Review Essay

THE STUDY OF ANCIENT METALLURGICAL TECHNOLOGY: A REVIEW

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Iron and Steel in Ancient China. Donald B. Wagner. Leiden: E. J. Brill, 1993. Pp. 573; illus.

Iron first appeared in quantity in the eastern Mediterranean world during the last two centuries of the second millennium B.C. (Waldbaum 1980). By the ninth century B.C. Assyrians and Urartians wielding iron weapons were marauding among indigenous populations (also iron-using peoples) in eastern Anatolia and western Iran (Curtis et al. 1979; Pigott 1989; Pleiner and Bjorkman 1974). Farther east, according to local archaeologist Dolkun Kamberi, iron was in use among peoples in Xinjiang province in westernmost China around the tenth century B.C. and in northern India by the same time, if not earlier (Chakrabarti 1976; Prakash and Tripathi 1986). In Thailand and Southeast Asia, the earliest iron artifacts are present in archaeological contexts that date to c. 700–500 B.C. (Pigott et al. in press).

In *Iron and Steel in Ancient China,* a meticulously researched volume, Donald B. Wagner reports that the earliest documented appearance of iron in some quantity in China proper is now c. sixth century B.C.. He states that among the examples of this earliest iron are artifacts wrought as well as cast (p. 406). No evidence of bloomery furnaces is currently recorded in China, however, and Wagner maintains that the early wrought iron was made from fining cast iron and was thus part of the cast tradition. In the early stages of acceptance of iron, the ancient Chinese clearly had technological options and made technological choices.

It has been possible for some time to argue for the existence of a pronounced chronological horizon sloping toward the east that signals the comparatively rapid appearance of iron across Asia. Until quite recently, however, little has been published to convince scholars, foreign and Chinese alike, that the technological impetus for the Chinese iron industry could have come from beyond the Great Wall and perhaps much farther west.

Now strong indirect evidence can be marshaled suggesting pronounced East/

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West contact in the centuries immediately preceding the appearance of iron in China and in the early centuries of its use. This evidence comes from the excavations of cemeteries in Xinjiang province that contained more than 100 mummified individuals who were clearly Caucasian (Mair 1995). The current dates for these individuals range from as early as c. 2000 B.C. into the first millennium B.C., and presumably this is just the tip of the iceberg. Little is known at present of the technological expertise of these Caucasians, but iron is archaeologically documented in western China in the tenth century B.C. (Dolkun Kamberi pers. comm.). This find dramatically demonstrates what has been difficult for scholars to accept even on a theoretical basis: namely, that during the prehistoric period there was substantial contact with Eurasian peoples on the borders of China, if not within China, and that with such contact could have come knowledge of metallurgical crafts.

Even in China there are now indications that diffusionist arguments are being entertained. The eminent Chinese archaeologist An Zhimin has stated in a recent issue of *Kaogu* (1993) that it is a fact that copper/bronze occurs relatively late in China and that contact from the West must be considered in any discussion of the development of bronze metallurgy.[1] He goes so far as to state that metal and its technology could have traveled along the Silk Road and that the technology could have been developed in the Qijia culture (2000–1600 B.C.) of northwestern China, which was well ahead of the central plains in its use of copper/bronze. Furthermore, An views the copper/bronze of the Longshan culture (2400–1700 B.C.), on the middle and lower reaches of the Yellow River, as inextricably linked to developments in the Qijia culture. This is a dramatic about-face from the previously strongly held Chinese position that such technology was exclusively an indigenous development. This new position—as well as the Xinjiang discoveries, made public after Wagner finished this volume—has renewed the controversy concerning the origins of Chinese metallurgy (copper/bronze and iron) and may require the rethinking of Wagner's arguments and those of others (e.g., Barnard 1983) that favor an indigenous development.

In this volume Wagner offers cogent arguments for the sociotechnical link between copper/bronze and iron technologies. He then, for the first time, brings together the disparate bodies of evidence that constitute the history of the coming of iron to China. No other Old World culture area has as yet such a comprehensive and in-depth treatment of this critical technological change.

There is probably no individual scholar who could do justice to a review of this entire volume, as it is such a skillful melding of data from a variety of fields. These include, broadly, the study and analysis of Chinese history, language, and texts; archaeology; process metallurgy; and metallography of artifacts. Furthermore, a great deal of the published material that Wagner covers is in Chinese, and translating it was no small undertaking. Wagner, trained as a historian, is affiliated with the Needham Research Institute in Cambridge, England. Joseph Needham authored the five-volume *Science and Civilization in China* and made other seminal contributions on the ancient Chinese iron industry (e.g., Needham 1958, 1980).

In his preface, Wagner describes *Iron and Steel in Ancient China* as "a study of the production and use of iron and steel in China from the earliest times to about the beginning of the Han period (the end of the third century B.C.)" and offers a

detailed chapter-by-chapter précis. In each chapter, sections devoted to conclusions reached as the discussion progresses are presented, as well as a quite speculative final chapter, "Concluding Remarks."

In the introductory chapter on the Bronze Age in China, Wagner focuses heavily on the textual sources on which much of the current understanding of ancient Chinese history is based. He reviews relevant archaeological evidence from the Neolithic through Zhou periods and the evidence for the use of bronze for agricultural implements, and discusses the origins and development of Chinese bronze technology as a precursor to the development of iron. Here he raises what even he would agree is the often over-debated issue concerning diffusion of technology vs. its independent, indigenous invention. Wagner states that no archaeological discoveries up to 1991 would alter his conclusions presented in this volume. But archaeological evidence does not remain static, and he had no opportunity to discuss the import of the Xinjiang discoveries for this issue or to assess An Zhimin's recent observations.

I would take issue with Wagner's remarks concerning the contribution to this discussion of the late, distinguished metallurgist Cyril Stanley Smith of the Massachusetts Institute of Technology. Smith played a pivotal role in guiding modern research in archaeometallurgy and spent a brilliant scholarly career looking at the nature of structure and hierarchy in all things. To say, as Wagner does, that Smith has no empirical evidence on which to base his views of the origins of technology is to ignore a lifetime of contemplation on the origins, development, hierarchy, and structure of materials. Smith was not basing his observations on personal belief alone: his was an analytical opinion, one that may well be proven more accurate than anyone might suppose at this juncture as the door inches open on the archaeology of China. Wagner dismisses too quickly the import of Smith's observations, which can be found in *A Search for Structure* (1981), a collection of his most important writings.

Also in chapter 1, Wagner discusses the large and well-preserved copper-smelting furnaces (c. sixth century B.C.) from the copper-mining complex at Tonglushan, which may range in date from the early second millennium B.C. to the first (see Zhou Baoquan et al. 1988; Vogel 1982; Wagner 1986). Such industrial installations, which are rare in any Old World context before the Christian era, are of particular importance because given their size and structure, such furnaces could have been used to smelt iron just as easily as copper. These large furnaces could have produced metallic iron by accident during copper smelting, thus introducing a new material that metalworkers could have attempted to recreate and experiment with. This Chinese evidence for the development of sophisticated furnaces at about the same time as the advent of iron in the archaeological record is perhaps the best Old World example from which one might argue the "iron from copper" hypothesis. This hypothesis has by no means been sufficiently tested, and many questions remain unresolved. The evidence from China is intriguing and should be reviewed together with the evidence from southwest Asia, where this topic has received more attention (e.g., Charles 1980; Cooke and Aschenbrenner 1975, 1980; Gale and Stos-Gale 1990; Moorey 1994:279–280; Pigott 1982; Pleiner 1986; Wertime 1968) and where furnaces of any type for any metal have remained rare archaeologically.

In his second chapter, Wagner reviews the evidence for the earliest iron use in

China, again treating both textual evidence (which he rejects in this regard) and archaeological/chronological evidence, the latter from Jiangsu, Hubei, Hunan, Henan, and Gansu, and including materials from the states of Qin, Wu, and Chu. Based on the evidence as it stands, he stresses that it is a working assumption to suggest that iron first appeared in the state of Wu, "a partially Sinified non-Chinese ('barbarian') culture in Southeast China" (p. xi), rather than in the states of Qin or Chu (p. 96). He then proceeds to develop, in chapter 3, a "likely story" of how the innovation of iron may have come about in this context. The choice of the word *innovation* as opposed to the term *discovery* used in the chapter title is to be applauded, because the two refer to different events. The innovation of iron was the product of a long process of accumulating technological knowledge set in motion from the earliest point of metal use in China, regardless of whether or not one maintains that the origins of iron technology were internal or external.

Also in chapter 3 Wagner writes that textual sources indicate that the state of Wu was seen as "barbarian" by peoples to the north, while at the same time it appears that the technology of bronze production, among other cultural elements, came to Wu from the north. Wagner suggests that the sociopolitical context in Wu was distinct from elsewhere. "There may have been a less strict division of labour, and production may have been on a smaller scale, less concentrated, and less under the control of a central authority (p. 145)." Here, in a different creative milieu, familiarity with metallic iron may have come through the process of bronze production. Bronze casters in Wu produced more agricultural implements (inventing several types in the process) than did those in the north. Such production may have been expensive in the Wu region, which lacked significant reserves of copper and tin. As a result, the state of Wu may have turned to iron produced in "blast furnaces of a type used in copper production" (p. xi) as an alternate and cheaper (though inferior?) metal under less tightly controlled social conditions than in the north. The techniques of "malleabilizing" and "fining" were "discovered," which allow the heat-treated, decarburized metal to be forged under a blacksmith's hammer. Wagner argues that during this period wrought- and cast-iron metallurgy were parallel developments, the former being an alien technology among highly skilled bronze founders. Was the technology "alien" enough to have come from abroad?

In his fourth chapter Wagner indicates that the data on early iron are skewed to some extent because mortuary contexts are almost exclusively the primary source. The compiled evidence suggests that by the late fourth/early third century B.C. iron, as an innovation, was well accepted for the production of weaponry and agricultural implements and other artifact classes. The use of iron to shackle prisoners or slaves was commonplace. The extent to which iron-manacled manpower—what Wilbur (1943*a*, 1943*b*) termed "industrial slavery"—played a role in Chinese metal production has been much discussed (e.g., Barnard 1979–1980:124; Franklin 1983:287; Taylor 1988:207). Wagner, in chapter 5, argues that slave labor was "not really economically suitable in iron production and that in the end the unrest, social, political, and possibly military, caused by the enforced labor of iron plantations may have been one of the reasons leading to the rise of Han state monopoly on iron production in 117 B.C." (p. 259).

Wagner suggests that iron appeared early in the state of Wu—c. sixth–fifth

century B.C.—and that the technology spread from Wu to Chu and at a later point from Chu, c. fourth–third century B.C. In the Chu state implements, not weapons, were made of iron. Use of iron spread west and north to other states. In approximately the third century B.C. it was being widely used for implements (mostly in cast iron) and weapons (mostly in wrought iron). For example, Wagner supports the "hypothesis that iron swords were not used in ancient China until the beginning of the third century B.C., and that the spread of their use was in part due to the influence of Qin" (p. 244). The remarkable volume and detailed nature of the data on Chinese iron weapons and implements are demonstrated dramatically through Wagner's meticulous research. Only what is known about iron in the Roman Empire may rival the depth and extent of knowledge of iron material culture and production in China. However, even the Roman evidence has not been brought together and published in a single-volume overview comparable to Wagner's magnum opus.

In chapter 5, again based primarily on textual evidence, Wagner discusses the organization of iron production, which was apparently concentrated in a few large ironworks. These ironworks were controlled by a small number of so-called "primitive industrialists" (Needham 1958 : 7) who from the third century B.C. on practiced industrial blast-furnace production of iron. Wagner points out in his final chapter that such "iron plantations" arose as a result of the inherently large-scale production organization of a blast-furnace complex, the need for iron (a ubiquitous ore), and, of particular importance, the proximity of fuel (forests, the source of charcoal). Only the products, it seems, moved over long distances, not the raw materials essential to production (p. 408).

As Wagner points out, however, archaeology in China has not yet been of much use in discussions of the earliest ironworks. The only published excavations are from the period following the iron production monopoly of the Han state, introduced in 117 B.C. Nor has archaeology revealed the presence in China of direct-process bloomery furnaces, which reduce iron in the solid state. Wagner does mention that Chinese archaeometallurgists maintain that iron artifacts of the Warring States period are the product of the bloomery process (p. 263), but in chapter 6 he presents cogent arguments to the contrary (p. 292 and following).

Chapters 6 and 7 focus on metallographic studies of wrought-iron and steel artifacts (chapter 6) and cast-iron artifacts (chapter 7). These chapters demonstrate Wagner's most unusual achievement in this comprehensive overview of ancient Chinese iron. He elected to begin the study of metallurgy in 1981 (with the eminent Danish metallurgist V. F. Buchwald) and has developed considerable competence in this science, sufficient to write knowledgeably of the production process and the laboratory analysis of iron. He begins with a useful introduction to the fundamentals of iron metallurgy, including the iron-carbon phase diagram and the craft of blacksmithing (welding, quenching, forging, tempering, the technical sophistication of the unique Chinese "hundredfold refined steel"). He discusses the production processes for wrought iron and the various types of cast iron and then gives an extensive review of the metallographic (that is, microstructural) evidence, most of which comes from Chinese sources. This metallographic discussion, which is accompanied by an appendix of Wagner's translations of metallographic reports in Chinese, is invaluable to those scholars who wish to assess for themselves the structural evidence for the various types of iron produced by the

Chinese. So much of this evidence has for years remained inaccessible because of language barriers and the obscurity of publications that scholars should find this section of unusual importance. Moreover, it is heavily illustrated with photomicrographs. However, the question must be asked: is there a large enough community of scholars who would find these photomicrographs of interest to merit their extensive publication? Presumably, the large number of photos and photomicrographs in this section in particular, when added to the large number of illustrations throughout the volume, contributed to the astronomical price for this book ($183.00). Many of the photomicrographs are not clear and may not serve the needs of those scholars, primarily metallurgists, who can actually interpret them. Perhaps some middle ground should have been found that would have permitted the book to be sold for a lower price. Such a high price only limits the distribution of a particularly valuable volume.

In his final and, by his own admission, speculative chapter, Wagner focuses primarily on future research perspectives. I was particularly intrigued by his statement that "*technological choices*—choices of one way out of many for the fulfillment of a particular need— ... are ... or can be, the fundamental concept of the history of technology" (p. 405). Wagner does not elaborate his views much further in theoretical terms, but he does go on to explore in thought-provoking terms the "historical causes and effects of a series of technological choices" (p. 407). The discussion of technological choice as a cultural phenomenon influenced by and in turn influencing social context has been actively pursued in other ancient culture areas—most notably in the New World, specifically the Andes (e.g., Lechtman 1977, 1979, 1984, 1993) and western Mexico (Hosler 1994). This approach demonstrates the true interpretive power that lies in the study of technology, as one window of many on its host culture.

As a historian pursuing the development of a technology, Wagner has set the stage for those future investigations which will look at this critical technological change in ancient China from a social/behavioral—that is, anthropological—standpoint.[2] Wagner addresses various themes pertinent to such a discussion, including issues of political ideology, structure, and control and their effect on production, both in bronze and iron. Regarding the organization of production, he recognizes its pivotal role in an industry dependent on the blast furnace. It would be a valuable exercise to bring to bear on the Chinese iron industry the results of recent analyses of craft specialization and/or the organization of production[3] (e.g., Brumfiel and Earle 1987; Costin 1991). Taken to extremes, one wonders how the members of the recently evolved "anthropology of technology" school (e.g., Lemmonier 1992; Pfaffenberger 1988, 1992) might pursue the analysis of the social and technological phenomenon of Chinese iron production. In this regard, I for one would like to see an international symposium convened, comprising scholars from all relevant fields, to discuss what Wagner has argued in this volume.

In effect, from the publication of this volume on, further studies will of necessity have to view Chinese iron technology as a *social product,* the product of a unique social context that has resulted in a unique "technological style." Wagner's fundamental summary work will permit the next level of interpretation to occur, and his speculations concerning Chinese iron are aimed in this direction. Wagner and the next generation of China scholars now have a chance to assess the social

consequences of a technological transition that from its outset profoundly influenced life and culture in ancient China and was in turn influenced by the unique social circumstances that characterized China in the mid to late first millennium B.C. China, with its wealth of social and cultural data (concerning, for example, politics, economics, trade, and demographics), may well offer researchers one of the best documented ancient Old World examples for the understanding of how, and under what circumstances, such a massive and complex industry as that of iron actually arose. Finally, those scholars who aspire to such accomplishments in the realm of ancient China need only learn Chinese, take up the study of metallurgy, and keep Donald Wagner's impressive volume in their library!

NOTES

1. Victor Mair of the Department of Asian and Middle Eastern Studies at the University of Pennsylvania brought to my attention and supplied translation for crucial sections of this article. His assistance is greatly appreciated.
2. As an example of an approach to the topic of ancient Chinese iron with social/anthropological questions in mind, see Taylor and Shell 1988. The work is based in part on Sarah J. Taylor's master's thesis at Cambridge University (1984).
3. Ursula Franklin's (1983) stimulating analysis of the organizational requirements of ancient Chinese bronze production and the role of holistic and prescriptive processes in this production merit mention in this regard. Although her work was not referenced by Wagner, her views provide interesting food for thought in the light of Wagner's thoughts on the development of the iron industry out of the earlier context of bronze production. Compare Barnard 1979–1980.

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