The Innovation of Iron

Cultural Dynamics in Technological Change

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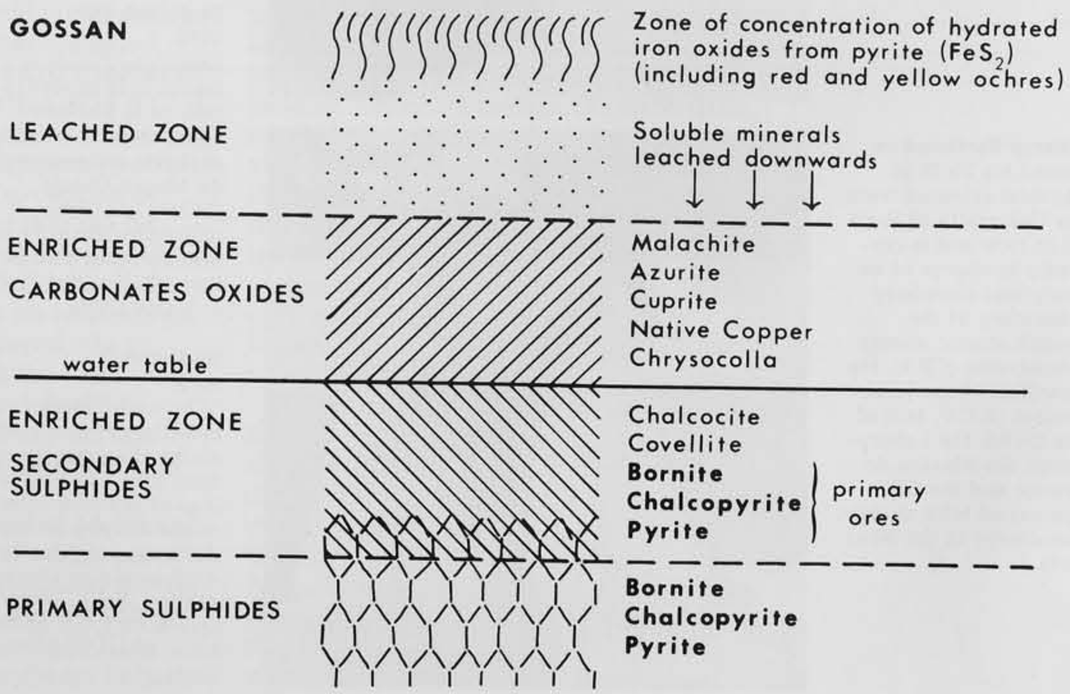
Scholars concerned with the phenomenon of ancient iron metallurgy have emphasized the interrelationship between the analytical, historical and archaeological evidence for proper interpretation of its complexity. While great strides have been made towards documenting not only early production technology (smelting and forging) but also the metal's earliest geographical and chronological distribution, the nature and functional consequences of its innovation and adoption have yet to receive comparable attention.

In a recent lecture (1981), Robert McC. Adams spoke of technology as knowledge: knowledge of how to reproduce things. And human behavior may be modified in the process of applying a new technology. But he was quick to avoid the connotation of technology as a standardized procedure producing routine results. He indicated that technology can be unpredictably variable with respect to materials and conditions but adaptive in terms of basic skills, knowledge and method. In this way, failure is normally avoided and the intended result achieved. In Adams' view the essence of technology is seen as "management of scarce resources, human and natural, under conditions of prevailing uncertainty." With technology in the above terms in mind, in the discussion to follow, the attempt is made to identify certain of the sociocultural processes specific to the innovation and subsequent widespread acceptance of iron and its associated metallurgy.

Innovation is the source of technological change. Homer G. Barnett defined an innovation as "any thought, behavior or thing that is new because it is qualitatively different from existing forms . . . every innovation is an idea or constellation of ideas some of which may be given overt and tangible expression" (1953:7). The production of iron may be seen in these terms as an innovative stage within a pyrotechnological continuum which began with the earliest intentional smelting of



1
Schematic cross-section of a copper ore body. The presence of iron in the gossan cap and the ores is denoted by bold face lettering. Ancient copper miners frequently encountered such iron-bearing copper ores as chalcopyrite.

2
Close-up photo of a specimen of malachite copper ore (note characteristic banding) which occurred in an iron-rich matrix in its original ore body. Under primitive smelting circumstances the smelting of such an ore with its adhering iron minerals could have resulted in metallic copper with appreciable iron content. Photo by Nick Hartmann, MASCA.

metallic ores, specifically those of lead and copper. Iron as an innovation represented a new line of development, a recombination of previously existing knowledge which resulted in an entirely new technological configuration (Wallace 1972: 469; Bee 1974: 174).

Several suggestions have been made as to why people are innovative, particularly with regard to metal-working technology. The first of these is that the innovation is simply accidental. The materials (ores and fluxes) and processes (roasting, smelting, refining) that constitute metal production, when brought together, have an almost inherent variability which can produce unpredicted results. Cyril Stanley Smith in his essay entitled "Structural Hierarchy in Art, Science and History" (1981: 374ff) argues that an imperfection present in an hierarchical system at one level often points to and allows the next higher level of structure to exist. In essence, the small imperfection serves as the nucleus for change in the structural hierarchy. Lacking such an imperfection, the original structure remains static with no potential for change. The nucleus for change appears at those points in the original structure undergoing some form of strain, an area Smith refers to as the "least contented" (1981: 382).

Within the framework of the tradition of copper smelting in the ancient Near East, how did iron emerge as an imperfection? In technological terms it was a relatively straightforward matter because not only do various ores of copper contain substantial amounts of iron but also the ores of copper and iron frequently co-occur in the same geological deposits. Furthermore, iron oxide, in its various forms, was the primary fluxing ingredient in the processes of copper smelting and bronze making. Consequently metallic iron was sometimes formed as part of the furnace by-products. We would expect that the metalsmiths became familiar with the basic properties of these by-products long before they began to intentionally smelt iron for its own sake. Their experimentation may have

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Bimetallic lion pin (HAS 62-523) with bronze lion cast on to an iron shaft, from Hasanlu, northwestern Iran *ca.* 800 B.C. Such bimetallic artifacts are common indicators of the transitional period between the Late Bronze and Iron Ages. The metalworkers who produced such artifacts may well have been the bronze smiths experimenting with iron as a relatively new material.

been stimulated by curiosity, need or desire.

Anthony F. C. Wallace (1972: 477) has stressed the role of aesthetic motivation in the innovative process as has Cyril Stanley Smith who points out that, "New forms appear aesthetically where . . . an existing style is impressed on a new material or different technique" (Smith 1981: 381). Smith argues that it is often the case that the technological innovation proceeds through the manipulation of decorative materials in what he terms an aesthetically sensitive environment. In the ancient Near East early iron artifacts from Bronze Age contexts, as well as many from the bimetallic phase just prior to the widespread adoption of iron, are often, though not exclusively, artifacts designed for decorative/ceremonial purposes.

To improve the chances for an innovation to be accepted, its adoption must be perceived as advantageous to society; facilitating this is a degree of knowledge about how to properly use the new idea (Rogers and Shoemaker 1971: 19). In the ancient Near East iron artifacts begin to occur sporadically during the early 3rd millennium (Waldbaum 1980), and by the later centuries of the same millennium there are indications that iron was being intentionally produced. Briefly stated, such indications include an iron dagger found at Alaça Hüyük in central Anatolia and dated *ca.* 2300 B.C., which is sufficiently large that the manufacture of the iron blade cannot be construed as accidental. Further evidence of early purposeful production of iron in this same region may come from the Assyrian trading colony of Karum Kanesh at Kültepe *ca.* 1900 B.C. Here texts refer to a material known as *amutum* which is now thought to be

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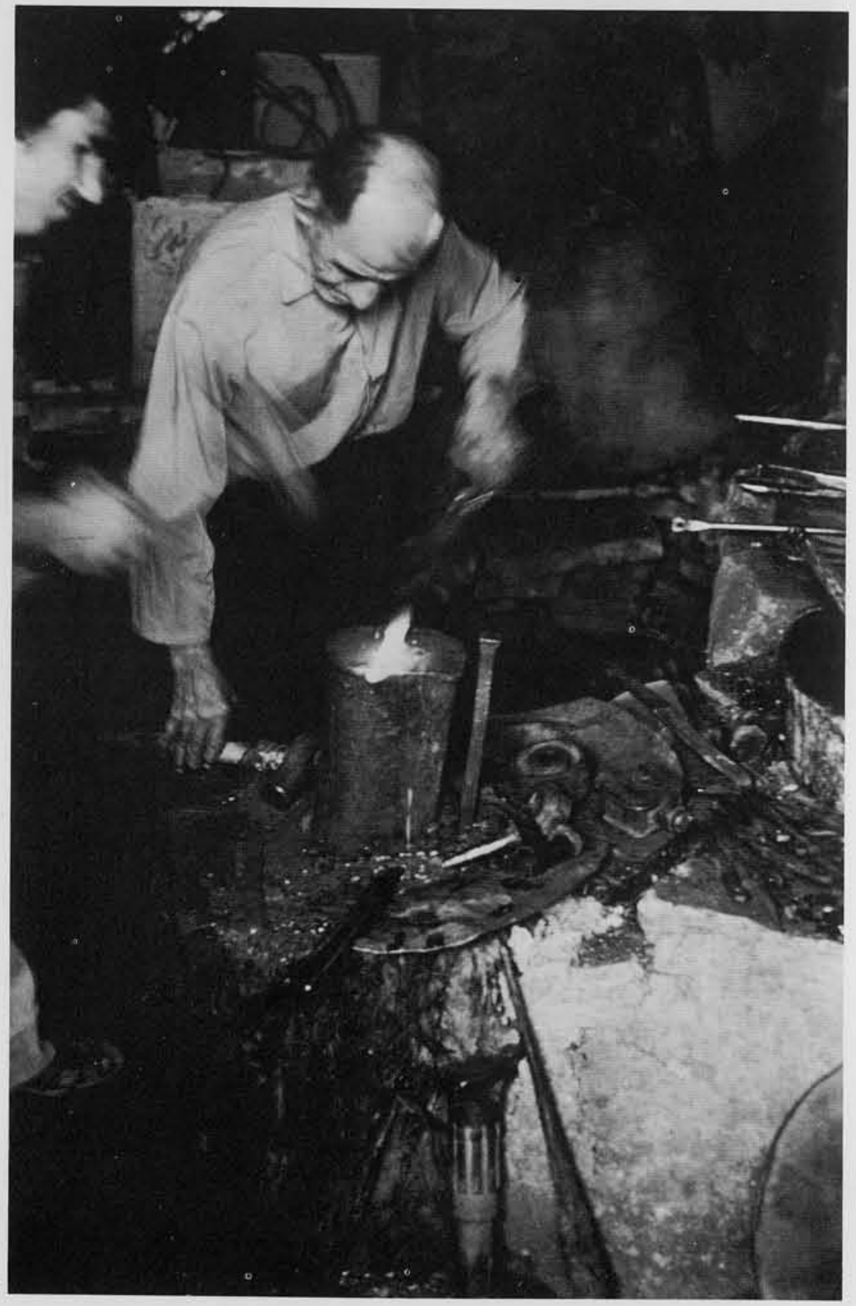

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Here a modern Iranian blacksmith with his apprentice directs the forging of a glowing pick. They are surrounded by the various implements which make up the blacksmith's basic tool kit. The forging of a number of wrought iron artifacts is a far more arduous task than the casting of multiple copper/bronze artifacts.

5
Bivalve stone mold for copper/bronze battle axe (HAS 60-177, 60-518) excavated at Hasanlu, northwestern Iran, *ca.* 800 B.C. Casting in such molds permitted the efficient, industrial production of standardized shapes in metal on a relatively consistent and large scale basis. Length: 22 cm. Photo courtesy of the Hasanlu Project.

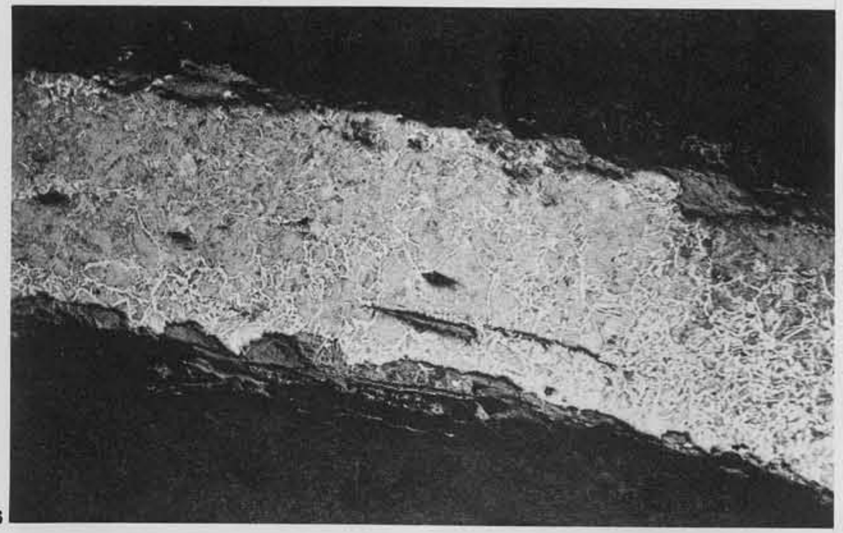
smelted iron (Maxwell-Hyslop 1974). Iron, at this time, had its circulation controlled to the point that it was not supposed to be traded abroad (Muhly 1980: 35). Subsequently, references to iron in Hittite contexts provide further substantiation of metalsmiths exercising a proper use of their technological knowledge of iron (Stech-Wheeler *et al.* 1981: 263).

Despite these suggestions of early intentional production, however, archaeological evidence for the production of significant quantities of iron is sparse prior to *ca.* 1200 B.C., when iron artifacts begin to occur in quantity over a widespread geographical area. This raises the question of why there was a time lag between the innovation of iron technology and its adoption on a large scale. An important reason for this delay may have been the fact that while iron ores are more economical to exploit than those of copper and tin, the energy required to work iron offsets this economic advantage (Smith 1971: 51). Forging iron is considerably more demanding than the mass production of copper/bronze artifacts by casting.

The difference between the working of iron and bronze lies in the production of the finished product, that is, in the physical labor and time involved in the forging of individual artifacts from iron on an industrial scale. With copper/bronze, multiple artifacts may be produced from casting following a single smelting operation, with little or no finishing required before they begin to circulate as functional or ornamental artifacts. With iron, a group of artifacts may be produced from the product of a single smelting operation (bloom) but a greater number of man-hours must go into working up pieces of bloom into functional artifacts. This difficulty inherent in the forging process meant that iron had to be produced on a large-scale basis to make it economically viable. A final drawback to iron's early acceptance was the fact that low-carbon wrought iron did not have substantially improved performance characteristics over its copper-base counterpart.

While the number of iron artifacts slowly increased between the period of iron's innovation and its subsequent adoption *ca.* 1200 B.C., there is no evidence for any real burst of technological development in iron-working itself in this interim period, and copper/bronze technology continued to dominate. Given the extent of our documentation of the various local metalworking traditions throughout this area, it can probably be concluded that the disadvantages of iron working were such that Bronze Age smiths, working independently in relatively isolated communities, were not prepared to work in it and lacked substantial incentive to do so on any scale. It is only after certain particular socio-cultural changes occurred in the Near East that iron production became desirable as well as feasible.

Among the critical societal changes occurring *ca.* 1200 B.C. were the collapse of the Hittite Empire and the movement of



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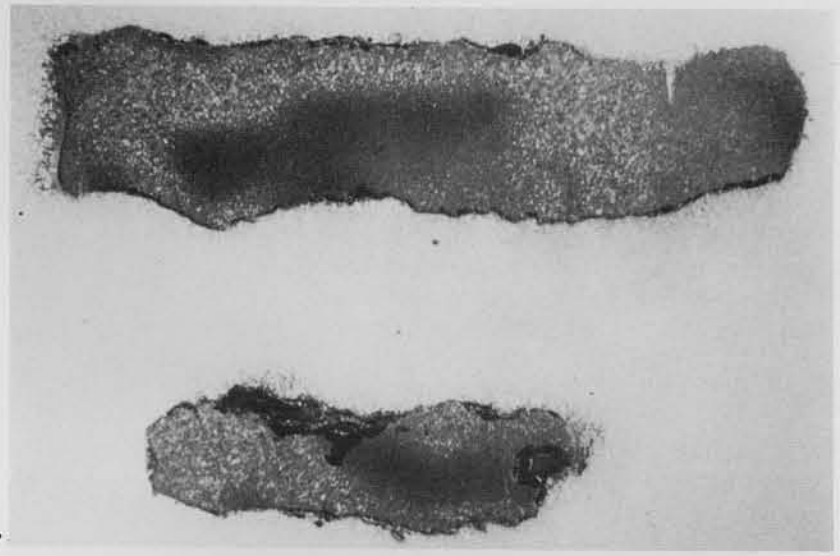
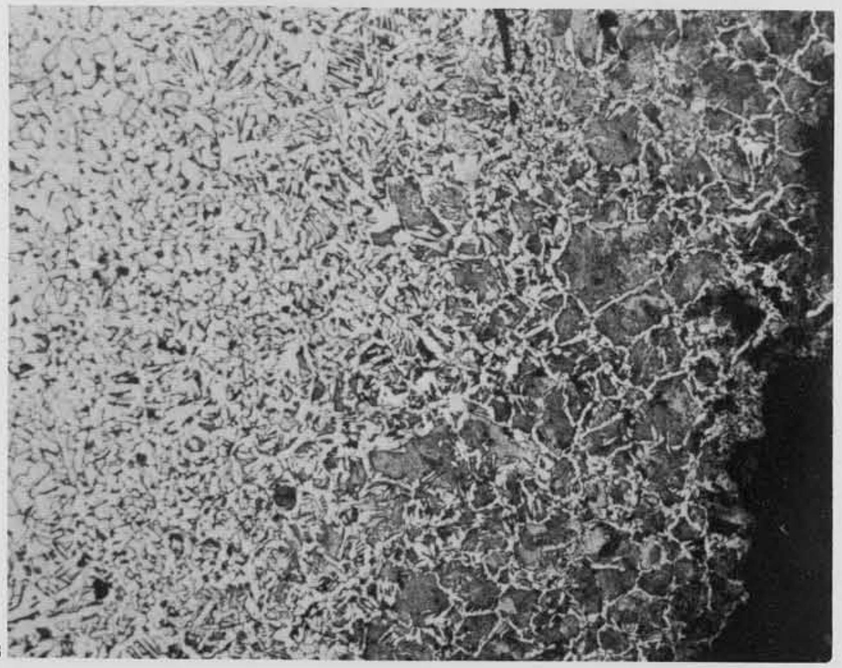
Low magnification view of microstructure of Baq'ah Valley, Jordan steel bracelet (I.55). The metal core of the bracelet, seen here about ten times normal size, is extensively carburized edge to edge which is indicative of a steel with a carbon content of approximately 8%. Photo by Nick Hartmann, MASCA.

7
From the site of Taanach in Palestine, an unfinished steel tool (TT 1879, *ca.* 10th century B.C.) is shown here in two cross sections, the larger of which is 3 cm. long. The lighter grained areas in each section constitute a carburized outer rim. Photo courtesy of Robert Maddin.

the Sea Peoples which produced major population shifts and general upheaval promoting socio-political reorganization on many fronts. Recently, the coming of iron (often steel) in Palestine under conditions of political decentralization at this time has been well-portrayed (Stech-Wheeler *et al.* 1981). Smith's concept, wherein a nucleus for change forming only in a zone under significant strain, is quite suitable to the conditions of iron's inception in this area.

While on present evidence, the particular situation in Palestine appears to be somewhat distinct, generally speaking in the Near East the widespread adoption of iron seems to coincide with the formation of new empires in the centuries following *ca.* 1200 B.C., which helped to foster the continuous repetition of this new technological pattern of metal production. During this period, peoples including the Philistines, the Assyrians, and the Urartians all consolidated their empires. These empires required large amounts of metal for their military, agricultural and construction needs as well as for the day to day needs of the populace. The centralized control which the political elite exercised over large numbers of persons made iron production reasonable, since it provided the administrative structure and the work force by which the various labor-intensive activities of iron production (mining, transporting, obtaining fuel, dressing, smelting, etc.) could be coordinated. Iron ores are more common than those of copper and tin. Furthermore, the tin necessary for bronze production had to be imported over long distances. Thus, under these centralized conditions, large amounts of iron could be produced more economically than





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Photomicrograph (x50) of unfinished tool (TT 1879) showing gradient of carbon content extending into the core of the tool from the outer surface (right edge). The gradient from the surface indicates that this tool has been 'steeled.' Photo courtesy of Robert Maddin.

artifacts in other metals. It appears, then, that iron production was adopted in the Near East when the organization of production was overseen by a group with a vested interest in an abundant and economical source of metals. Their socio-political organization was such that iron best filled these demands.

The quality of the metal does not appear to have influenced the decision to adopt iron in Assyria (Pleiner and Bjorkman 1974; Curtis *et al.* 1979), by far the largest empire in the early Iron Age of the Near East. There, early iron continued to be a wrought iron with a heterogeneous carbon distribution, without any clear physical advantages over the bronze that was being produced at the same time. In other areas, however, particularly in Palestine, there is increasingly strong evidence for the production of actual steel soon after 1200 B.C. (Stech-Wheeler *et al.* 1981: 255). The properties of steel, including mechanical strength and the ability to hold an edge, are such that the material is decidedly superior to wrought iron and bronze. These properties would have hastened its adoption and consequently the reputation of steel may have become attached to ordinary iron in adjacent regions where industrial scale production of iron was to occur.

To conclude, then, knowledge of iron and the ability to produce it intentionally preceded its widespread adoption by centuries in the Near East. Much has been written about the coming of iron, particularly on the consequences of its adoption which have been thought to have had far-reaching socio-cultural and ecological implications (see Childe 1950; Adams 1968; Wells 1981). With this in mind and given the current state of our understanding of the technological phenomenon of iron metallurgy, it appears that socio-cultural processes exercised a somewhat greater influence in the ultimate acceptance of iron as an innovation than any immediate recognition of the metal's potential or realized technological superiority.

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