Materials Transitions in History

Whenever technologies are introduced that out-perform old ones, materials scientists hope that "materials revolutions" will occur. We have come to realize, however, that technological replacements—or "materials transitions"—are governed by many factors, including the availability of the constituents, the reproducibility of the material, the possibility of scaling-up production, the cost benefits, the risks involved, and the accepted norms of the field and the society. What is surprising is that this has always been the case. Early transitions occurred in just as complex a manner. This realization has led archaeologists to approach early materials industries as "sociotechnical systems" in which technologies are inextricably linked to social behavior and societal organization as well as to tools and techniques. Archaeometallurgical studies can provide insights into both the factors that cause new technologies to be adopted and perpetuated by societies and the barriers that prevent materials from being generally used, no matter how superior. An example of how societal beliefs can assist a materials transition is the introduction of bronze in China. An example of how societal beliefs can inhibit transition is the failure of the Incas to develop iron.

Bronzeworking initially occupied a relatively minor position within Chinese society, especially when compared with other precious materials such as jade. Most of the early pieces were small, simple tools and ornaments in copper and bronze that were either hammered or cast. Archaeological discoveries since the 1950s at such sites as Erlitou, Zhengzhou, and Yinxu have shown that the metals industry went through a metamorphosis between 1900 and 1600 BC, however. The quantity and sophistication of the artifacts exploded. Large, intricate artifacts were introduced, such as bronze ritual-vessels that ranged in size from several to 875 kg. The catalyst for this metamorphosis is now believed to have been the rise of a new belief system. Chinese rulers began to believe that their ability to lead relied on ancestral guidance and that the benevolence and guidance of ancestral spirits could be obtained only by making offerings of wine and food in large bronze cauldrons as tall as waist high. Thus, the ability to rule and retain power became dependent on the ability to make and maintain bronze ritual vessels. As the significance of bronze increased within the belief system of China, so did its uses. Large quantities of bronze military equipment begin to appear in the archaeological record at about the same time. Extensive mining complexes were established in central and western China to satisfy the demand engendered by these new applications at the Shang and Zhou Dynasty urban-centers. The site of Tonglüshan near Wuhan in the Yangtze region, for example, revealed the remains of a large copper mine and a slag heap of roughly a half million tons. Thus, bronze was initially adopted and perpetuated not for its mechanical properties but for its religious significance within the society.

Whereas a belief system aided the adoption of a new metal in China, it hindered technological transition in Andean society. Inca metallurgy in the 15th century AD consisted of small-scale, labor-intensive methods for producing copper and gold. Small furnaces were used to produce a conglomerate of slag and copper prills. This conglomerate was then crushed, and the prills were collected and remelted. The draft for these furnaces was produced by men blowing through blow-tubes. The limited draft provided by human lung-power meant that the temperatures required for large-scale copper production and the smelting of iron could not be reached. Bellows were probably not invented because they would have challenged the status of human breath in Andean culture. Breath held special significance and effectiveness in Inca ritual. Ethnographic work suggests that the Incan cosmos was suffused with a life force that could be directed by breath. For example, the ritual for boys coming of age included their blowing into the air tufts of wool that were pulled from sacrificial llama lambs. Thus, the Inca probably believed that human breath was integral to the smelting process. It was human breath that directed the life force into the furnace and caused the ore to transform to metal. Even if bellows were made, they would not have been considered suitable for smelting because the air produced would not have had the life force needed for the successful completion of the process within the context of Incan beliefs. In the case of the Inca, therefore, it was the belief system that restricted technological innovation.

Archaeometallurgical studies can now transcend the simple construction of technological progressions and we now try to understand early metals industries within the context of their associated social and symbolic aspects. These aspects both affect and are affected by the adoption, development, and perpetuation of materials technologies. The insights provided by the study of early technological systems will surely deepen our understanding of the present materials technologies.

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FOR FURTHER READING: R.M. Ehrenreich, ed. *Metals in Society: Theory Beyond Analysis*, vol 2. (MASCA, Philadelphia, 1991); K.C. Chang, *Art, Myth, and Ritual: The Path to Political Authority in Ancient China* (Harvard University Press, Cambridge, 1983); H. Lechtman, "The Significance of Metals in Pre-Columbian Andean Culture," *The American Academy of Arts and Sciences Bulletin* **38** (1985) p. 9; I. Shimada and J.F. Merkel, "Copper Alloy Metallurgy in Ancient Peru," *Scientific American* **265** (1991) p. 80.

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