What Caused The Iron Age?

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This paper explores the proximate cause of the Iron Age. Why did nations of the Eastern Mediterranean switch from bronze to ferrous metals between 1200 and 1000 BC, while Egypt did not commonly use ferrous metals for utilitarian purposes until 600 BC?

To answer that question, it is first necessary to define why 1200 to 1000 BC in the Near East is considered the transition from Bronze Age to Iron Age. Paradoxically, it is not the smelting of iron that distinguishes the Bronze Age from the Iron Age. At least one Mesopotamian smelted iron artifact (distinguished from meteoric iron by its lack of nickel) dates from 5000 BC. Increasing numbers of smelted iron objects appear in Mesopotamia, Anatolia, and Egypt between 3000 and 2000 BC, including a circa 2800 BC iron sword from Tell Asmar. But iron in the Early Bronze Age was rare and expensive. At the end of the third millennium, iron appears to have been five times as expensive as gold. The weapons and tools made of iron are ceremonial in nature, and the other uses of iron are ornamental.[1]

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[1] Jane C. Waldbaum, *From Bronze to Iron: The Transition from the Bronze Age to the Iron Age in the Eastern Mediterranean*, (Göteborg, Sweden: Paul Aströms Förlag, 1978), 15; Jane C. Waldbaum, "The First Archaeological Appearance of Iron," in *The Coming of the Age of Iron*, ed. Theodore A. Wertime and James D. Mulhy, (New Haven, Conn.: Yale University Press, 1980), 70-74; Herbert Maryon, "Early Near Eastern Steel Swords," *American Journal of Archaeology*, 65:173. See R. J. Forbes, *Studies in Ancient Technology*, (Leiden: E.J. Brill, 1964), 9:253, for the value of iron at the end of the third millennium.

From 2000 to 1600 BC, the Middle Bronze Age, references to iron appear in literature with some frequency, but it remained a ceremonial or ornamental metal. At least one Old Assyrian text records that iron was eight times more valuable than gold. Only in the late Bronze Age, from 1600 to 1200 BC, does iron start to become a working metal in some regions — and even then, bronze remains the dominant metal for weapons and tools.[2] Iron was valuable enough that Hattusilis III attempted to appease another ruler (believed to be Assyria's Shalmaneser III) in the thirteenth century BC with the gift of an iron dagger blade.[3]

Why was iron so valuable? While it is impossible to know for sure, many scholars believe that early iron production was not intentional, but a by-product of smelting other metals. Forbes points out that the Nubian gold gravels from which Egyptians obtained gold dust were rich in magnetite sand. While not as dense as gold, magnetite is considerably denser than other common sand minerals, and is often found with gold. Forbes believes that when the Egyptians melted gold, at least some magnetite ended up in the crucible, producing small quantities of iron between the gold and the slag.[4] One objection to this theory is that iron is 50% soluble in gold at gold's melting point, and therefore little iron would be present separate from the gold itself.[5]

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[2] Waldbaum, "The First Archaeological Appearance of Iron," 75-77.

[3] Forbes, *Studies in Ancient Technology*, 9:253-255; Waldbaum, "The First Archaeological Appearance of Iron," 80; Maryon, 65:173.

[4] Forbes, *Studies in Ancient Technology*, 9:200-201; Jim Martin, *Recreational Gold Prospecting*, (Burbank, Cal.: Darwin Publications, 1983), 18-19. In the personal experience of this author, panning for magnetite is *far* easier than panning for gold; this theory has at least a surface plausibility.

[5] Theodore A. Wertime, "The Pyrotechnologic Background," in *The Coming of the Age of Iron*, ed. Theodore A. Wertime and James D. Mulhy, (New Haven, Conn.: Yale University Press, 1980), 14.

An older theory postulates that ancient smelters may have mistakenly used iron ore instead of copper ore in the production of copper or bronze. The smelter, having discovered that wrought iron was inferior to bronze because it would not hold an edge, saw no reason to intentionally smelt iron.[6] One very serious problem with this explanation is that iron remained more valuable than gold throughout the Bronze Age. Iron ores were relatively abundant. The quantity of iron produced by such a smelting mistake, and the absence of the desired metal, would have suggested the ore was the source. It seems unlikely that a smelter would not repeat such a "mistake" if the result was a metal as valuable as iron.

In the 1960s, another theory of iron as copper smelting accident came out of experimental archaeology conducted by Theodore Wertime and Cyril Stanley Smith. Based on archaeological evidence, as well as traditional Near Eastern smelting practices, Wertime and Smith demonstrated that the iron ores sometimes used as flux for copper smelting can be reduced to sponge iron as part of the copper smelting process.[7] This model explains why the Bronze Age produced iron, but only in very small quantities. Smelters used a variety of materials as fluxes. Depending on the temperature, the amount of oxygen present, the iron content (if any) of a particular flux, and the quantity of flux used, the production of sponge iron would have seemed a completely random event. Thus, the smelter would be unable to reliably repeat the process that had accidentally produced iron.

Since production of iron precedes the Iron Age by several millennia, when does the Iron Age begin, in the sense that it identifies the importance of iron to a culture? Waldbaum suggests the beginning was "when iron ceased to be

6 Forbes, *Studies in Ancient Technology*, 9:215-216.
7 Wertime, "The Pyrotechnologic Background," 13-17.

considered precious and was finally accepted as the predominant material for making tools and weapons... ."[8] But such a definition requires the drawing of conclusions concerning ancient notions of "precious."

A more quantifiable definition distinguishes three stages of iron development. In the first stage, a society uses iron for ornamental purposes, or for ceremonial tools and weapons — not for working use. In the second stage, the society uses iron for utilitarian purposes, but bronze still predominates. In the third stage, the society uses iron more commonly than bronze as a working metal.[9] This definition is somewhat more useful, because it distinguishes the first stage (which is still in the Bronze Age) from the second and third stages. This determination can be made by examining the number of iron and bronze implements archaeologists find associated with each period and culture.

But this still doesn't explain *why* iron replaced bronze. Iron is *not* superior to bronze for tools. Wrought iron, the form first encountered by Near Eastern smelters, is roughly equivalent in hardness to annealed 10% tin bronze, and inferior to *all* cold-worked tin bronzes. It is only when carbon dissolves into the iron (carburization) and the artisan quenches the resulting steel that ferrous metals have a definite hardness advantage over bronze.[10]

The development of steel, of course, made iron production essential. Indeed, 1200 BC is a commonly accepted date not only for the start of the Iron Age, but also for the discovery of carburization of iron. While the location of this discovery remains uncertain, it appears that in the Hittite kingdom, a

[8] Waldbaum, "The First Archaeological Appearance of Iron," 82.

[9] Anthony M. Snodgrass, "Iron and Early Metallurgy in the Mediterranean," in *The Coming of the Age of Iron*, ed. Theodore A. Wertime and James D. Mulhy, (New Haven, Conn.: Yale University Press, 1980), 336-337.

[10] Waldbaum, *From Bronze to Iron*, 68; Tamara S. Wheeler and Robert Maddin, "Metallurgy and Ancient Man," in *The Coming of the Age of Iron*, ed. Theodore A. Wertime and James D. Mulhy, (New Haven, Conn.: Yale University Press, 1980), 116.

blacksmith discovered how to make steel by heating iron in contact with carbon.[11] But the production of steel was probably quite random at first. Throughout the eastern Mediterranean area in the first two centuries of the Iron Age, iron weapons appear alongside bronze weapons, with no evidence that iron provided any military advantage over bronze weapons.[12]

The discovery of carburization was apparently an accident, and the discoverer probably did not know how he did it the first time. Indeed, until the eighteenth century AD, the conversion of iron to steel was misunderstood as removing some impurity from iron – not adding carbon to it.[13] Ferrous artifacts become more common after 1200 BC, but they do not replace bronze immediately, and as will be seen later in this paper, ferrous metals replace bronze first in tools, then in weaponry.

The discovery of carburization was almost certainly an accident, as was quenching of steel, since neither is a component of bronze working. Such an accident suggests that artisans worked iron for utilitarian purposes. Who would have noticed how well a piece of iron jewelry kept an edge? This argues that steel was a serendipitous discovery when iron had crossed the line from ornament to utility metal.

Another model to explain the start of the Iron Age asserts that the Hittites discovered carburization around 1400 BC, and maintained a monopoly on the new technology for 200 years. This model explains the start of the Iron Age as the result of technology diffusion after the collapse of the Hittite nation in the twelfth century BC. According to this diffusion theory, Hittite

[11] James D. Muhly, "The Bronze Age Setting," in *The Coming of the Age of Iron*, ed. Theodore A. Wertime and James D. Mulhy, (New Haven, Conn.: Yale University Press, 1980), 50-52; Forbes, *Studies in Ancient Technology*, 9:209, 217, suggests a date as early as 1400 BC for the discovery of carburization.

[12] Waldbaum, "The First Archaeological Appearance of Iron," 84-85.

[13] R. J. Forbes, *Man the Maker: A History of Technology and Engineering*, (New York: Abelard-Schuman, 1958), 202-203; Mulhy, 52.

collapse scattered the secrets of smelting and carburization throughout the eastern Mediterranean as craftsmen moved out of Asia Minor.[14]

But the Hittites made little military use of iron, suggesting that if they had mastered the art of making steel, they did not see it providing them an advantage over their neighbors. Especially because iron ores are plentiful, if the Hittites were the source of this new technology, it is strange that they made so little use of it. Furthermore, as the graphs later in this paper show, iron's rise in prominence in the two centuries after the Hittite collapse was slow, suggesting an evolutionary change — not a sudden breakthrough.[15] This argues against Hittite diffusion as the proximate cause of the Iron Age.

A more plausible explanation for the Iron Age is a shortage of bronze. This theory argues that a bronze shortage gripped the eastern Mediterranean in the eleventh and tenth centuries BC.[16] The evidence for this bronze shortage is that existing items of bronze were remelted and reused.[17] Indeed, after 900 BC, when the Greeks were already making wide use of the new technology of steel, bronze suddenly made a comeback for weapons and jewelry.[18]

What caused the bronze shortage? Bronze is usually made of copper and tin. At first glance, a *copper* shortage does not seem a plausible reason. Unlike tin ores, which are quite rare, copper ores are common throughout the

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14 Forbes, *Studies in Ancient Technology*, 9:217.

15 Waldbaum, *From Bronze to Iron*, 67-68; Waldbaum, "The First Archaeological Appearance of Iron," 81-83; O. R. Gurney, *The Hittites*, 2nd ed., (Baltimore: Penguin Books, 1954), 82-84; J. G. Macqueen, *The Hittites and Their Contemporaries in Asia Minor*, (Southampton: Thames & Hudson, 1975), 51; R. J. Forbes, *Studies in Ancient Technology*, 9:253-255; Forbes, *Man the Maker*, 55-56.

From some of the popular accounts of Hittites and iron, the reader envisions a blacksmith running through the streets with a cherry-red iron sword, shouting the Hittite equivalent of "Eureka!"

16 Snodgrass, 348-349; Waldbaum, "The First Archaeological Appearance of Iron," 82-83.

17 Forbes, *Studies in Ancient Technology*, 9:255.

18 Waldbaum, *From Bronze to Iron*, 70-71.

Eastern Mediterranean. But Cyprus was the big producer of copper in the Late Bronze Age, dwarfing all local sources. One can credibly hypothesize that a disruption of the Cypriot copper trade would reduce the supply, and thus dramatically raise the price of *all* Eastern Mediterranean copper, from whatever source.[19] As evidence for this disruption, at roughly the time that Thrako-Phrygians were destroying the Hittite Empire, something or someone seems to have seriously damaged Cyprus'copper exporting capacity:

> [S]everal of the copper working sites... were destroyed between the mid-12th and early 11th centuries and not extensively resettled – the local copper industries presumably being ruined as well.[20]

Cyprus appears to have stopped exporting copper (at least for a while) after 1200 BC – at the traditional opening of the Iron Age.[21] If interruption of Cypriot copper exports caused the Iron Age, one would expect Cyprus to lag behind its copper customers in the transition from bronze to iron because it would not have needed to use iron. But Cyprus entered the Iron Age at the same time as the rest of the Eastern Mediterranean. In addition, in the late thirteenth and twelfth centuries BC, evidence appears that Cyprus was also beginning to recycle bronze. This suggests that tin, not copper, was the limiting factor in producing bronze.[22]

A tin shortage is the more plausible explanation for the bronze shortage. The Hittite Empire was only one of the nations destroyed by the Thrako-Phrygian invaders, or by peoples that they set in motion. All evidence suggests that the tin used in making bronze came from outside the Near East, apparently through (but not *from*) Iran. It would not be a surprise if political

[19] Muhly, 40-45.
[20] Waldbaum, *From Bronze to Iron*, 65.
[21] Waldbaum, *From Bronze to Iron*, 61, 65.
[22] Waldbaum, *From Bronze to Iron*, 72.

disruption destroyed existing tin trade routes and relationships to the detriment of bronze-making.[23]

What statistical evidence exists to tease out the underlying causes of the transition from bronze to iron? At first glance, this would seem like an unpromising direction for a student's paper to take, but Jane Waldbaum's *From Bronze To Iron* provides enough data to engage in meaningful analysis. For each region of the Eastern Mediterranean, Waldbaum tabulated twelfth through tenth century BC artifactual finds by metal, category, and by century.

The criticism may be validly raised that the regions Waldbaum tabulated do not correspond precisely to identifiable nations — for example, Anatolia includes a number of different cultures. But because the goal of this paper is to look for evidence as to whether the transition reflected regional or local changes, this combining of cultural units is not necessarily a serious handicap.

Bronze and ferrous metals are almost exclusively the metals for the "weapons and armor" category. The same is true for tools. Because the goal is to understand the bronze to ferrous transition, this paper will examine only these metals, and only these two categories in Waldbaum's data. The analytic method employed will be to examine what percentage of artifacts in these two categories are bronze, and what percentage are ferrous metals,[24] and how these percentages change over the course of the three centuries that mark the beginning of the Iron Age.

[23] Waldbaum, "The First Archaeological Appearance of Iron," 82-83; Muhly, 30-38.
[24] Unfortunately, Waldbaum was unable to obtain enough information to provide any more detailed breakdown of the ferrous metals based on carbon content.

Cliometric analysis, like any other form of historical analysis, is only as meaningful as the data that goes into it. But computer-generated data seems to cause suspension of critical faculties in many people. It is therefore important, before analyzing the data, to understand its limitations.

Not surprisingly, many of the excavated artifacts come from tombs.[25] This creates problems of how meaningful this data is concerning real life artifacts. Grave goods are sometimes less functional than their real world equivalents (as in many Egyptian tomb items of symbolic purpose). Sometimes grave goods are more expensive than their ordinary counterparts, reflecting the high status of the deceased. This may influence the relative ratios of bronze to ferrous metals among the artifacts — and it is difficult to guess which way this may bias the data.

There are also some region-specific problems with this data. There are almost no Egyptian iron artifacts from the twelfth and tenth centuries, and the eleventh century iron artifacts come from a single royal tomb. The recovered Anatolian iron artifacts are so rare that Waldbaum is reluctant to draw any conclusions from a statistical analysis of the data. The Aegean Islands data is excluded from analysis in this paper because so few items in the categories "tools" and "weapons and armor", of either metal, appear.[26] There is no shortage of Syrian artifacts, but here the problem is that the "only North Syrian site with relevant material datable to the 12th to 10th centuries is Hama."[27] For those regions for which enough data is present, however, it provides some intriguing clues about the transition from bronze to ferrous metals.

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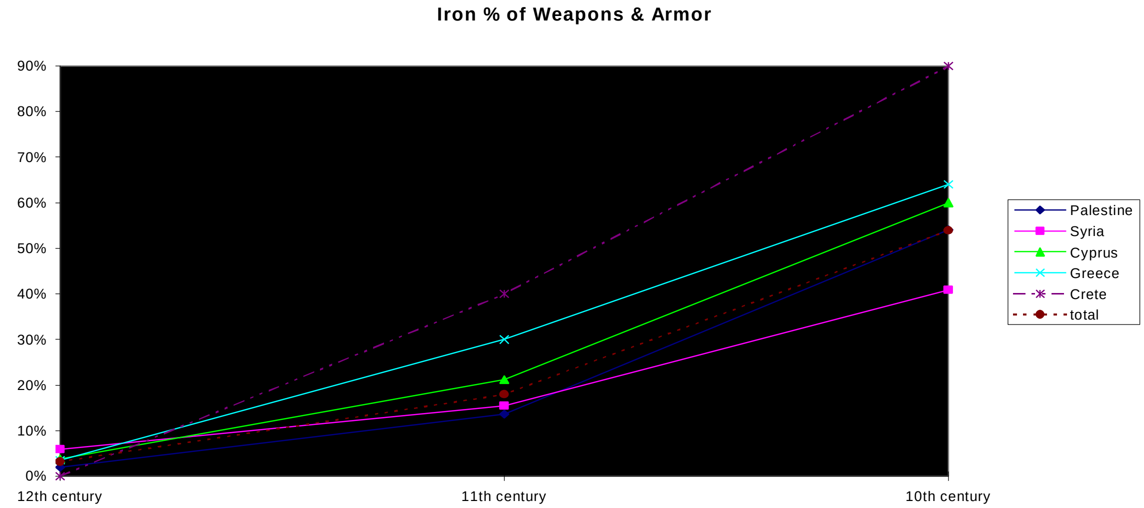
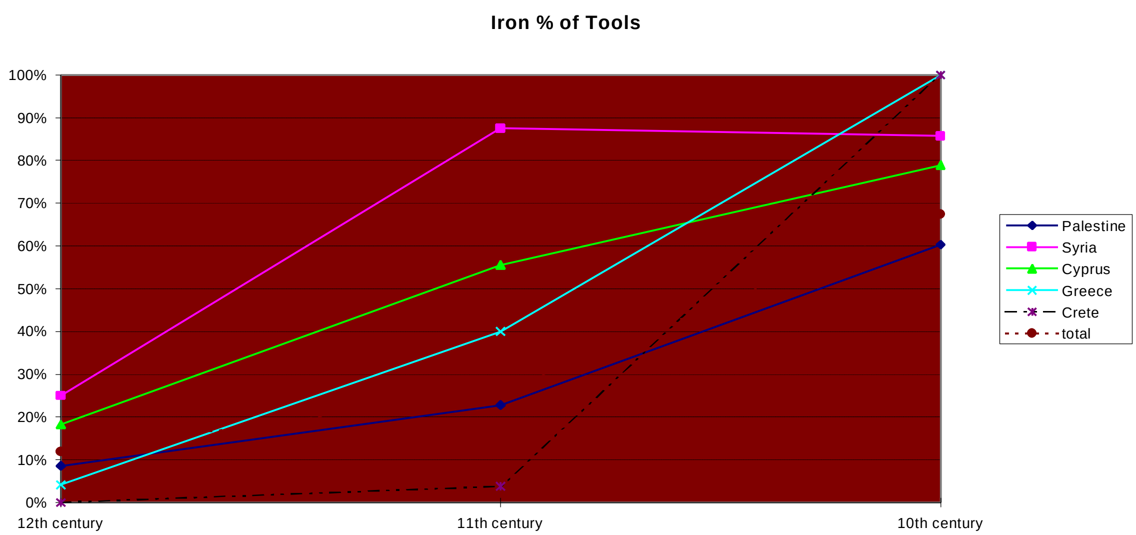
[25] Waldbaum, *From Bronze to Iron*, 41, 49, 56.
[26] Waldbaum, *From Bronze to Iron*, 53, 56.
[27] Waldbaum, *From Bronze to Iron*, 27.

For each of these regions, in spite of cultural, political, and geographical differences, the bronze to ferrous metal ratios in each region change at roughly the same rate:[28]



While some regions switched over to iron more rapidly than others, the slope of the curves is astonishingly similar.

For tools, the rate of change is not quite so strongly correlated:



[28] All data derived from Waldbaum, *For Bronze to Iron*, 38-58.

Nonetheless, there are strong similarities in how Greece, Palestine, and Crete changed from bronze to iron in the use of tools. (Syria's early lead in the use of iron for tools might be nothing more than a statistical quirk caused by the limited source of Syrian artifacts, especially because no similar Syrian lead in iron armor and weapons is apparent from this data.)

It is also apparent that ferrous metals displaced bronze in tools before weapons and armor. A tool that loses its edge or bends prematurely is a nuisance; a sword that loses its edge in battle puts a warrior's life at risk. This tends to confirm the theory that iron was originally a second-best alternative to bronze, until the accidental discovery of carburization.

If the switch from bronze to iron was the result of a localized discovery or cultural change, one would expect this change to appear first in one society, followed by the others. Yet the most dramatic leader is the Syrian use of iron for tools — and even this lead over the other Eastern Mediterranean societies (except for Crete) is for no more than a century. For iron armor and weapons, the clear leader is Crete — the laggard society for iron tools.

Not only are the *percentages* of iron utilization very similar, but how rapidly each of these societies switched from bronze to iron is quite similar. This suggests similar constraints on each society encouraging the transition, which implies a regional cause for the Iron Age. This conforms to the bronze shortage theory discussed on page 6.

Whether the underlying cause was a tin shortage, or a copper shortage, it is easy to understand why Eastern Mediterranean societies first turned to iron as a cheaper, less effective alternative to bronze. After the discovery of carburization and quenching, steel was both cheaper *and* more effective than bronze.

Other societies, however, did not embrace iron for utilitarian purposes for centuries after the technology arrived. Egypt, for example, did not move to the widespread utilitarian stage of iron for more than 400 years after the rest of the Eastern Mediterranean. Some have argued that the reasons are purely cultural in nature:

> Till then the innovation did not satisfy a *socially approved* need of Egyptian culture; long-established economic and political institutions offered a quite unconscious resistance to the use of cheap iron.[29]

But if a lack of social approval is the reason for the late use of iron as a utilitarian metal in Egypt, how does one explain isolated examples of utilitarian smelted iron during the Bronze Age? Perhaps a better explanation for the late large scale smelting of iron in Egypt is that the bronze shortages that afflicted the nations of the Eastern Mediterranean did not affect Egypt.

Egypt had its own sources of copper ore in the Sinai, but still bought heavily from Cyprus. While tin ore deposits are now mined in the Eastern Desert of Egypt, "it is doubtful whether these deposits were known or worked in antiquity."[30] Nonetheless, because of Egypt's much more southerly location relative to the other Eastern Mediterranean nations, the tin exports from Iran to the Eastern Mediterranean disrupted by invasion around 1200 BC might have continued to Egypt without interference. With adequate supplies of bronze, Egypt would have had much less reason to experiment with the inferior metal iron — and thus, less opportunity to discover steel.

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[29] V. Gordon Childe, *Social Evolution*, (Cleveland, Ohio: World Publishing, 1963), 169. While this opinion is widely held, Walther Wolf, *Die Bewaffnung Des Altägyptischen Heeres*, (Leipzig: J.C. Hinrichs'sche Buchhandlung, 1926; reprinted Leipzig: Zentralantiquariat, 1978), 44-45, points to a 12th dynasty spearpoint as the oldest example of the utilization of iron as a commodity item. However, the spearpoint in question was in a grave, so whether it represents a "commodity item" or a funerary good is certainly arguable. Wolf, 63, also asserts that 19th dynasty Egypt (ca. 1303-1200 BC) starts the development of iron swords.

[30] Waldbaum, *From Bronze to Iron*, 65.

In seeking explanations for technological change, it is tempting to see such change as the logical expression of chance discovery. Perhaps this is a seductive idea to twentieth century people because so many of the significant discoveries of modern times were lucky accidents: penicillin, nitroglycerin, and X-rays, to name a few. But modern Western society encourages and rewards innovation, and most people regard innovation as a generally positive influence on their lives. Modern Western society accepts that the only constant is change. It is no surprise that twentieth century man assumed, until recently, that a chance technological discovery was the proximate cause of the Iron Age.

Throughout most of human history, societies have changed very slowly, regarding change with suspicion. Such societies would have taken the dramatic change from bronze to iron only under the most pressing need. From the available evidence, this pressing need was a critical bronze shortage. A sudden disruption of the political structures that made possible long-range trade in tin apparently induced this shortage.

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