Chapter 25
Early Metal in South India: Copper and Iron in Megalithic Contexts

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Introduction

There exist heterogeneous archaeological traditions in South Asia, including varying histories of metallurgy (e.g., see Chakrabarti 1992; Chakrabarti and Lahiri 1996; Possehl and Gullapalli 1999 Tripathi 2008). Consequently, multiple models of the development and adoption of copper and iron metallurgy are necessary and appropriate. For example, while northern South Asia has witnessed a Bronze age followed by an Iron age, the situation in the southern peninsula (South India) seems to be significantly different. An early (pre-iron) copper/bronze metallurgical industry in South India is not well attested; rather, it is indicated only by relatively sparse occurrences of copper artifacts in late Neolithic contexts. The archaeological record for the occurrence of metal (both iron and copper/bronze) in the Iron Age Megalithic contexts, by contrast, is much more robust, and it is this corpus of material that forms the early metallurgical tradition of South India (Fig. 25.1).

There are three interrelated issues that shape any discussion of early metallurgy in South India: the megalithic monuments that constitute a significant part of the archaeological landscape of South India during the Iron Age, the dominance of iron, and the relative paucity and limited distribution of early copper. The prominence of iron in the archaeology of South India stems from its significantly greater presence in the archaeological record, and from a theoretical framework that privileges iron over copper. The dominance of the archaeological research by megalithic monuments makes it difficult to tease apart issues of the early metallurgy and megalithic traditions—indeed, attempts to explain the nature of the megalithic monuments have defined much of the research into the Iron Age.

In this chapter, I provide an overview of the early South Indian metallurgical tradition. My goal is to outline the trends and developments in the field and to highlight potentially useful avenues of further research. This cannot be and is not

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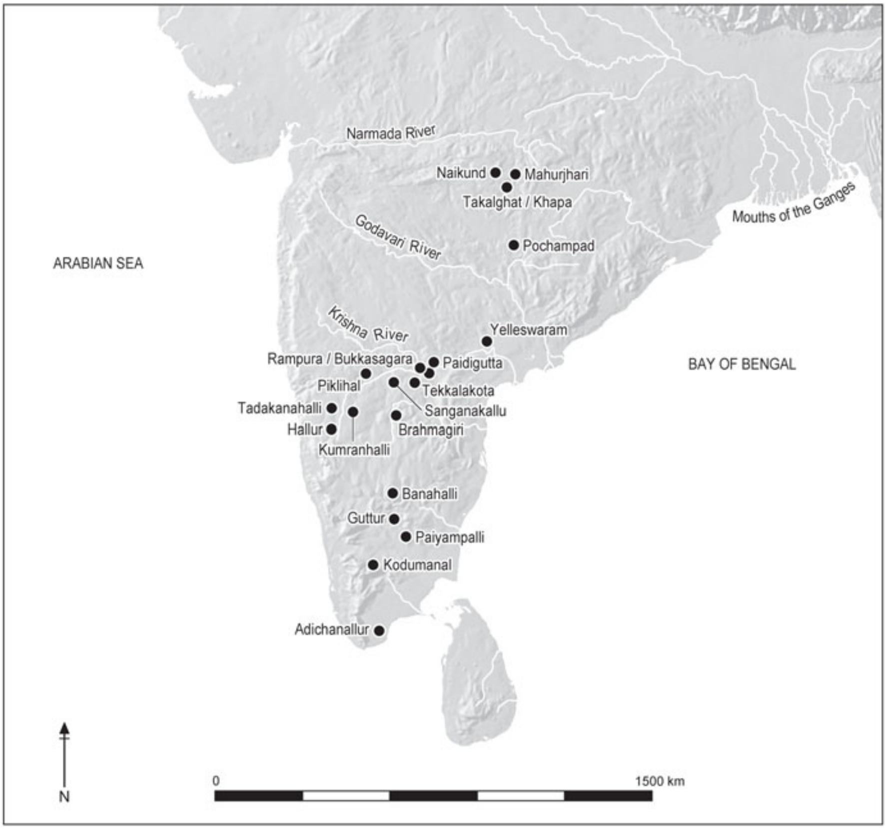

Fig. 25.1 Map showing the location of sites mentioned in the chapter. Note that Naikund, Mahurjhari and Takalghat/Khapa are located in the Vidarbha region of Maharashtra

meant to be an exhaustive catalog of all sites and all evidence. I begin with a discussion of dominant models of early metallurgy—specifically of iron metallurgy—in South India, focusing on the question of diffusion versus indigenous development. I then briefly review the nature of megalithic archaeological record before delving into the evidence for early metallurgy. I end by discussing possible directions for future research.

Modeling Early Metal in South India

Interpretation and modeling of early metallurgy in South India has been shaped by two primary concerns, both focusing on iron metallurgy because of its dominance in the archaeological record. The first is whether the early iron in the peninsula was the result of diffusionary or migratory processes or whether iron was an indigenous development. The second concern has been to understand and demonstrate the skill of the early practitioners of metal technologies. Taken together, these concerns have directed archaeological research towards an emphasis on uncovering the earliest evidence for various ferrous metallurgical practices through excavation and through artifact analyses.

Concern with whether or not the early metallurgical traditions of South India (and indeed, all of South Asia) were indigenous developments arises from the fact that early models privileged migrations of various groups of people into the subcontinent, with each group bearing a specific cultural or archaeological correlate. Early attempts to investigate and explain the presence of the megalithic monuments and their attendant cultural characteristics focused on diffusionary paradigms that connected the South Indian megalithic monuments to others in Southwest Asia and beyond. Their presence in the peninsula of South Asia was explained through a variety of migration theories that also included linguistic and anthropometric data (e.g., Parpola 1973; see Kennedy 1975 for an overview). The most persistent of these groups has been the Aryans, Indo-European speaking peoples, whose entry into the subcontinent has been understood to be the explanation for everything from the decline of the Indus Civilization to the advent of iron technology (see Leach 1990; Parpola 1973; Shaffer 1984; Shaffer and Lichtenstein 1995).

No archaeological evidence exists for the requisite type of large scale migrations, but with or without the Aryans, others (e.g., Wheeler 1959) saw the beginning of iron technology as a result of diffusionary processes. For example, the excavator of Hallur notes in the excavation report that the "people who arrived here with iron, came with the full knowledge of metallurgy and finished tools (Nagararaja Rao 1971, p. 91), " and more recently the excavator of Paidigutta (in Andhra Pradesh) posits that "the newly arrived iron-age folk co-existed with the already existing Neolithic-Chalcolithic people. Though the newcomers had the advanced trends such as iron in their tool-kit and stone for building structures, they preferred to dwell at the same site and in the same rich context (Sastry 2000, p. 29)." This latter statement highlights the emergence of a new technology within apparent cultural continuity and the fact that the question of indigenous development and diffusion needs to be further delineated within South India (see further).

Analysis of skeletal material from the graves points to a phenotypic variability in the Iron Age populations and, importantly, shows no sign of an invasion of people. Kenneth Kennedy asserts that "earlier statements of racial identities based upon a specific set of morphometric criteria [do not] support any theory that iron was diffused to South Asia by foreign populations whose origins lay outside of this part of the world. . . . The skeletal evidence does not support any hypothesis of catastrophic and sudden population replacements in peninsular India during the Iron Age (Kennedy 2002, p. 123; see also Kennedy 1975)."

Obviously, diffusion of technological practices does not necessarily imply movement of people, and the lack of evidence for migration does not mean that diffusion of such practices did not take place. However, beginning with Chakrabarti (1976, 1977, 1992), the model of diffusion into South Asia has been successfully challenged using material from archaeological excavations and survey over the past two decades. Chakrabarti used radiocarbon dates, the tradition of pyrotechnology in the subcontinent, and the varied character of the Iron Age to argue for indigenous development within the subcontinent (see also Possehl and Gullapalli 1999; Tripathi 2008). Not only is there is consistent evidence of continuity between pre-Iron Age and Iron Age deposits, but there is also evidence of pre-Iron Age experimentation with iron and no evidence of possible diffusionary mechanisms. Also, most pertinent here, the earliest Iron Age dates in the subcontinent (c. 1000 BC) have come from South Indian contexts, and therefore render problematic diffusionary models that hypothesized overland introduction of iron into South Asia from the Iranian plateau and which would indicate that the earliest iron be found in the northern subcontinent (but see Tewari 2003 for new dates that may push back the earliest iron in northern India; Tripathi 2008).

Although the early date of iron technology has been established, there has been little explicit discussion of how iron was adopted or adapted into society. That is, while iron metallurgy seems to have been an indigenous development, we still do not know how the knowledge of iron production was organized, maintained (and perhaps even guarded), and transmitted within and between the various groups that inhabited the South Indian Iron Age landscape (see discussion of Johansen (2007) below).

There is geographic variation within South India with regard to when iron metallurgy appears, a variation that needs to be investigated and explained, since even though for the region as a whole there is evidence for indigenous development, there remains the question of how many centers of development existed within South India. If iron metallurgy emerged in a restricted area, how was it spread to other areas of South India so that by the late centuries BC there seems to be such widespread evidence for it?

Bridget and Raymond Allichin argue that "the range of identical tool-types, repeated many times, at site as far apart as Nagpur and Adichanallur—some 1450 km apart—must testify to the diffusion of a fairly tightly knit group of iron workers (Bridget and Allichin 1967–1968, p. 335)." The fact that there seems to be pastoral and agricultural components to the Iron Age economy lends support to the idea of an itinerant group of specialist metalworkers moving across the landscape. If the similarity in morphology is further enhanced by similarity in technological style, it may indicate that we do have a situation in which specialized knowledge is being disseminated to a select group of producers. However, identifying these mechanisms would require significantly more metallurgical analyses on larger sets of artifacts.

Concomitant with the focus on early iron have been attempts to ascertain the level of metalworking skill of these early producers, including identifying the earliest evidence for steeling. The apparently utilitarian nature of the iron artifacts has emphasized a utilitarian approach to explaining adoption—the hypothesized technical superiority of iron over copper and bronze. This emphasis on utility and desirability is evinced in the nature of technical analyses of iron artifacts that focus on evidence for steeling and hardening, for example. There is also an emphasis on determining level of skill as other metallurgical analyses (of iron) have focused on determining the efficacy of iron extraction, the frequency of steeling, and the ability to exploit certain characteristics (as seen in the discussion of technical analyses).

Because of this emphasis on early iron, research into early metallurgy in South India has tended to neglect early copper and gold. Of course, the limited presence of these metals combined with the greater and relatively early presence of iron associated with the striking megalithic monuments and the existence of a Bronze Age in northern South Asia makes this understandable. Explanations of the presence of pre-Iron Age copper tend to imply diffusion from the more established copper and bronze traditions of central and northern South Asia (see Chakrabarti and Lahiri 1996, Bhardwaj 2000) , while others (notably Srinivasan 2006) have postulated a local indigenous tradition of copper and bronze working based on ethnographic fieldwork and their metallurgical analyses.

More systematic investigation of the early copper metallurgy in South India, moreover, would also enhance current understanding of iron development, since both technologies seem to be fully elaborated together rather than in sequence, as is the case in many other contexts. While it is clear that the development of an Iron Age without a preceding Bronze Age has significant implications for contemporary paradigms of early metallurgy, the nature of those implications is not yet clear.

Megalithic Monuments

Although the distribution of megalithic monuments spans much of South Asia, with significant traditions in the north, northwest, and central parts of the subcontinent, the greatest concentration occurs in the south (Deo 1985). Here, the focus will be on the megalithic tradition usually associated with the Iron Age in South India. Many of the monuments are found along the Godavari and Krishna Rivers and their tributaries (such as the Tungabhadra River); there is also a cluster of monuments known as the Vidarbha megaliths that are located in eastern Maharashtra, set apart geographically and chronologically from those monuments further south (see Brubaker 2001 for a good discussion on geographic and chronological distribution and attendant maps). The megaliths are funerary monuments or memorials incorporating a variety of large stone constructions. Most—but definitely not all—of these monuments contain primary and secondary inhumations and associated burial furniture, sometimes in great quantity. There exists variation in their form, nature, and function; however, while variations have been identified, it is not yet clear what, if anything, those variations mean. Furthermore, although it is possible to delineate numerous regional groupings of megaliths within South India, the two broad groups mentioned above (in the Godavari and Krishna systems and the Vidarbha region) will be of concern here.

These megalithic monuments are visible and relatively easily recognizable on the landscape (for example, as alignments of standing stones, stone slab supported by boulders or arrangements of boulders and cairns) and consequently have been the focus of more sustained research than the habitation sites related to the cemeteries.

Once thought to be minimally or even nonexistent, habitation sites have now been much more widely identified.

Most of these monuments do include large stones as structural or identifying elements, but not all sites defined as megalithic contain large lithic elements. Perhaps the best example of this is Adichanallur (also spelled Adittanallur). Adichanallur is one of 38 sites reported by Alexander Rea on the banks of the Tambraparni River, with skeletal remains (skulls and some post-cranial material, and sometimes ash) in large red-ware urns. The urns were buried in pits, some as large as 2.74 m in diameter and 4.5 m deep, and also contained grave goods that included artifacts of iron, copper and gold, stone beads, black and red pottery, traces of cloth and rice and millet (Rea 1915; Kennedy 1987, p. 263). There is no significant lithic accompaniment and, although technically not megalithic in the literal sense, this and other sites like if are included within the megalithic tradition on the basis of chronology and associated material culture, especially the presence of iron and the Black and Red Ware.

The term "megalithic" not only has chronological and cultural connotations but also has been used to identify the South Indian Iron Age. Even though iron is associated with megalithic monuments, the monuments are not chronologically confined to the Iron Age, as their construction continues into the first centuries AD in the South, and is further attested to ethnographically in various parts of the subcontinent. So although megaliths persist, the Megalithic period in the archaeological literature has become synonymous with the Iron Age.

Sir Mortimer Wheeler (1947–1948) established the relative chronology of the Megalithic period at Brahmagiri and Chandravalli in Karnataka (then Mysore), by fitting it between the southern Neolithic and Early Historic periods (although his absolute dates have now been revised earlier). Radiometric dates from various sites indicate that the earliest Iron Age levels at these Megalithic sites date to the beginning of the first millennium BC; the earliest date for contexts with iron in the region (ca. 1100 BC) is from the Neolithic/Megalithic Transition Period at Hallur on the Tungabhadra River in Karnataka (Nagaraja Rao 1971, 1985; Possehl and Gullapalli 1999, pp. 168–169). The earliest dates for the Vidarbha megaliths as a whole fall in the seventh century BC (Deo 1970), so as a group they are slightly later than those further south. The Iron Age spans the period from approximately 1200 BC to 300 BC, with the terminal dates assigned on the basis of the emergence of Early Historic cultural indicators (e.g., urbanism, Indo-Roman long-distance trade, and epigraphy) (Chakrabarti 1992, p. 80; Moorti 1994, p. 5). Evidence from the late Megalithic contexts has pointed to participation in the long-distance exchange networks (Moorti 1994; Srinivasan 2004) that also characterize the subsequent Early Historic period.

Jane McIntosh (1985) has identified four periods of megalith building that can be divided into two phases based on the distribution of sites, funerary rites, and grave morphology. She notes that the earliest period is coterminous with the distribution of the Neolithic cultures of South India (in Andhra Pradesh, Tamil Nadu, and Karnataka), indicating a continuity of cultural tradition rather than intrusion. The next period sees the spread of megalithic monuments into the Vidarbha region of Maharashtra and the appearance of horse skeletons and equipment in the graves. Horses and vehicles are present, along with pottery and metal artifacts including tools and horse trappings. The horse skeletons in some cases exhibit cut marks on the bone indicating possible sacrifice and burial along with the human interment (Thomas 1992, p. 13). The final periods of megalith building are associated with innovations in the style of the graves and the introduction of funerary containers such as urns and sarcophagi (McIntosh 1985).

The number of habitation sites recorded and investigated is small compared to the number of cemeteries and tombs excavated. The research that has focused on the nature of the funerary monuments themselves has been dominated by attempts to create inclusive typologies and have been many descriptions of the varieties of Megalithic burial monuments in South India (e.g., Krishnaswami 1949; Wheeler 1959, pp. 154–158; see also Allchin and Allchin 1967–1968, pp. 331–333), resulting in varied typologies. For example, Wheeler (1959) offers eight types while Moorti (1994, p. 2–3), on the other hand, offers only two major categories. These attempts, however, have for the most part been unsuccessful. The large number of monuments as well as variations in their construction has made typologies cumbersome as analytical tools (see Moorti 1994 for further discussion). Until recently little attempt had been made to move beyond his work, with research focusing on description and categorization of the monuments and the material culture (see Chakrabarti 1992, pp. 80–85; Moorti 1994 for further discussion; also Brubaker 2001; Mohanty and Selvakumar 2002; Mohanty and Walimbe 1993). Not surprisingly this imbalance in research has led to an incomplete understanding of the society and culture that erected these monuments, including but not limited to their metallurgical practices.

Neolithic Copper

The earliest metal artifacts from the South Indian archaeological record are of copper. They appear in small numbers during the Neolithic and continue into the Iron Age. Although their number increases during the Iron Age, they are consistently fewer than those made of iron and they tend to include fewer tools and more decorative and ornamental artifacts. Unstratified contexts of copper artifacts include copper hoards, which have been found in Tamil Nadu, Karnataka, Andhra Pradesh and Kerala (Chakrabarti and Lahiri 1996, p. 75; Gupta 1989, p. 92).

The Southern Neolithic of India has been dated from the mid third millennium BC, though most dates fall in the mid second millennium BC, and lasts until c. 1000 BC, or the beginning of the Iron Age (Korisettar et al. 2002; Nagaraja Rao 1985; Paddayya 1973). Copper artifacts begin to appear in Late Neolithic contexts (Biswas 1996: 158–60), with the earliest ones confined to sites in Karnataka and Andhra Pradesh (Chakrabarti and Lahiri 1996: 75). They consist of axes, fishhooks, needles, chisels, swords, beads and other ornaments, and various fragments (Allchin 1960; Biswas 1996, pp. 158–160; Chakrabarti and Lahiri 1996, p. 75; Sastry 2000).

One site with Late Neolithic copper artifacts is Hallur, a habitation and burial site on the left bank of the Tungabhadra River in western Karnataka. It is a mounded site with two periods of occupation—Neolithic and Early Iron Age—with an overlap between the two that indicates continuity of earlier cultural characteristics with the emergence of Iron Age ceramics and iron artifacts. Megalithic monuments—cairns and dolmenoid cist-circles—are located approximately 2 miles to the west and north of the site, on hilly slopes, which may be contemporary with the site but were not excavated (Nagaraja Rao 1971, pp. 12–13, 30).

The Late Neolithic phase at the site yielded three copper artifacts in conjunction with a Late Neolithic stone blade industry, polished stone axes, beads (including one gold bead, which was identified as an intrusive Early Iron Age artifact based on its type) and ceramics. The copper artifacts were found associated with floors of circular structures, and are described as "a miniature, double-edge axe, made on thin sheet of copper with a broad edge and concave middle, looking like a brooch or bow. . . . [A] flat, miniature axe, with a broad cutting edge, and is like a *Parasu* in shape. Made on a thin sheet of copper. . . . A small fish hook, with the out-curved upper end flattened and the end of the hook pointed. Made on a round copper wire (Nagaraja Rao 1971, pp. 89–91)." a similar double edged axe comes from Paidigutta, Andhra Pradesh: Sastry 2000: 182–83). The small size of the first two artifacts (smaller than 5 cm) leads the excavator to speculate that they were either cult objects or, in the case of the *Parasu* axe, a tool used for detailed work in scraping leather (Nagaraja Rao 1971, pp. 89–91). Analysis of Neolithic copper artifacts from two other sites (Tekkalakota and Brahmagiri) indicates that they are over 90 % copper. However, there is no evidence of smelting associated with the Neolithic sites (Bhardwaj 2000, p. 38; Chakrabarti and Lahiri 1996, p. 75; Rao and Malhotra 1965).

An intriguing feature of the southern Neolithic is the presence of ashmounds. These accumulations of often vitrified ash dot the landscape of the southern Deccan, and have been the focus of some speculation. Local inhabitants regarded them as the graves or remains of *rakshasas* or demons; early explorers thought the ash to be volcanic or slag resulting from industrial activity. However, the first excavation of a mound proved that they were artificial, and Bruce Foote associated them with Neolithic settlements and proposed that the ash was burnt cow dung (Allchin 1963). In the 1950s the ash was chemically identified as cow dung. Allchin and Allchin (1967–1968) proposed cattle pens and domestication centers, with periodic burning of the dung accounting for the creation of the mounds. Paddayya's (1998, 2002) work in Budihal has shown that far from being single purpose cattle pens, these mounds are a combination of animal penning yards and settlement areas, with the yard occupying a central area, surrounded by habitation. The evidence points to a pastoral camp, since the mound is located in poor agricultural soils, but in areas that would have provided good pasture. Included in the material culture are ceramics and stone implements including flakes stone tools. At Budihal an enormous area of debitage characterized as a chert workshop, 'the only known blade industry workshop in the context of the southern Neolithic culture', was excavated (Paddayya 1998, p. 12). Furthermore, at Kupgal bits of quartz and feldspar were found to be mixed in with the ash, indicating a redeposition of the dung (Paddayya 1973).

Thus what emerges clearly is that the nature of the ashmounds is not yet settled, and more recent scholars have emphasized the symbolic, monumental, and phenomenological aspects of these features (see Bauer et al 2007; Boivin 2004;

Johansen 2004). Of interest here is the fact that some of these ashmounds are in proximity to megalithic monuments. While earlier scholars saw the megaliths and the attendant iron technology as intrusive phenomena (e.g., Wheeler 1947–1948, pp. 199–202), excavations at Palavoy in Andhra Pradesh have found Iron Age pottery and two iron artifacts within an ashmound. The fact that ash mounds seem to be in the vicinity of megalithic sites combined with the stratigraphic overlap between the two periods and similarities in the creation of cultural landscapes and in burial patterns have been used to argue for a continuity between the Neolithic and Megalithic periods (Chakrabarti 1999, p. 239; Moorti 1994, p. 111; Rami Reddy 1990; see Johansen 2004, p. 310) and consequently a continuity of technological traditions as well.

Iron Age Metal

It is with the first millennium BC that significant numbers of metal artifacts—specifically, of iron, copper, and gold—appear in the archaeological record, along with evidence for iron production. Although from limited contexts these two lines of evidence argue for the emergence of a metal age (see discussion in "New Directions" below). The paucity of copper in earlier contexts contrasts with the *relatively* greater presence of copper. Although there is more copper than during the previous period, there are still fewer artifacts of copper and bronze than of iron.

A wide variety of iron artifacts are associated with megalithic Iron Age burial and habitation contexts, and the habitation mound at Hallur provides some of the earliest contexts. Eighteen iron artifacts were found, most of them associated with ashy and burnt deposits and pits cut into such deposits. They were not associated with any structural remains, unlike the earlier copper artifacts. One copper rod fragment was found from the Early Iron Age contexts, and one gold bead assigned to the Early Iron Age although found in earlier deposits. The iron artifacts consist of arrowheads (9), spearheads (2), knife blades (4), and points (2) with one artifact not described. Two arrowheads from the same context are described as being heavily encrusted with grains of rice and millet (Nagaraja Rao 1971, pp. 91–92).

Chakrabarti (1992, pp. 81–85; see also Tripathi 2008, pp. 113–118) provides a list of early artifact types that includes axes, hoes, spades, sickles, pickaxes, stone-cutter's wedges, bar wedges, crowbars, chisels and adzes, knives, tripods, swords, daggers and dirks, spear arrowheads, ceremonial scalloped axes, trisula (trident), hook-lamps, pendants, unknown objects. As a whole, taking into account later Iron Age contexts, these artifacts include weapons (e.g., daggers, swords, arrowheads, spearheads), tools (e.g., axes, knives, sickles, chisels, hoes, nails, adzes), utensils (e.g., pans, saucers, ladles), and toiletry articles (bangles, nail parers) as well as horse equipment (bits and ornaments). Horse equipment seems to be concentrated in the Vidarbha region (see Brubaker 2001). Excavations at the associated habitation/burial sites of Takalghat and Khapa (in the Vidarbha region, seventh-sixth century BC) point to a potential differential deposition of iron artifacts between the two contexts.

While artifacts like ladles, bangles, and arrowheads are common to both contexts, the excavator notes that the burials contained more tools and weapons than domestic artifacts (Deo 1970, p. 45; Fig. 25.1).

There have been some instances of bimetallic artifacts. A megalith at Mahurjhari (a site in the Vidarbha region) yielded a dagger with an iron blade and a bronze hilt (Deo 1973, p. 46). Other such artifacts have been reported from Pochampad, from the grave pit of Megalith 1: "On the eastern and western fringes of the pit were placed two iron implements, probably javelins. . . . Few barbed and socketted arrow heads were placed to the left of the skull. . . . Daggers and copper hilted knives were kept on either sides to the skull. In the south eastern corner of the pit, a large copper hilted dagger was also found fixed in between a red ware pot and stone pedestal (Murthy 2000, p. 98)."

Additionally, from the burials at Mahurjhari, copper bowls, lids with decoration, bangles, horse ornaments like bells and face pieces, and pieces of copper wire (compared to iron weapons, carpentry tools, agricultural tools, toiletry articles, and horse equipment) (Deo 1973, pp. 37–43). It is also interesting to note that at Takalghat and Khapa, which offer a direct comparison of habitation and funerary contexts, the majority of the copper artifacts (in categories similar to Mahurjhari) were found in the burials rather than in the habitation (Deo 1970, p. 51; see Brubaker 2001 for a discussion of regional characteristics).

Some sites have yielded significant numbers of bronze artifacts. The excavation of the urn burial field at the site of Adichanallur in southern Tamil Nadu has yielded bronze artifacts including ornamental vase stands, bowl lids, bowls, jars, cups, sieves, strainers, plaques, bangles, necklaces, ear ornaments, and diadems. The excavator, Alexander Rea, lists 122 bronze artifacts (compared with 394 iron artifacts). He also identifies 20 gold artifacts, 19 of which he identifies as diadems, items of various shapes with holes through which strings could pass that attached them to the body (Rea 1915; see also Chakrabarti and Lahiri 1996, pp. 90–92; Sundara 1972).

Gold artifacts are regularly found in Iron Age contexts, although not always and not in great numbers. Mahurjhari (in addition to Adichanallur discussed above) may be an exception. The excavators describe 2 necklaces, several groups of beads and ear ornaments, gold leaf fragments, and a group of circular disks, all from burial contexts (Deo 1973, pp. 54–56; see also Deglurkar and Lad 1992).

Production Evidence

Investigations into metal production practices have, for the most part, focused on the Iron Age and consequently that will be the focus of discussion here. Compared to the number of metal artifacts that have been uncovered from Iron Age contexts, there is limited production evidence, partially due to the fact that few habitation or non-funerary sites have been excavated. Samples of metal artifacts have been analyzed to identify composition and, less frequently, to provide information on techniques of production. However, such analyses have addressed only a very small number of the available artifacts, making it difficult to identify trends within and across sites and to hypothesize effectively about the nature and distribution of production practices. The data on furnaces and associated pyrotechnological installations are even fewer, and, as with the artifact analyses, their small number makes it difficult to assess to what extent their characteristics are typical of Iron Age metal production practices. Investigation of ancient mining locations and practices have come to light mainly through survey, especially the work of geologists.

Mining

Gold, copper, and iron ore are present in South India and there is evidence that all three metals were mined and exploited in antiquity, although there has been little archaeological investigation of mining operations.

Allchin (1962; see also Dube 2001) provides an overview of the evidence for ancient gold mining activity in South India, incorporating material reported by British geologists and officers. There is evidence for old workings in and around the Kolar, Gadag, and Hutti regions of Karnataka, where there is still significant contemporary gold mining. Although the shafts and depressions that indicate ancient mining have been recorded, less has been noted of the associated artifacts, if any, making determining chronology of use and cultural affiliation more difficult. The workings are indicated by shallow depressions, mounds of rubble, stone mauls, and hollows in rocks. Some areas (such as that around Hutti) have a high density of old workings-several hundred in less than 200 km^2. Shafts range from 30 m to 100 m deep, with timbering used in galleries. Firesetting was used as a method of excavation, indicated by presence of ashes, charcoal, and ventilation shafts. The fact that there were attempts to bail out water from the deeper shafts is evinced by water pots at the bottom of some old workings. Rope marks on timbers and stone attest to ore being hauled up to the surface. Mortar holes and depressions in rocks adjacent to the shafts and boulders used to crush ore indicate that ore processing began near the mines (Allchin 1962; Willies 1992).

There are several dates from the Hutti and Kolar gold mines. Two samples of timbers from a depth of 250 ft in the Hutti mines were dated to 1890 +/− 70 BP and 1810 +/−70 BP (Allchin 1962; Agrawal and Margaband 1975–1976, p. 139 note that the dates were probably based on a 5568 half-life and thus when converted to 5730 half-life would be 1945 +/− 70 BP and 1865+/−70 BP). A wood sample from a mine in the same area was dated to 1290+/−60 BP (Nagabhushanam et al. 2008). Two dates from the Kolar mines are 1290+/−90 BP and 1500+/−115 BP, although no information was provided regarding the context or nature of the samples (Agrawal and Margaband 1975–1976, p. 139). There are also two dates from gold mines in Chigargunta in Andhra Pradesh. Charcoal and wood samples were dated to 1270+/−110 BP and 1050+/−110 BP respectively (Agrawal et al. 1991, p. 330).

Taken together, these dates indicate gold mining activities spanning from the late centuries BC to the late first millennium AD, with an overlap in the dates of the Kolar and Hutti mines indicating contemporary exploitation. However, since mines by their very nature tend to be long-lived, with potential reuse of framing timbers and other such features, reliance on only radiocarbon dates tends to mask nuances in changes in use patterns. Addressing this requires investigating mining sites as archaeological sites, with the attendant emphasis on material culture and on integrating the mines into their broader social and economic contexts. Allchin (1962), for example, points to diagnostic artifacts found at Hutti-a stool, pot, grinding stone, and stone disks-to support the dating of the mining there to the last centuries BC and first centuries AD, possibly related to the expansion of the Mauryan polity. He also notes that iron gouges were found at Kolar and Hutti and argues that gold mining could not have predated the South Indian Iron Age (although exploitation of surface gold could have started during the Neolithic). These hypotheses must remain tentative until further investigation.

Ancient copper mines are located in Karnataka and Andhra Pradesh, although information about them is less robust. In Andhra Pradesh, old workings have been identified in northern districts (Bellary, Guntur, Kurnool, and Nellore). At Agnigundala (also spelled Agnikundala) in Guntur, old copper workings are spread over 3 km2 and are indicated by ore dumps, pounding stones, furnaces, and slag. Although no datable artifacts were recovered from these workings, material from Bandlamottu Hill in the same range was dated to 900+/−80 BP, 655+/−90 BP and 535+/−90 BP (Agrawal et al. 1976; Biswas 1996; Shrivastava 1999). Wood from the Ingaldhal copper mines of Karnataka was dated to 2010+/−110 BP (Agrawal et al. 1991, p. 332). Biswas (1996, p. 320) notes an undated copper mine associated with a megalithic settlement in the Hassan district of northern Karnataka. The mine shafts were associated with evidence for crushing, washing, and smelting ore.

Iron ore is prevalent throughout much of South Asia, and South India is no exception (Chakrabarti 1977, 1992). Ironically, despite the number of iron artifacts and the instances of iron smelting furnaces and slag that have been uncovered, there is the almost no information about ancient iron mines in South India. Various types of ores such as magnetite, hematite, and limonite are present in various forms including iron rich sand. Scholars have also argued that iron ore is more easily available on or near the surface (including in the form of ferruginous sand) and therefore may have left less significant traces of mining (see Tripathi 2008, pp. 103–111). Chakrabarti (1977, pp. 168–169) also makes the important point that while much of this iron ore may not be of high enough quality for modern iron smelting industries, it was apparently more than adequate for ancient metalworkers. Therefore, modern assessments of the presence of iron ore are of limited utility since they are concerned with ores appropriate for modern industry.

Unlike gold mining and production, there seems to have been no hiatus in the production of iron in the region. Therefore, while early scholars and chroniclers had to deduce the existence and impact of gold mining based on old workings, they encountered plentiful evidence of robust iron production practices. Such ethnographic information describing pre-industrial iron smelting has played a prominent role in attempts to reconstruct ancient iron production practices.

Smelting and Forging

The primary indications of production activities are deposits or heaps of slag which have been reported from numerous sites and from surface surveys. The frequency and consistency of such reports is such that it indicates that production activities were widespread across the landscape and among sites. Although a series of furnaces have been excavated from various sites, there exists an overall paucity of such evidence. The published material provides relatively limited descriptions of the furnaces, their contexts, and associated material culture, making tenuous any assessment of or elaboration on the data provided. While all the furnaces do indicate production practices, the precise nature of those practices-for example, distinguishing between bloomery and cast iron production, or identifying crucible steel production-is sometimes unclear (see below). Additionally, because of the relatively small number of excavated furnaces, it is difficult to identify patterns in production practices and therefore difficult to determine whether a given instance is indicative of widespread techniques or whether it is an aberration. Furthermore, the excavated furnaces are mostly dated to the latter part of the Iron Age, rather than to the beginning, meaning that they are less relevant to investigations of how iron technology may have initially emerged in South India.

Here I provide an overview of the evidence for metal production taking place in South India. While there is significant evidence of ferrous metallurgical activity, the evidence for the production of other metals such as copper and gold is less.

Of the 399 megalithic sites analyzed by U.S. Moorti (1994, pp. 38–42, 110), 91 have yielded evidence of various production activities, including ore, slag, and furnace fragments relating to iron, copper, and gold metallurgical activities. He lists 68 sites that have evidence of iron smelting, 3 with evidence for copper smelting, 18 with evidence for gold working and 2 with evidence of silver working. He further notes that approximately 40 % of megalithic sites are located in resource-rich zones that include metal ore deposits.

Mudhol (1997, pp. 6–8) identifies a series of ancient iron working sites in northern Karnataka, based on the presence of slag and ash. He argues that there is evidence that many megalithic sites are associated with nearby iron-smelting and iron-working installations. However, there is little or no excavation or further evidence to corroborate most of these identifications, and it is unclear whether the indications of iron slag are from surface or excavation contexts and what the stratigraphic relationship is between the slag and the Megalithic monuments (e.g., Allchin 1960, where the slag is noted on the surface and is dated to the medieval period). If these identifications are accurate, however, then it would seem to indicate that there is a significant occurrence of iron working in proximity to these Megalithic monuments and habitation sites.

A furnace that has been often cited in discussions of early iron production evidence comes from the Iron Age Megalithic site of Naikund in the Vidarbha region (Deo and Jamkhedkar 1982). This is a well described furnace with an associated habitation area dated from the sixth to the fourth centuries BC. Gogte (1982a) found the furnace, located at a distance from the two mounds being excavated, using a three-probe resistivity survey. It was excavated independently in a 4×4 m trench. As outlined in Possehl and Gullapalli (1999), the furnace was circular, built up of interlocking clay bricks, about 30 cm in diameter and 25 cm in height. The bottom of the furnace was paved with bricks. A tap hole for the slag was detected, and two (vitrified) tuyères were recovered, as well as 40 kg of slag. Only one piece of iron was recovered, corroded and approximately 5 cm long by 5 cm thick. A few pieces of iron and manganese ores were also recovered, which, along with debris located about 1 km to the southeast of the site, indicate the possible exploitation of the nearby manganiferrous belt. However, despite the relatively detailed description of the furnace, there does not seem to be any architectural context that can help reconstruct the relationship between production activities and the habitation. Gogte (1982b) also attempted to evaluate the efficiency of iron smelting carried out at the site. He determined that using about 10–12 kg per operation, these Megalithic smelters were able to produce 3.0–4.2 kg of pure iron.

An iron smelting furnace has been reported from Banahalli in Karnataka (dated 400–300 BC). Excavations revealed a bowl shaped cavity in the ground, associated with slag, ash, and charcoal. At the bottom of the furnace were a "cake of metallic iron" (Mudhol 1997, p. 35) and a large amount of slag, while excavations at Paiyampalli (c. 640–380 BC) in Tamil Nadu yielded large amounts of iron slag (Ramachandran 1989, p. 326; Archaeological Survey of India 1964–1965, p. 22, 1967–1968, p. 28). Sasisekaran (2004, pp. 17–21; see also Sasisekaran and Raghunatha Rao 2001) notes that a series of sites in Tamil Nadu have yielded fragments of furnaces, tuyères and slag. Although many of these remains have either been disturbed or are not well described (or both), their consistent presence across the archaeological landscape does indicate that metallurgical practices were not confined to certain regions. The scale of production at these sites as well as the distribution of production practices in relation to sites in their immediate vicinity would begin to provide information regarding the organization of production. A glimpse of such patterning comes from the site of Kodumanal, discussed below.

Evidence from two sites—Kodumanal and Guttur—has been identified by their excavators and by other scholars as being of special importance in the development of iron and steel metallurgy in South India. As will be discussed below, however, these assertions can only be tentative until more information is brought to light about the metallurgical installations in each case and more systematic analyses of metal artifacts are undertaken.

Kodumanal (Rajan 1994) is a megalithic burial and habitation site that covers approximately 100 acres and is located on the banks of a tributary of the Kaveri River in Tamil Nadu. Its occupation has been dated to between the third century BC and the third century AD, based on ceramic and epigraphic evidence. The site has yielded significant evidence of bead and metal (iron) manufacture, as well as of participation in long distance trade, including the Indian Ocean trade. The evidence for metal production comes from two distinct areas of the settlement, in the northern and southern areas, each of which has yielded two different types of metallurgical installations (Rajan 1998b; see also Rajan 1998a; Sasisekaran 2002).

One of the iron smelting furnaces was delineated through excavation and is described as having a circular base surrounded by slag, vitrified brick bats, and tuyère fragments. There was also a granite slab associated with the furnace, which is interpreted as an anvil; if this is so, it seems to indicate both smelting and forging occurring at this site.

To the north of the smelting furnace two additional furnace installations were excavated, one of which is described. It consisted of a large oval furnace which is surrounded by more than twelve smaller, circular furnaces. A crucible was found in one of these furnaces, and the entire installation is interpreted by the excavator as an early furnace for the production of crucible steel (as opposed to the production of wrought iron, which was taking place at the southern furnaces described above) (Rajan 1994, pp. 95–96). Other scholars have characterized this as the production of wootz (Sasisekaran and Raghunatha Rao 1999, p. 266).

This assertion of early crucible steel production needs further investigation, clarification, and elaboration. Crucible production of steel allows for a product with carbon and structural homogeneity, while limiting the presence of slag and other inclusions. Paul Craddock notes that in the South Asian context, "the most familiar products of crucible steel were the so-called Damascus-patterned blades forged from a very special variety of the crucible steel, and the term wootz could be used specifically for this patterned variety" (2003, p. 239). Confusion arises because of a conflation of all crucible steel with wootz; if the two terms are understood to mean the same thing, then any evidence for pre-medieval crucible steel would necessarily be understood to refer to wootz. However, it is possible to be engaged in the production of crucible steel without producing wootz, and Craddock (2003), through an examination of documentary material, argues that there is evidence for early (first centuries AD) crucible steel production in South Asia. He notes that the evidence from Kodumanal (and from sites in Sri Lanka) could be the archaeological confirmation of the documentary evidence. This assessment is dependent on further information about and analyses of the crucible and the iron artifacts manufactured at the site (see next section for discussion of the analysis of iron artifacts from Kodumanal).

The excavator notes that there are discernible differences between the locations of iron smelting as opposed to steel production. Based on the distribution of artifacts and production debris, he argues that craftworkers involved in the stone and steel industries were located in the northern part of the site, with agriculturalists in the center and agriculturalists and iron smelters in the southern areas. The iron and steel production areas of the settlement were separated by approximately 300 m. A resistivity survey suggested that iron smelting furnaces were concentrated in the southern area of the settlement (spread over 100 m^2), and a lack of significant structural remnants or artifacts besides potsherds suggests that this was the edge of the habitation. The steel production area, by contrast, had evidence of post-holes, indicating a superstructure as well as coins and inscribed sherds, which in conjunction with adjacent trenches seems to indicate a more central location. The stratigraphic relationship between the iron and steel installations is unclear, although they are interpreted as being contemporary. The excavator argues, based on the differential nature of structural remains, that the steel producers occupied a higher social/economic position than the iron producers, which indicates the apparently differential valuing of steel over iron (Rajan 1994, pp. 61–66).

Guttur (Archaeological Survey of India 1982–1983, pp. 71–72; see also Raghunatha Rao and Sasisekaran 1997; Sasisekaran 2002), is a site in northwestern Tamil Nadu whose occupation spans from Megalithic to Late Medieval and modern periods (third century BC to ninth century AD, based on ceramics and other artifacts), with no earlier Neolithic component. Excavation in three trenches has revealed structures with several rooms constituted of stone and brick walls and earth floors. In another trench, whose spatial and stratigraphic relationship to those with the structures is unclear, the excavators uncovered what were initially described as "elongated, oval shaped, trough-like terracotta objects recalling Megalithic sarcophagus" (*sic*; Archaeological Survey of India 1982–83, p. 72). Due to the lack of funerary objects or bone, and the presence of terracotta pipe fragments encrusted with iron and a large quantity of iron slag, the excavators hypothesized that these installations might have been iron smelting furnaces; they did not assign a time frame for these installations.

During later surveys, fourteen other sets of similar installations, now identified as "twin furnaces," were located in addition to those already excavated (Raghunatha Rao and Sasisekaran 1997; Sasisekaran 2002). Raghunatha Rao and Sasisekaran (1997, pp. 349–350; see also Sasisekaran 2002, p. 21)) argue that these installations were iron smelting furnaces based on the presence of slag and apparent bellows and tap holes, and also on the fact that they closely resemble working furnaces described by European travelers and chroniclers such as Robert Bruce Foote. While these historical reports indicate that the furnaces were producing wrought iron, those at Guttur have been identified as potentially producing cast iron.

The assertion that the Guttur installations produced cast iron is based on metallographic analysis of one artifact and the presence of possible terracotta "molds." These hollow terracotta rings dating from the late Iron Age (c. third century BC) have been found at other sites in Tamil Nadu. They are approximately 30 cm in diameter and have a spout (Sasisekaran 2002, p. 22). However, it is unclear if there is any explicit evidence connecting these terracotta objects to iron production activities.

Most recently, Peter Johansen's (2007, 2008) work at the Iron Age sites of Bukkasagara and Rampuram reinforces and elaborates on the spatial patterning of production activities apparent in the studies mentioned above. Significant evidence for metal production in the form of smithing and forging slag occurred at Bukkasagara and was concentrated in a circumscribed area. There was less metallurgical evidence at Rampuram; however, it too was spatially delimited within the site and indicates smithing rather than smelting activities. Such evidence means that the smiths would have had to acquire their iron from elsewhere, and perhaps points to a systematic differentiation of iron production activities based on stage of production, an argument that has also been made for other parts of South Asia. Iron production is too broad a term in that it does not capture the potential for differential organization of the various stages of production (see Gullapalli 2005).

At Bukkasagara and Rampuram, Johansen's ceramic and architectural (including mortuary) analyses at these sites reveals patterns of social differentiation in which certain practices such as commensality, mortuary rituals, and iron production were of significance. Although in its initial stages, this research begins to delineate possible relationships between the control of iron production (at least one stage of it) and social and political distinctions within Iron Age society, such as those that are also reflected in Robert Brubaker's (2001) analysis of megalithic cemetery size, form and distribution across South India.

Analysis of Metal Artifacts

A number of metal artifacts have been analyzed, and in most cases it has been to identify the constituent elements of each artifact. Indeed, many excavation reports contain a compositional analysis of some iron and copper/bronze artifacts to determine the nature and extent of alloying. For example, a number of iron artifacts have also been analyzed for their composition, primarily to determine carbon content and therefore the extent (if any) of steeling (see Chakrabarti 1992, pp. 93–95 for a general discussion; examples include analyses of 1 to 2 artifacts from Takalghat and Khapa (Munshi and Sarin 1970, pp. 78–79) and Mahurjhari (Joshi 1973, p. 77)). Here, the focus is on studies that have gone beyond composition and that have addressed other aspects of production.

As Possehl and Gullapalli (1999) note, analyses of early iron artifacts have revealed that specific properties of iron were being exploited by Iron Age smiths and that there existed an apparently long tradition of lamination techniques used in their fabrication (see also Agrawal et al. 1990; Agrawal et al. 1983) analyzed three iron artifacts—two implements and an axe—from Tadakanahalli (northern Karnataka, ca. 1000 BC). Multiple sections were taken from each sample, allowing the reconstruction of the production process. The investigators concluded that each artifact was composed of two definite layers; that the edge was mainly martensite, meaning that the implements had undergone quenching; that layers of ferrite and pearlite are present; and that martensite decreases and pearlite/ferrite increases toward the interior. Similarly, metallurgical analysis of two iron artifacts (fragments of a sword and dagger) from Kodumanal in Tamil Nadu indicated a differential hardness between core and edge of the blade (Sasisekaran and Raghunatha Rao 1999, p. 266–272).

The artifacts from Tadakanahalli discussed previously showed that layers of wrought iron, which had been carburized, were forged with high carbon sheets, indicating that the smiths were able to manipulate high carbon and low carbon sheets to their advantage. A spear from Kumaranhalli (northern Karnataka, c. 1200 -1100 B.C.) and another axe from Tadakanhalli were subjected to metallographic analysis. The results also revealed alternating layers of carburized (characterized as a hypoeutectoid steel) and uncarburized iron,which had been hammered and welded together (Agrawal et al. 1990). Mudhol's metallographic analyses of various iron artifacts indicate the presence of this technique at other sites (Mudhol 1997, pp. 61, 64). Analysis of four artifacts from the Vidarbha megaliths also indicates consistent evidence for lamination (Joshi et al. 2008), as did that of an iron bar from Mallappadi, Tamil Nadu (Sasisekaran 2004, pp. 38–39).

Seven iron artifacts and a piece of slag from Kodumanal were analyzed –two arrowheads, an iron chisel, a sword bit, dagger, nail, and bead (Sasisekaran 2004, pp. 44–54). The two arrowheads were hot forged, which resulted in higher carbon contents at the surface. They had variable microstructures and varying hardnesses at different areas. The chisel was of a high-carbon steel resulting from carburization during the forging process, while the dagger had a body of low carbon steel with a high carbon cutting edge and exhibited evidence of bands having been welded together. The nail and bead were hot forged and exhibited varying microstructures. All of these artifacts had slag inclusions. The exception seems to have been the sword bit which was heavily corroded but whose microstructures revealed spheroidal graphite iron. However, the investigator points out that more artifacts would have to be analyzed to determine whether this was an accident or intentional.

The microstructure of an iron artifact (not described) from Guttur was analyzed and revealed significant variations across a cross section of the artifact and included pearlite, cementite, and ledeburite. The latter is interpreted as evidence for the presence of molten metal (cast iron), with variation in cooling resulting in the variation in microstructures. Compositional analysis of another heavily corroded artifact yielded the presence of iron oxide, phosphorus, and sulfur. The ore for the furnaces may have been the locally available ferruginous sand, and XRD analysis of slag indicates that the ore was of high quality and high in iron oxide (Raghunatha Rao and Sasisekaran 1997, pp. 353–354).

The copper artifacts of the Iron Age have received relatively less analytical attention. Srinivasan (1997, 2006; Srinivasan and Glover 1995, 1997) has analyzed high-tin bronzes from megalithic sites in South India, including Adichanallur. She argues that these artifacts "reflect sophisticated bronze working practices with the use of a specialized alloy known as wrought and quenched high-tin bronze alloy. . . . These not only rank amongst the earliest such alloys known in the world but also suggest that bronze metallurgy at the time was more advanced than previously suspected (Srinivasan 2004, p. 1)." Her analysis of slag from northern Karnataka has also pointed to the existence of local bronze working, refuting arguments that these metal objects (if not the technology as well) were imported from Southeast Asia (Srinivasan 1998; see Rajpitak and Seeley 1979). Other analyses of copper have focused on identifying the composition of the artifacts (e.g., Joshi 1973, p. 77; Munshi and Sarin 1970, pp. 78–79).

Six of the gold artifacts from Mahurjhari were analyzed (Nasnolkar 1973, pp. 78–79): a ring, three earrings, an ear ornament, and some gold leaf. Although all of these artifacts have been identified as gold, compositional analysis revealed that all were composed of gold and silver. Prasad and Ahmad (1998) note that the gold deposits of South India contain silver of varying percentages, such that the color of the gold ranges from yellow to almost white. They also note that native silver deposits are extremely rare in India. In this case, the percentage of gold ranged from 6 % (the gold leaf) to 74 % (the ear ornament), which resulted in varying shades of gold. Nasnolkar suggests that although the ear ornament now looks blackish because of tarnish, if it was heated it would look perfectly white. All except one pair of small earrings were manufactured by hammering. The small earrings are tubular, and were manufactured by pulling the metal through a piece of bone or stone. The tube was then filled with a lacquer or resin and then shaped using a wooden cylinder.

What emerges from this overview of production evidence is that there is a great deal of interesting and significant information waiting to be exploited. The fullest potential of such data can only be realized when more mines and furnaces are located and when series of artifacts are analyzed, rather than small samples. Such analyses will then yield patterns that can speak to the intentions and capacities of the metalworkers of the Iron Age.

New Directions?

A great deal of progress has been made over the past decades in the investigation and understanding of the megalithic monuments of South India and their associated metal technologies. However, it is also very obvious that a great deal has yet to be done. New approaches to the monuments are emerging that situate them within the construction of political and symbolic landscapes (e.g., Bauer et al. 2007; Brubaker 2001; Johansen 2004). This move from a static and descriptive to a dynamic approach is a promising one that offers alternative means of engaging with the Iron Age landscape of South India. Similar shifts need to occur in the investigation of metal technologies in order to build on what has been done (see also Mohanty and Selvakumar 2002).

A primary concern is the lack of contextual information regarding production practices. A focus on funerary contexts has meant that little evidence of production has been uncovered leading to an inadequate understanding of how metal technologies functioned within Iron Age societies. The research has also been dominated by one mode of consumption—that of funerary contexts—but with little relation to daily activities and other forms of consumption of such trade. In many ways, the symbolic and ritual significance of the funerary deposits can only emerge through comparison with other modes of using and disposing of the metal artifacts. It is interesting that the initial appearance of this new technology—one that is especially amenable to recycling—is associated with significant numbers of artifacts being taken out of circulation as they are interred with the dead. This seems to indicate that symbolic understandings of metal technology were as important as (or more important than?) utilitarian ones.

Certain trends that have only been hinted at so far—the differential deposition of copper in habitation and funerary contexts—need to be further investigated. Such investigations can also help us to understand the role of the multiple metal technologies within Iron Age societies. What was the relationship between iron, copper, gold, and silver? Furthermore, what was the significance of the bimetallic artifacts, if any? Is there any significance to the recurrence of laminating as a technique of production? Finally, what was the dynamic between metal and stone technologies? Allchin and Allchin (1982, p. 329), for example, note that the stone blade and stone axe industries of the Neolithic differentially persist in the Iron Age. Mohanty and

Selvakumar (2002, pp. 333–334) argue that a paradigm shift needs to occur, one in which megalithic sites are not simply understood as discrete entities within a chronological or typological framework but are instead situated within local and regional landscapes arising out of specific cultural processes and patterns.

Such a repositioning requires moving away from general discussions of diffusion and migration that tend to mask the various levels at which such processes can work and that blur the distinction between initial local development and the subsequent dissemination of the new technology across the landscape. The utility of an emphasis on determining antiquity (and therefore "origins") has been exhausted; delineating metallurgical traditions and their roles within and relationships to social forms may prove to be a more fruitful avenue—one that builds on past research rather than replicates it. Although Allchin and Allchin (1982, p. 335) point to a similarity of form, there is also emerging evidence for a differentiation of process. Craddock (2003; see also Bronson 1986) notes two methods for the production of crucible steel in South India; Johansen's (2007) research may lead to identification of forging sites as distinct from smelting sites, while at the same time Rajan's (1994) work at Kodumanal seems to indicate several production related activities at one site, with attendant social implications. Although chronologically separated, these examples indicate potentially dynamic landscapes in which control over production and metallurgical production techniques may be two of many dimensions. Indeed, the variation and similarity embodied within the aspects of the archaeological record of the Iron Age—a combination which has tended to stymie attempts at comprehensive typologies—may best be approached, in part, by investigating how iron production practices were manipulated and adapted within the contexts of dynamic local Iron Age societies.

An emphasis on origins and expertise—on the first appearances of a predetermined technological standard—undervalues its subsequent manipulation, adaptation, and elaboration within specific social and cultural contexts. Such an approach obscures any potential stages of experimentation that may have been a prelude, in this case, to the consistent and purposeful production of iron. In South India such a stage is yet to be defined, so although we know when iron artifacts begin appearing in the archaeological record, we do not know how the metalworkers arrived at that point. Ironically, the delineation of such a stage may put to rest any lingering doubts about the indigeneity of iron in South India for we would be able to situate iron production within a set of local practices. Joyce White and Elizabeth Hamilton (this volume) put forward an effective argument about the origins of Southeast Asian bronze metallurgy by moving beyond formal similarities in artifacts. They argue that the practice of metal production in Southeast Asia has affinities to Eurasian metal traditions and that this is an important component of the problem that must not be overlooked. Their holistic approach to metal technologies can be instructive here, for it highlights the efficacy of systematically incorporating production techniques and the social contexts of use and production into the discussion.

These are by no means all of the questions and possible directions that emerge regarding early metal in South India. However, if we are to be able to address the types of questions put forth by the editors of this volume, we need to significantly change the paradigm that structures our approach to the megalithic monuments and metal technologies of the Iron Age of South India.

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References

Agrawal, D. P., & Margaband, C. (1975–1976). Ancient gold workings: Some new ^{14}C dates. *Puratattva, 8,* 138–139.
Agrawal, D. P., Margabandhu, C., & Shekar, N. C. (1976). Ancient copper working: Some new ^{14}C dates. *Indian Journal of History of Science, 11*(2), 133–136.
Agrawal, D. P., Kusumgar, S., & Yadava, M. G. (1991). Physical research laboratory radiocarbon date List VI. *Radiocarbon, 33* (3), 329–344.
Agrawal, O. P., Narain, H., & Bhatia, S. K. (1983). Technical studies of iron implements from the megalithic site Tadakanahalli. *Puratattva*, *12*, 97–100.
Agrawal, O. P., Harinarain, Prakash, J., & Bhatia, S. K. (1990). Lamination technique in iron from artifacts in ancient India. *Journal of the Historical Metallurgy Society 24*(1), 12–26.
Allchin, F. R. (1962). Upon the antiquity and methods of gold mining in ancient India. *Journal of the Economic and Social History of the Orient, 5* (2), 195–211.
Allchin, F. R. (1960). *Piklihal Excavations*. Hyderabad: Andhra Pradesh Government Archaeological Series No. 1, Government of Andhra Pradesh.
Allchin, F. R. (1963). *Neolithic Cattle Keepers of South India: A Study of the Deccan Ashmounds*. Cambridge: Cambridge University Press.
Allchin, B., & Allchin, R. (1982). *The rise of civilization in India and Pakistan*. Cambridge: Cambridge University Press.
Archaeological Survey of India. (1964–1965). Excavation at Paiyampalli, District North Arcot. Indian Archaeology—A Review, 22–23.
Archaeological Survey of India. (1967–1968). Excavation at Paiyampalli, District North Arcot. Indian Archaeology—A Review, 26–30.
Archaeological Survey of India. (1982–1983). Excavation in Gutturmalai, Guttur, District Dharampuri. Indian Archaeology—A Review, 71–72.
Bauer, A. M., Johansen, P. G., & Bauer, R. L. (2007). Toward a Political Ecology in Early South India: Preliminary Considerations of the Sociopolitics of Land and Animal Use in the Southern Deccan, Neolithic through Early Historic Periods. *Asian Perspectives*, *46*(1), 3–35.
Bhardwaj, H. C. (2000). *Metallurgy in Indian Archaeology*. Varanasi: Tara Book Agency.
Biswas, A. K. (1996). *Minerals and Metals in Ancient India: Volume I, Archaeological Evidence*. New Delhi: D.K. Printworld.
Boivin, N. (2004). Landscape and Cosmology in the South Indian Neolithic: New Perspectives on the Deccan Ashmounds. *Cambridge Archaeological Journal*, *14*(2), 235–257.
Bronson, B. (1986). The making and selling of wootz, a crucible steel of India. Archaeomaterials, 1 (1), 13–51.
Brubaker, R. (2001). Aspects of Mortuary Variability in the South Indian Iron Age. *Bulletin of the Deccan College*, *60–61*, 253–302.
Chakrabarti, D. K. (1976). The Beginnings of Iron in India. *Antiquity*, *50*, 114–124.
Chakrabarti, D. K. (1977). Distribution of iron ores and the archaeological evidence of early iron in India. *Journal of the Economic and Social History of the Orient*, *20*(2), 166–184.
Chakrabarti, D. K. (1992). *The Early Use of Iron in India*. Delhi: Munshiram Manoharlal Publishers.
Chakrabarti, D. K. (1999). *India: An Archaeological History*. Oxford: Oxford University Press.
Chakrabarti, D. K., & Lahiri, N. (1996). *Copper and its Alloys in Ancient India*. Delhi: Munshiram Manoharlal.

Craddock, P. T. (2003). Cast Iron, Fined Iron, Crucible Steel: Liquid Iron in the Ancient World. In P. Craddock & J. Lang (Eds.), *Mining and Metal Production Through the Ages* (pp. 231–257). London: The British Museum Press.

Deglurkar, G. B., & Lad, G. P. (1992). *Megalithic Raipur (1985–1990)*. Pune: Deccan College Post Graduate and Research Institute.

Deo, S. B. (1970). *Excavations at Takalghat and Khapa (1968–1969)*. Nagpur: Nagpur University.

Deo, S. B. (1973). *Mahurjhari Excavation 1970–1972*. Nagpur: Nagpur University.

Deo, S. B. (1985). The Megaliths: Their Culture, Ecology, Economy and Technology. In S. B. Deo & K. Paddayya (Eds.), *Recent Advances in Indian Archaeology: Proceedings of the Seminar held in Poona in 1983* (pp. 89–99). Poona: Deccan College Post-Graduate and Research Institute.

Deo, S. B., & Jamkhedkar, A. P. (1982). *Excavations at Naikund 1978–1980*. Bombay: Government of Maharashtra, Department of Archaeology and Museums.

Devaraj, D. V., Patil, C. S., Joshi, N. V., & Gangadhara, T. S. (1996). *Heggadehalli: Report on Megalithic Excavation: 1995*. Mysore: Directorate of Archaeology and Museums.

Dube, R. K. (2001). India's contribution to the mining, extraction and refining of gold: Some observations related to the pre-Christian era. In Ramachandra Rao, P. & Goswami, N. G. (Eds.), *Metallurgy in India: A retrospective* (pp. 163–181). New Delhi: India International Publisher.

Erdosy, G. (1995). Language, material culture and ethnicity: Theoretical perspectives. In G. Erdosy (Ed.), *The Indo-Aryans of Ancient South Asia: Language, Material Culture and Ethnicity* (pp. 1–31). New York: Walter de Gruyter.

Gogte, V. D. (1982a). Megalithic iron smelting at Naikund (Part 1): Discovery by three-probe resistivity survey. In S. B. Deo & A. P. Jamkhedkar (Eds.), *Excavations at Naikund 1978–1980* (pp. 52–55). Bombay: Government of Maharashtra, Department of Archaeology and Museums.

Gogte, V. D. (1982b). Megalithic iron smelting at Naikund (Part 2): Efficiency of iron smelting by chemical analysis. In S. B. Deo & A. P. Jamkhedkar (Eds.), *Excavations at Naikund 1978–1980* (pp. 56–59). Bombay: Government of Maharashtra, Department of Archaeology and Museums.

Gullapalli, P. (2005). *Smelting and Smithing: The organization of iron production in Early Historic southeastern Rajasthan*. PhD Dissertation submitted to the Department of Anthropology, University of Pennsylvania, Philadelphia.

Johansen, P. G. (2004). Landscape, monumental architecture, and ritual: A reconsideration of the South Indian ashmounds. *Journal of Anthropological Archaeology*, *23*, 309–330.

Johansen, P. G. (2007). *The Production of Settlement Landscapes and Social Difference in Iron Age South India: Surface Collection and Documentation at Bukkasagara and Rampuram, Karnataka*. Poster presented at 2007 Annual Meeting of the American Anthropological Association, Washington DC.

Johansen, P. G. (2008). *A Political Economy of Space: Social Organization and the Production of an Iron Age Settlement Landscape in Northern Karnataka*. PhD Dissertation submitted to Department of Anthropology, University of Chicago, Chicago.

Joshi, A. P. (1973). Analysis of Copper and Iron Objects. In S. B. Deo (Ed.), *Mahurjhari Excavation 1970–1972* (p. 77). Nagpur: Nagpur University.

Joshi, S. V., Deshpande, P. P., Mohanty, R. K., Dhokey, N. B., & More, M. A. (2008). Metallographic investigations of iron objects found in the Megalithic burials in Vidarbha region of Maharashtra. *Puratattva, 38,* 244–250.

Kennedy, K. A. R. (1975). *The Physical Anthropology of the Megalith Builders of South India and Sri Lanka*. Canberra: Oriental Monograph Series of the National University of Australia.

Kennedy, K. A. R. (1987). Hauntings at Adittanalur: An Anthropological Ghost Story. In J. Jacobson (Ed.), *Studies in the Archaeology of India and Pakistan* (pp. 257–295). New Delhi: Oxford and IBH.

Kennedy, K. A. R. (2002). Megalithic Pochampad: The Skeletal Biology and Archaeological Context of an Iron Age Site in Andhra Pradesh, India. *Asian Perspectives*, *41*(1), 103–128.

Krishnaswami, V. D. (1949). Megalithic Types of South India. *Ancient India*, *5*, 35–45.

Korisettar, R., Venkatasubbaiah, P. C., & Fuller, D. Q. (2002). Brahmagiri and beyond: The archaeology of the Southern Neolithic. In Settar, S. & Korisettar, R. (Eds.), *Indian Archaeology in Retrospect, Volume I: Prehistory* (pp. 151–225). New Delhi: Manohar.

Leach, E. (1990). Aryan Invasions over Four Millennia. In E. Chnuki-Tierney (Ed.), *Culture Through Time: Anthropological Approaches* (pp. 227–245). Stanford: Stanford University Press.

McIntosh, J. R. (1985). Dating the South Indian megaliths. In J. Schotsmanns & M. Taddei (Eds.), *South Asian Archaeology 1983* (pp. 467–494). Naples: Universitario Orientale, Dipartimento di Studi Asiatici.

Mohanty, R. K., & Selvakumar, V. (2002). The Archaeology of the Megaliths in India: 1947–1997. In S. Settar & R. Korisettar (Eds.), *Indian Archaeology in Retrospect, Volume I: Prehistory* (pp. 313–351). New Delhi: Manohar and Indian Council of Historical Research.

Mohanty, R. K., & Walimbe, S. R. (1993). A Demographic Approach to the Vidarbha megalithic culture. *Man and Environment*, *18*, 93–103.

Moorti, U. S. (1994). *Megalithic Culture of South India: Socioeconomic Perspectives*. Varanasi: Ganga Kaveri Publishing House.

Mudhol, M. S. (1997). *A Technical Study of Megalithic Metal Objects*. Mysore: Directorate of Archaeology and Museums.

Munshi, K. N., & Sarin, R. (1970). Analysis of Copper and Iron Objects from Takalghat and Khapa. In S. B. Deo (Ed.), *Excavations at Takalghat and Khapa (1968–1969)* (pp. 78–79). Nagpur: Nagpur University.

Murthy, P. R. (2000). *Megalithic Culture of the Godavari Basin*. Sharada Publishing House, Delhi.

Nagabhushanam, P., Sangurmath, P., Patil, M. L., & Sukhija, B. S. (2008). Ancient gold mining activity in the Hutti-Maski greenstone belt, Karnataka, India: Radiocarbon perspective. *Current Science, 95*(3), 389–391.

Nagararaja Rao, M. S. (1971). *The Protohistoric Cultures of the Tungabhadra Valley*. Dharwar: M.S. Nagaraja Rao.

Nagararaja Rao, M. S. (1985). The earliest Iron Age graves in Karnataka. In V. N. Misra & P. Bellwood (Eds.), *Recent Advances in Indo-Pacific Prehistory* (pp. 469–470). Leiden: E.J. Brill.

Nagaraja Rao, M. S., & Malhotra, K. C. (1965). *The Stone Age Hill Dwellers of Tekkalakota.* Pune: Deccan College Post-Graduate and Research Institute.

Nasnolkar, M. M. (1973). Analysis of Gold Objects. In S. B. Deo (Ed.), *Mahurjhari Excavation 1970–1972* (pp. 78–79). Nagpur: Nagpur University.

Paddayya, K. (1973). *Investigations into the Neolithic Cultures of the Shorapur Doab, South India*. Leiden: E.J. Brill.

Paddayya, K. (1998). Evidence of Neolithic cattle penning in Budihal, Gulbarga District, Karnataka. *South Asian Studies 14*, 141–153.

Paddayya, K. (2002). The Problems of Ashmounds of Southern Deccan in the Light of Recent Research. In K. Paddayya (Ed.), *Recent Studies in Indian Archaeology* (pp. 81–111). New Delhi: Munshiram Manoharlal Publishers and Indian Council of Historical Research.

Parpola, A. (1973). *Argument for an Aryan Origin of the South Indian Megaliths*. Tamil Nadu: State Department of Archaeology, Government of Tamil Nadu.

Possehl, G. L., & Gullapalli, P. (1999). The Early Iron Age in South Asia. In V. C. Pigott (Ed.), *The Archaeometallurgy of the Asian Old World* (pp. 153–175). Philadelphia: University Museum Press.

Prasad, B., & Ahmad, N. (1998). Probable sources of silver in ancient India: A historico–scientific approach. In Tripathi, V. (Ed.), *Archaeometallurgy in India* (pp. 185–190). New Delhi: Sharada Publishing House.

Raghunatha Rao, B., & Sasisekaran, B. (1997). Guttur—An Iron Age industrial centre in Dharmapuri District. *Indian Journal of History of Science*, 32(4), 347–359

Rajan, K. (1994). *Archaeology of Tamilnadu (Kongu Country)*. Delhi: Book India Publishing Company.

Rajan, K. (1998a). Archaeology of the South Arcot Region with Special Reference to Megalithic Burial Complexes. *Man and Environment*, *23*(1), 95–105.
Rajan, K. (1998b). Further excavations at Kodumanal, Tamil Nadu. *Man and Environment*, *23*(2), 65–76.
Rajpitak, W., & Seeley, N. J. (1979). The bronze bowls from Bon Don Ta Phet, Thailand: An enigma of prehistoric metallurgy. *World Archaeology, 11*(1), 26–31.
Ramachandran, K. S. (1989). Paiyampalli. In Ghosh, A. (Ed). *An Encyclopedia of Indian Archaeology: Gazetteer* (pp. 325–327). New Delhi: Munshiram Manoharlal Publishers.
Rami Reddy, V. (1990). Ashmounds in South India: A Review. In A. Sundara (Ed.), *Archaeology in Karnataka (Papers Presented at the National Seminar on Archaeology, 1985)* (pp. 85–99). Mysore: Directorate of Archaeology and Museums.
Rea, A. (1915). *Catalogue of the Prehistoric Antiquities from Adichanallur and Perumbair*. Madras: Madras Government Museum.
Sasisekaran, B. (2002). Metallurgy and metal industry in ancient Tamil Nadu—An archaeological study. *Indian Journal of History of Science*, 37(1), 17–29.
Sasisekaran, B. (2004). *Iron industry and metallurgy: A study of ancient technology.* Chennai: New Era Publications.
Sasiekaran, B., & Raghunatha Rao, B. (1999). Technology of Iron and Steel in Kodumanal—An Ancient Industrial Centre in Tamil Nadu. *Indian Journal of History of Science*, *34*(4), 263–272.
Sasisekaran, B., & Raghunatha Rao, B. (2001). Iron in Ancient Tamilnadu. In Ramachandra Rao, P. and Goswami, N. G. (eds.), *Metallurgy in India: A Retrospective* (pp. 92–103). New Delhi: India International Publisher.
Sastry, D. L. N. (2000). *Paidigutta Excavations: A Proto Historic Site in Lower Thungabhadra Valley, Mehaboobnagar District, Andhra Pradesh*. Jaipur: Publication Scheme.
Shaffer, J. G. (1984). The Indo-Aryan Invasions: Cultural Myth and Archaeological Reality. In J. R. Lukacs (Ed.), *The People of South Asia: The Biological Anthropology of India, Pakistan and Nepal* (pp. 77–90). New York: Plenum Press.
Shaffer, J. G., & Lichtenstein, D. A. (1995). The concepts of "cultural tradition" and "palaeoethnicity" in South Asian archaeology. In G. Erdosy (Ed.), *The Indo-Aryans of Ancient South Asia: Language, Material Culture and Ethnicity* (pp. 126–154). New York: Walter de Gruyter.
Shrivastava, R. (1999). Mining of copper in ancient India. *Indian Journal of History of Science*, 34(3), 173–180.
Srinivasan, S. (1997). The Composition of Bronze Slags from Kalyadi in South India, and its Implications for the problem of Tin in South Indian Antiquity. In A. Sinclair, E. Slater, & J. Gowlett (Eds.), *Archaeological Sciences 1995* (pp. 136–142). Oxford: Oxbow Books.
Srinivasan, S. (1998). High Tin Bronze Working in India: The Bowl Makers of Kerala. In Tripathi, V. (Ed.), *Archaeometallurgy in India* (pp. 241–250). Delhi: Sharada Publishing House.
Srinivasan, S. (2006). Megalithic High-tin Bronzes: Ethnoarchaeological and Archaeometalurgical Insights on Manufacture and Possible Artistic and Musical Significance. *Man and Environment*, *31*(2), 1–8.
Srinivasan, S., & Glover, I. (1995). Wrought and Quenched and Cast, High Tin Bronzes from Kerala State, Southern India. *Journal of Historical Metallurgy*, *29*(2), 69–75.
Srinivasan, S., & Glover, I. (1997). Archaeometallurgical Implications of New Findings of Traditional Crafts of Making High-tin 'delta' Bronze Mirrors and 'beta' Bronze Vessels in Kerala State of South India. In P. Vandiver, J. Druzik, J. Merkel, & J. Stewart (Eds.), *Materials Issues in Art and Archaeology V* (pp. 81–105). Warrendale: Materials Research Society.
Sundara, A. (1972). Chronological Order of Megalithic Tomb-types in Karnataka. In D. P. Agrawal & Ghosh, A. (Eds.), *Radiocarbon and Indian Archaeology* (pp. 239–251). Bombay: Tata Institute of Fundamental Research.
Tewari, R. (2003). The origins of iron-working in India: New evidence from the Central Ganga Plain and the Eastern Vindhyas. *Antiquity, 77*(298), 536–545.
Thomas, P. K. (1992). Faunal background of the Iron Age culture of Maharashtra. *Man and Environment, 17*(2), 75–80.

Tripathi, V. (2008). *History of iron technology in India (from beginning to pre-modern times).* New Delhi: Rupa & Co.

Wheeler, M. (1947–1948). Brahmagiri and Chandravalli 1947: Megalithic and other cultures in the Chitaldrug District, Mysore State. *Ancient India*, *4*, 180–310.

Wheeler, M. (1959). *Early India and Pakistan: To Ashoka.* New York: Frederick A. Praeger.

Willies, L. (1992). Ancient and post-Medieval mining sites in the Khetri Copper Belt and Kolar Gold Field, India. *Bulletin of the Peak District Mines Historical Society 11*(6), 285–295.