provides a new perspective for archaeologists in evaluating the past.

4 Archaeology and Society

Answers to questions such as "What does archaeology offer to a society? Why is it significant? Why should it be in interaction with society?" determine the role of archaeology as a social science. It is essential to stress the importance of archaeology to the individual who is the smallest component of society before its importance to society as a whole. Archaeology is a branch of science that illuminates humanity's history as a result of many years of study. Considering this framework, it does not directly affect the individual during his or her life. On the other hand, he/she can individually continue to progress in his/her life along with heritage awareness of his/her ancestors as a small representative of humanity. There is the help of known parts of human history, which will help him/her understand his or her location within the history of humanity when he/she looks back. A person developing himself/herself through archaeological science discoveries will undoubtedly step into the future equipped with knowledge of the past. Otherwise, he/she will not know where they come from and where to go and will finally become lost in terms of community. For instance, if an architect has mastered the architectural values of dwellings from the first examples in human history to the present, this will help him/her to reach unique horizons in terms of creativity, inspiration, and aesthetics. This example can touch many science fields, such as medicine, agriculture, ceramics, design, and technology. In short, as the study of everything in the past, archaeology should be one reference guide in an individual's personal development. When learning modern sciences today, archaeology sometimes answers questions that we did not know existed. In this sense, it is understood that archaeology is multi-layered and can inspire many areas by shedding light on the future. The importance of archaeology for society is that it is a science that enables society to advance more strongly in the future thanks to knowledge it obtains from the scientific study of the past. For example, archaeology, which has been carried out in Turkey for many years as an activity removed from society, has started to change with time thanks to many of the author's esteemed colleagues' efforts. By touching society, more in the future, archaeology will allow society to gain a broader perspective. We do not doubt that societies with knowledge revealed by archaeology will be more contemporary and more advanced in the future.

The role and importance of archaeology as a social science have long been debated. The effort of archaeologists studying such a long process as human history to return to the present and share their investigations with the present society is only one of archaeology's sociological aspects. From a more general perspective, as the science of the past, archaeology covers the universal aesthetic values of thousands of years ago, inspiring any humanmade artifacts such as modern homes, cars, jewellery, toys, parks, and monuments.

There is no doubt that all kinds of media are useful in archaeology, reaching today's communities. For instance, when the "Gypsy Girl" mosaic with her famously sad eyes was found during the Gaziantep Zeugma Excavation, archaeologists and the community as a whole touched not only archaeologists but also the community as a whole. Everyone found something of their own in the gaze of this gypsy girl looking at us with sadness from across the ages, as shown in the Art Performance. This was a crucial bridge established by archaeologists between the past and the future. Archaeology, the science of the past, seeks to illuminate our future by shedding light on human history's unknowns. In other words, it takes on the task of keeping the common memory of humanity by recording where humanity's adventure came from and where it is going from the Stone Age to the Space Age. The future can never be isolated from the past. The introduction of excavations and research done in archaeology, a human science, to the public using any media tools will allow new culture bridges. This assigns an important duty to archaeologists to carry out excavations and research and publish these results, besides explaining to society the importance of discoveries for humanity's history. Archaeoparks or archaeological site centers, of which various examples we have seen in world archaeology in recent years, are points where archaeology touches society just like experimental archaeology practices performed with society members.

Archaeology, as integrated with social sciences, includes:

- Archaeology is an interdisciplinary science that uses some methods of the social sciences; and
- Social science, whose methodologies ultimately cover a broad range of sciences, including economics, ethnography, history, sociology, philology, geography, philosophy, and anthropology, correlates with archaeology.

Archaeology mainly focuses on ancient human activity and its environment from a cultural perspective. As a social science, archaeology has the task of building a bridge between today's man and ancient man. In this context, it is important to share archaeological findings with today's society. Archaeopark projects in ancient settlements and education in museums constitute important focuses of archaeology's opening up to society.

5 Conclusion

Archaeometry, founded by physical and chemical methods, may have formed the first generation of archaeological sciences. Particularly between 1950 and 2000, basic archaeometric analyses started and began to be updated. From the 2000s to the present, new techniques and methods began to emerge in archaeometry. The second generation, which can also be called the evolution period, is continuing. An innovative third generation, which will continue with quite different analyses as shown by today's improvements, is expected in the future given current developments. Advances in the hard sciences (physics, chemistry, biology) are beginning to be integrated into problem-solving in archaeological field studies. Thus, archaeological sciences' contribution increases in understanding an archaeological settlement, an ancient community, or culture or reaching accurate and proven information.

In light of current studies, archaeology is unimaginable without the positive sciences. Developments in these branches of science will also affect archaeological studies. In other words, a positive correlation between the positive sciences and archaeology is on the agenda. New discoveries or devices will maintain their importance in achieving precise results in archaeological studies. While all these developments make archaeology an interdisciplinary science, they may also allow it to interact with all sciences. In this context, many joint studies, e.g., population dynamics, population distribution, etc., can be done with the social sciences. In the future, archaeological studies can develop new perspectives to the extent that it benefits from the positive sciences or social sciences in understanding the past. New scientific methods and discoveries in the archaeological sciences will undoubtedly open new horizons that we cannot even imagine today in the field of archaeology. Thus, the future of archaeology is quite exciting. Archaeologists attaching importance to interdisciplinary studies will illuminate the unknowns of the puzzle of humanity's history more decisively than ever before. In this responsibility framework, it is necessary for archaeologists to follow current developments, have basic information about which materials can be analyzed, and include them in their projects. Today, many archaeologists are unaware of archaeometric analysis and still trying to excavate using old methods. Future archaeologists are expected to be trained in archaeological sciences and to be better equipped. In this respect, the archaeologists who first uncover archaeological finds are like a conductor. Indeed, they are the key persons who will provide solutions to many archaeological problems by determining which analysis they need in any conditions, cooperating with relevant science branches, and developing projects.

Archaeology directs archaeometry. In other words, archaeological sciences help solve an archaeological problem, and a new study is carried out using new theories and methods they offer. This allows archaeometry to develop solutions and remain up to date continually. It is like a locomotive carrying the science of the past, archaeology, to the future. Today's archaeometry applications clearly show us that it will not be possible to carry out an archaeology project without archaeological sciences in the future. The use of new technologies integrated into archaeological science in the future will bring expansion in the field of archaeology that we cannot foresee today. Studies bringing together the social sciences, art, and archaeology are beginning to emerge.

Core Messages

- Archaeology is an interdisciplinary science involving natural and social sciences.
- Over the past decade, archaeological fieldwork underwent dramatic changes associated with archaeological prospection technologies and methodologies.
- Archaeological sciences and archaeometry play an important role in investigating our past and protecting buried and still standing heritage.
- Recently, new approaches with the help of analyses of social sciences and humanities have helped us understand ancient social structure, economy, settlement models, etc.
- When considering the possibilities that the first archaeologists had at their disposal 100 years ago, it would be possible to predict future archaeologists become equipped with a fertile source of fascinating technological or scientific possibilities that significantly facilitate information extraction from archaeological sites.

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