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THE ARCHAEOMETALLURGY OF THE ASIAN OLD WORLD

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Editor

Waldbaum

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The Coming of Iron in the Eastern Mediterranean

Thirty Years of Archaeological and Technological Research

Jane C. Waldbaum

ABSTRACT Until the mid 1960s, theories on the advent of iron in the eastern Mediterranean were based on a number of largely unexamined assumptions, all predicated on the belief that iron was inherently superior to and more desirable than bronze as a utilitarian and military material. This article will review some of the major archaeological and technological research of the past three decades on the early production and use of iron and will show how this new research has affected our thinking on these previously held assumptions. It will examine some of the newer hypotheses currently being explored, and then point out some of the major unanswered questions that remain. [Final ms. received 8/96.]

Until the mid 1960s, thinking on the advent of iron was based on a number of largely unexamined assumptions, all predicated on the belief that iron was inherently superior to and more desirable than bronze as a utilitarian and military material: (1) that the beginning of the "Iron Age," when iron was introduced on a fairly wide scale, represented technological "progress" through the substitution of a "superior" material (iron) for an "inferior" one (bronze); (2) that the earliest iron used was meteoritic in origin; (3) that the earliest production of smelted iron took place under closely guarded "monopolistic" conditions, such as the supposed control by the Hittites of Anatolia over the supply of iron in the Bronze Age Mediterranean; (4) that iron only became more widely available when this monopoly was broken; and (5) that iron was disseminated into certain areas by invaders provided with the new, improved material—e.g., invaders from the north or "Dorians" in Greece, and invaders from the west or Philistines in Palestine.

Over the past thirty years or so, interest in the problem of iron and the reasons for its introduction to and spread through the eastern Mediterranean has been steadily growing. A number of studies have addressed themselves to the older assumptions, often drastically revising them, and have also advanced new theories and raised important new questions as to the relationships between the introduction of new materials and the cultural conditions that led to their adoption.

These studies have tended to take one of several approaches. The first (primarily archaeological) focuses on the objects: the types, functions, geographic and chronological distribution, and context of iron artifacts are documented and often compared to their counterparts in bronze. This has yielded valuable information on the appearance and uses of iron and on when, where, and for what purposes it began to replace bronze (see, e.g., Waldbaum 1978, 1980, 1982; Snodgrass 1980, 1982; McNutt 1990).

Perhaps ancillary to the archaeological approach is the philological, that is, the analysis of ancient texts referring to iron and other metals with a view to illuminating such matters as the relative values, uses, and systems of exchange of metals, which cannot always be determined by study of the objects alone. The relationship between the literary and the archaeological sources, however, while sometimes complementary, is often ambiguous and sometimes contradictory (e.g., Košak 1982, 1986; Limet 1984, 1986; Maxwell-Hyslop 1972, 1980; Heltzer 1977, 1978; Bjorkman 1973; Fensham 1969; Vaiman 1982; Zaccagnini 1990).

A third major avenue of research is technological. Through chemical and metallographic analysis of metal artifacts their relative effectiveness can be assessed, the introduction of new technologies can be observed, and patterns of application of these new technologies over time and geographic range can be documented. In the eastern Mediterranean, these studies often have been hampered by the lack of material available for destructive analysis and by the poor state of preservation of the remains. With few exceptions, researchers have not been able to sample large bodies of objects, nor indeed, to obtain material from all relevant areas. Nevertheless, analytical research, in particular that done by

R. Maddin, J. Muhly, T. Stech, V. Pigott, and others, has begun to elucidate some of the problems involved, at least in Cyprus (Maddin 1982; Stech et al. 1985; Åström et al. 1986), Palestine (Notis, Pigott, et al. 1986; Notis, McGovern, et al. 1986; Stech-Wheeler et al. 1981; Muhly et al. 1990), and to some extent, Hittite Asia Minor (Muhly et al. 1985). In addition, technological expeditions have also been mounted in the field to explore the distribution and availability of ore sources, fuels, and other ecological factors relevant to the production of metals, while examination of ancient mining operations and metalworking installations presents a clearer picture of available resources and production capabilities (e.g., Rothenberg 1988, 1990 and papers by Constantinou, Weisgerber, Koucky and Steinberg, Bachmann, Rothenberg, in Muhly et al. 1982). While this area of investigation is currently providing some of the most fruitful results, its application to early metallurgy in the eastern Mediterranean is still in its early stages and there are many questions left to be answered.

This article will review some of the major research on iron over the past three decades, show how this has affected our thinking on previous assumptions, examine briefly some of the newer hypotheses currently being explored, and then point out some of the major unanswered questions.

"SUPERIORITY" OF IRON TO BRONZE

One of the first developments to have a major impact on thinking about early iron was the demonstration, in literature accessible to non-scientists, that wrought iron, the most common product of direct iron smelting and forging, is not superior to hardened bronze until it has been steeled (carburized) and heat-treated (quenched and tempered) (Smith 1967: 40, fig. 39) or at least coldworked by hammering (Rehder 1992:44). Thus, the mere ability to smelt and forge iron did not by itself confer a strategic military edge over opponents possessing bronze alone until techniques of steeling had been mastered and consistently applied. This fact, while long known to metallurgists, was not until recently generally understood by archaeologists and historians, leading to a number of serious misconceptions in the earlier literature on the subject. The technological inferiority of early wrought iron is now generally accepted (see, e.g., Waldbaum 1978:68–69; 1980:87–88; Snodgrass 1980:337–338; McNutt 1990:113–114 and articles by Hartmann and Champion in Stig Sorensen and Thomas 1989), and has generated new theories for the adoption of iron as well as stimulating scientific research on the introduction of steeling techniques.

IRON IN THE BRONZE AGE: METEORITIC AND SMELTED

It has been shown that both meteoritic and smelted iron artifacts were known and used in most regions of the eastern Mediterranean during all of the Bronze Age and even before (Fig. 2.1). Iron appears sporadically over a wide span of time and space, ranging from a few specimens in fifth and fourth millennium contexts in northern Mesopotamia, Iran, and Egypt; to somewhat more from third millennium or Early Bronze Age (EBA) sites in Mesopotamia, Egypt, and Anatolia; to a few from the Middle Bronze Age (MBA; ca. 2000–1600 B.C.) in Egypt, Anatolia, Cyprus, and Crete; and considerably more from a wider variety of sites in the Late Bronze Age (LBA; ca. 1600–1200 B.C.) in Egypt, Anatolia, Syria, Palestine, Cyprus, Greece, Crete, and the Aegean Islands (Waldbaum 1980:79, table 3.4).[1]

By 1980, the total number of iron objects reported from Bronze Age contexts amounted to somewhat over 100, to which may be added another 50 or so that have come to my attention since then (see Appendix A). With the exception of a possible MBA tool blade from Pella in Jordan (App. A, no. 1), a "nail" from Middle Helladic (MH) Asine in Greece (App. A, no. 18), decorative studs on a box from Acemhöyük (App. A, no. 34), a blade from LB Beşiktepe in northwestern Turkey (App. A, no. 33), pieces of slag from LB Kāmid el-Lōz in Lebanon (App. A, no. 15) and Late Helladic (LH) III Tiryns in Greece (App. A, no. 26), and some small "tubes," "rods," and a rivet from Timna (App. A, nos. 7, 8, 12), all the recent additions to the repertoire are either jewelry pieces or fragments that cannot be identified.

In addition to the newly identified examples of early iron, several pieces, earlier said to be iron, have been shown not to be on recent examination. These include an LH laminated ring from Dendra in Greece (Varoufakis 1982:315), a so-called iron meteorite from Hagia Triada in Crete (Varoufakis 1982:317), and three LBA (Hittite period) artifacts from Alaca Hüyük in Turkey—a nail, a needle, and a bracelet (Muhly et al. 1985:71).

Even as late as 1980 little technological research had been carried out on this material, in part because its poor state of preservation precluded meaningful analysis, but also because of the difficulty in obtaining permission to sample these rare objects. Some of these early iron artifacts were analyzed for nickel under the assumption that significant nickel content indicated meteoritic origin. By this criterion, objects from fifth millennium Iran (Sialk); fourth

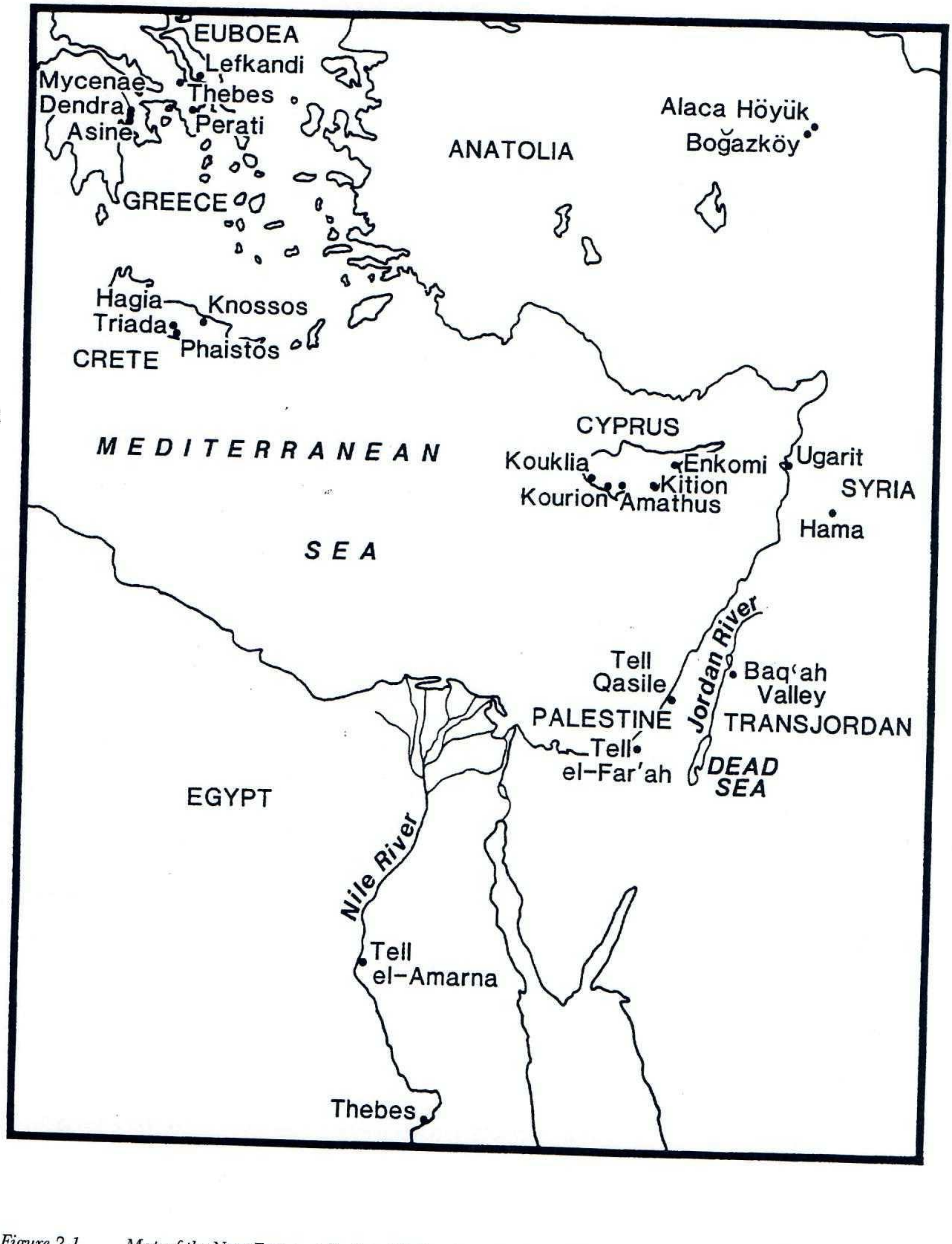

Figure 2.1 *Map of the Near East and Eastern Mediterranean showing some Bronze Age and Early Iron Age sites at which iron has been found. (Prepared by the University of Wisconsin-Milwaukee Cartographic Services.)*

millennium Egypt (Gerzeh); third millennium Mesopotamia (Uruk, Ur), Anatolia (Alaca Hüyük), and Egypt (Dier el-Bahari); and second millennium Syria (Ugarit) and the Tomb of Tut-ankh-amen in Egypt were deemed to be of meteoritic origin (Waldbaum 1980:72–79). Few of these were also analyzed metallographically to reveal the structure characteristic of meteoritic iron. More recently, Varoufakis has examined several of the iron objects from Bronze Age Greece. Although he was not able to perform metallographic analyses, he did take samples for atomic absorption analyses (Varoufakis 1981, 1982). Of the eight rings he examined, ranging from the fifteenth to the thirteenth century B.C. in date, seven contained nickel in quantities from 1.48 to 10.77%; two also contained cobalt (ring bezel from Kakovatos, Pylos, 2.25% Co; ring from Mycenae Tomb 68, 1.29% Co; App. A, no. 22), and one, from Dendra, was not iron at all but made of a copper hoop and lead bezel with an original silver layer that had corroded away. He also examined a small plate from LH IIIB Volos, and two knives from twelfth century B.C. (LH IIIC) Perati, and showed that they contained negligible quantities of nickel (Varoufakis 1982:315–316). Finally, a piece of iron wire wrapped around a gold ring from Late Cycladic (LC) IIB Kition (App. A, no. 35) contained only trace quantities of nickel (Karageorghis 1974:89, n. 2).

Although it is usually assumed that early iron artifacts containing nickel in quantities over one percent were made of meteoritic iron (Waldbaum 1980:69), Varoufakis considers whether these artifacts could have been produced by smelting nickel-rich iron ores such as the laterite deposits (which also contain cobalt) found at Atalanti and on Euboea in Greece (Varoufakis 1981:31; 1982:317 and see also Photos 1989). The point has also been raised by Piaskowski (1982), who performed metallographic analyses on a series of nickel-rich iron objects from Iron Age Europe and showed that they had, in fact, been smelted. Piaskowski proposed that such iron was produced by the smelting of "a mixture of an iron ore and a complex iron-nickel-cobalt-arsenic ore, most probably chloanthite" (Piaskowski 1982:242).

There are several objections (or perhaps cautions) to be noted here before we abandon the notion of Bronze Age use of meteoritic iron: first, Hittite, Egyptian, and Mesopotamian literary texts use terms for iron that seem to suggest knowledge of a meteoritic source for the material (Hittite "black iron of heaven"; Egyptian "iron of heaven"; Sumerian "iron from heaven" [Bjorkman 1973:113–114; Limet 1984:191]). Second, nickel-rich iron ores are very difficult to work (Piaskowski 1982:242; Photos 1989:418) and would seem an odd choice for inexperienced smiths. On the other hand, recent evidence does show that Bronze Age ironworkers did not always choose the most appropriate or easily worked ores (Muhly et al. 1985:77). Third, although there are very few analyses to go on, use of nickel-rich iron in the eastern Mediterranean seems to die out after the thirteenth century, at least in Greece (Varoufakis 1982:317). This could mean either that metalworkers were abandoning meteoritic iron as they became more familiar with smelting techniques or that they had learned to choose more easily worked ores with greater consistency. Only metallographic analyses of the known nickel-rich artifacts will resolve the issue.[2]

A number of tested objects from the Bronze Age, however, showed no nickel and hence (presumably) were the product of smelting operations, though whether they resulted from deliberate smelting of iron ores or were byproducts of copper or lead smelting is still unknown.[3] Pickles (1988:4–5) has suggested that early iron artifacts that do not contain nickel were made of native or telluric iron rather than smelted. Native iron is, however, extremely rare, found now primarily on Disco Island, Greenland (Wertime 1980:11) and also does contain some nickel and cobalt (Piaskowski 1982:238). Since it is relatively easy to produce small quantities of iron accidentally through the smelting of copper or lead (Wertime 1980:12–17; Pickles 1988:10; McNutt 1990:111–112), this seems more likely than use of native iron, which in any case should be sought among the objects containing small amounts of nickel and cobalt. Analysis of several hundred Late Bronze Age copper artifacts deposited as votive objects in the Egyptian temple at Timna in the Wadi Arabah of southern Palestine, in fact, showed "substantial quantities of metallic iron in the copper" (Rothenberg 1988:12), while analyzed iron artifacts from the site contained significant amounts of copper (Gale et al. 1990:186). Research at Timna involving experimental copper smelting operations suggests that iron can indeed become incorporated into the copper during smelting, either from iron oxides used as flux or from the ore itself (Craddock 1988:178–179; Gale et al. 1990:183–185). Furthermore, metallic iron could be recovered from iron-rich copper and forged into usable forms (Gale et al. 1990:185). The Timna analytical team concluded that the iron objects found at Timna "had been produced locally as an adventitious byproduct of copper smelting" (Gale et al. 1990:189). They strongly suggest "that iron smelting was first discovered in a copper smelting furnace" (Rothenberg 1988:12).

Examples of early iron containing no nickel came from Samarra (ca. 5000 B.C.); third millennium Mesopotamia (Tell Asmar and Chagar Bazar); Anatolia (Alaca Hüyük) and Egypt (Giza and Abydos); MBA Buhen (Nubia), Lapithos (Cyprus), and Pella (Jordan) (Waldbaum 1980:72–79; Smith et al. 1984 for Pella); and second millennium Palestine (Timna; Gale et al. 1990:186). Since some of the objects of smelted iron came from the same regions (Mesopotamia, Anatolia, Egypt) and even the same sites (Alaca Hüyük) as objects whose iron contained nickel, it does not seem possible to make regional distinctions with regard to available technologies.

Metallographic analyses have been performed on a few specimens of Bronze Age iron. An object identified by the excavator as a small blade or point was found in a MBA tomb at Pella in Jordan (App. A, no. 1). The piece was analyzed and shown to have been a steel containing ca. 0.8% carbon, which had probably been quenched. Not enough of the original outer layers of the object was preserved to determine whether it had also been tempered, nor could it be ascertained whether the steel was produced deliberately or accidentally. Nevertheless, the piece, if properly identified as ancient, would represent the earliest example of steel that has been recognized to date (Smith et al. 1984:234–235).[4] Since this is the only object to have been analyzed metallographically so far for which so early a date has been proposed, it must be viewed in isolation and cannot be used to claim priority in "invention" of steel technology for MBA Palestine. It is, at any rate, a manufactured piece and not meteoritic. Only time, and more analyses on more securely dated pieces, will show whether the object represents a true technological advance or must remain an anomaly.

A few artifacts of Hittite Empire date from Boğazköy and Alaca Hüyük have been sampled and analyzed metallographically (Muhly et al. 1985:76–79). One of these, a nail, was too corroded to yield information; two, a lugged axe and a knife blade, had been carburized, the former probably by accident, the latter by uncertain means; and one, a socketed point, had not been carburized (Muhly et al. 1985:78–79). On the basis of these, admittedly few, samples the analysts concluded that Hittite smiths could not yet fully control their product since they did not consistently carburize functional artifacts to produce steel (Muhly et al. 1985:79–80). For now, these are important as examples of smelted iron.

An iron ring from a Late Bronze Age context at Kāmid el-Lōz (ancient Kumidi) in Lebanon was found to be mildly carburized. It was one of only two finished iron objects from this period at the site. The other, a pin fragment, was too corroded to analyze (Frisch et al. 1985:146–148, and see below, App. A, nos. 13, 14).

A few fragmentary iron objects from Timna were examined metallographically. These included a small rod (Rothenberg 1988:148, no. 21; App. A, no. 8); a gilded earring (Rothenberg 1988:148, no. 22; App A, no. 9); a small tube embedded in a sea shell (Rothenberg 1988:148, no. 23; App. A, no. 7), and a tube with an iron rivet (Rothenberg 1988:168, no. 497; App. A, no. 12). All of these were completely rusted or mineralized and provided no information about the techniques used to work them (Tylecote 1988:186, 190).

Direct evidence for smelting in Bronze Age contexts is rare but not entirely lacking. I have already mentioned a piece of iron-arsenic slag found in a LH IIIB context, possibly a metal workshop, at Tiryns (Kilian 1983:304, 306, fig. 31; App. A, no. 26). To this may be added a fragment of speiss, one of several collected from a domestic context at Boğazköy, and interpreted as probably resulting from the smelting of an ore containing iron, arsenic, and sulfur. Muhly and colleagues point out that smelted iron containing arsenic deriving from such an ore would have been brittle and difficult to forge, perhaps showing that the smelters did not fully understand the nature of the ores they were using and did not always select appropriate ores (Muhly et al. 1985:77).

Speiss was also found in the Late Bronze Age palace workshop area at Kāmid el-Lōz (App. A, no. 15; Hachmann 1986:27 for the workshop), where it was interpreted as a possible byproduct of copper- or lead-working (Frisch et al. 1985:144–146, 158). Also found at Kāmid el-Lōz were lumps of hematite iron ore and the small pieces of finished iron already mentioned (App. A, nos. 13, 14; Frisch et al. 1985:77–78, 95–96, 105–108, 111). While the preponderance of the evidence from the Kāmid el-Lōz workshops was for copper production, and there was no direct evidence for iron smelting or forging, the excavators and analysts believe that some kind of iron metallurgy did take place there, perhaps utilizing the same furnaces as the copper operations and producing little or no slag from the iron-rich hematite ore (Frisch et al. 1985:178–180). Whether or not this hypothesis is valid must await further scientific discussion of the published evidence.

Another iron smelting operation is reported for the thirteenth century level at Tel Yin'am in Palestine (Liebowitz 1981:82–84; 1993; Liebowitz and Folk 1984). The nature of this installation has been called into question (Stech-Wheeler et al. 1981:261; Rothenberg 1983), though more recent investigators are somewhat more accepting of it as an early and somewhat tentative experiment with iron smelting (Muhly et al. 1990:164).

The evidence for Bronze Age iron production thus accumulated is still slim; it does show, however, that smelting took place in at least two different regions in the Late Bronze Age, and possibly in four.

Iron in the Bronze Age remained rare and expensive and, judging from context, its use was confined primarily to ornamental, ritual, and ceremonial functions rather than military or utilitarian ones, even in areas where smelting appears to have been known (Waldbaum 1978:17–23; 1980:69–82). This suggests either that these artifacts were not suitable for utilitarian purposes or that techniques for producing iron in quantities sufficient for such purposes had not yet been mastered.

THE "HITTITE MONOPOLY" ONCE AGAIN

Another area of research has been on the question of the supposed Hittite "monopoly" over the production and distribution of iron in the Late Bronze Age. I have elsewhere stated my objections to this hypothesis, noting the variety of actual iron objects and texts referring to iron objects available outside of Hittite Anatolia, as well as the essentially local nature of many of the artifacts from such places as Greece and Egypt (Waldbaum 1978:21; 1980:81). A number of iron artifacts, including utilitarian ones, have, indeed, been found in Hittite contexts. There are, however, at least a few objects of a functional nature outside of Hittite Anatolia (viz., the MB steel "blade" from Pella, the MH nail from Asine, and a previously recorded tool point from an LH jeweler's workshop in Kadmeian Thebes [Waldbaum 1980:77]). In no area, however, including Hittite Anatolia, does iron begin to approach bronze as the material of choice for artifacts of daily use, nor does it appear that iron was being exploited as a strategic material, an unlikely prospect in any case, until the techniques for consistent production of steel were mastered.

I have demonstrated above that smelted iron had been produced, at least in small quantities, much earlier than the time of the Hittite Empire, and that in the Late Bronze Age, or Hittite Empire Period, there is evidence for smelting not only at Boğazköy, the Hittite capital, but also in Greece and possibly Syria-Palestine. The few analyzed artifacts confirm that the Hittites were able to smelt, but not always to control the quality of finished products.

Hittite texts are often cited as evidence for Hittite expertise in iron production. Košak (1982, 1986) has collected a number of texts that testify to a far greater quantity and variety of artifacts than can be seen in the archaeological record. Some texts also speak of a specialized guild of blacksmiths as distinct from workers in other metals (Košak 1986:126; Zaccagnini 1990:500). Most of these documents are either palace inventories or ritual and festival texts, and Košak concludes that the items mentioned "served ornamental, prestigious and ceremonial purposes" (Košak 1986:134; but see Siegelová 1984:71–168 for a more utilitarian interpretation of the texts). That is, iron artifacts mentioned in the texts, while apparently more abundant, were no different in function from most of those found archaeologically. Texts referring to iron, sometimes in substantial quantities, are known from other Near Eastern kingdoms of the Bronze Age (Waldbaum 1978:17–18; 1980:75–76, 80; Limet 1984, 1986; Zaccagnini 1990: 500), and while these are somewhat fewer than their Hittite counterparts, they seem to reflect a similar attitude towards iron.

In sum, while the Hittites may have made somewhat greater use of iron than their neighbors, nevertheless, like other Bronze Age cultures, they seemed to esteem it more for its prestige value than for its utilitarian effectiveness. Although they could smelt it, it does not seem to have been readily available among the Hittites for routine purposes; nor does it seem to have been guarded as a military secret. In other words, there are no apparent technological, strategic, or economic reasons to postulate a Hittite monopoly on iron in the Late Bronze Age. My earlier skepticism about the existence of a Hittite monopoly still stands, and is supported by the results of both technological and philological investigations.

IRON AFTER CA. 1200 B.C.

I have previously shown that finds of iron artifacts throughout the eastern Mediterranean become gradually more abundant in relation to bronze for utilitarian and military purposes and appear in a greater variety of types as time goes on. Although the rates at which it was substituted for bronze vary somewhat from region to region, by the tenth century B.C. iron could be said to be in "common use" in most of the eastern Mediterranean (Waldbaum 1978:24–58).

In the past fifteen years a number of new sites producing metalwork have been published and the metal artifacts from them have been examined in some detail. This is not the place to catalogue all the individual objects discovered since the mid 1970s. Rather, I will discuss the data from a few significant, recently published sites from Palestine, Cyprus, and Greece, all of which yielded metal objects from the period in question and for all of which the excavators and other scholars responsible for publication provided scientific studies of the metals as well as full archaeological descriptions of quantities, types, and contexts for the objects included. Study of the material from these sites—the Baq'ah burial caves of Transjordan, Palaepaphos-*Skales* in Cyprus, Lefkandi in Euboea, and Nichoria in the southwest Peloponnese—provides much new information on many aspects of the problems involved in dealing with this period. Unfortunately, there is still little evidence for this period from well-documented sites in Egypt, Syria, or Anatolia,[5] nor is there much new to add to the picture for Crete and the Aegean Islands other than Euboea.[6]

TRANSJORDAN: BAQ'AH VALLEY BURIAL CAVE A4

Burial Cave A4 of the Baq'ah Valley in Transjordan, dating to the Iron IA period, twelfth century B.C., contained the remains of at least 233 burials including individuals of all ages and both sexes. Among the finds are some 134 metal objects, of which 98 or 73% are copper-base and ±36 or 27% are iron. All the metal artifacts are jewelry or dress fastenings, including remains of about 21 copper-base anklets or bracelets and 30 iron anklets or bracelets of which 8 are complete; 35 copper-base rings and 6 iron rings of which 3 are complete; 35 copper-base earrings; 5 copper-base toggle pins (Fig. 2.2), and 2 small "metal" squares of indeterminate use. In contrast with earlier Cave B3 at the same site, no weapons or tools were found in either metal (McGovern 1986:258–267, figs. 82–86).[7] The burials in this cave were not wealthy. The amount of metal deposited averages less than one piece per individual and no artifacts in luxury materials such as gold or ivory were found. There were also few signs of foreign contact, making it likely that the metal artifacts found in the cave were of local manufacture (McGovern 1986:338).

Five of the iron anklets or bracelets were analyzed (App. B, no. 27). According to proton-induced x-ray emission spectrometry (PIXE) analysis, none contain nickel and one has a high cobalt level (ca. 0.40%).

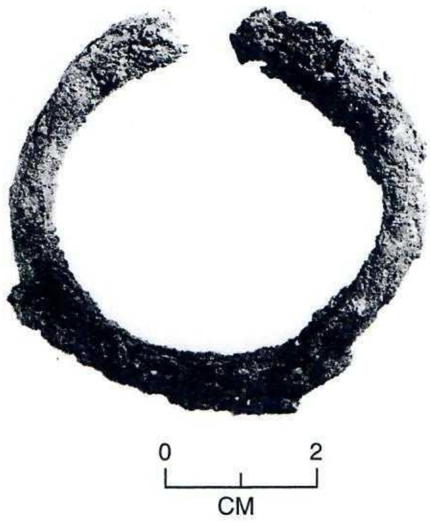

Figure 2.3 *Mild steel anklet or bracelet from Baq'ah Cave A4, no. A4.226; University Museum no. 81-6-55, ca. 1200–1050 B.C. (McGovern 1986:pl. 29b). (Photo courtesy P.E. McGovern.)*

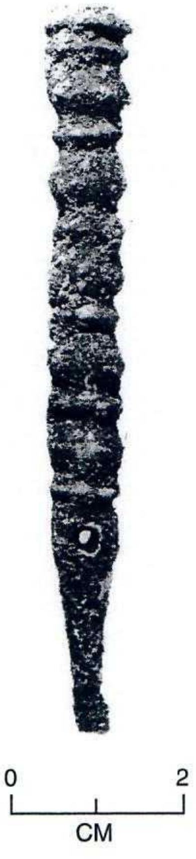

Figure 2.2 *Bronze toggle pin from Baq'ah Cave A4, no. A4.223; Cu 87.3%, Sn 11.1% (Notis, McGovern, et al. 1986:279, 282, pl. 33m). (Photo courtesy P. E. McGovern.)*

Four were found on metallographic examination to be mild steel (Fig. 2.3), although without signs of quenching and tempering (Notis, Pigott, et al. 1986:272–278).

The finds from Cave A4 boost the numbers and proportions of iron in relation to bronze for twelfth century Palestine considerably beyond what has been reported earlier (Waldbaum 1978:27, table III.1, 36, table III.10, 39–42). These figures will be further augmented when the finds from two new sites are published. The first is a similar Early Iron Age burial cave at Pella in the Jordan Valley. This cave was discovered in 1987 and contained the remains of over 100 burials and a "large group of iron artifacts" (number unspecified). According to McGovern (1988:52), "[t]he vast majority of the iron artifacts from the Pella tomb were anklets/bracelets and rings of the same types as those from the Baq'ah tomb." The second is a cave tomb at the site of Khirbet Nisya, about eight miles north of Jerusalem. Although pottery from the tomb was poorly preserved, it appears to date to the Iron I period. Remains of some 50–55 disarticulated individuals were found. The metal finds consisted primarily of jewelry in both bronze and iron: 33 bronze items and 18 iron, including 10 pieces identified as bracelets, 1 ring, and several fragments. One of the iron bracelets was analyzed by the team of Vincent Pigott at MASCA and Michael Notis at Lehigh University, and found to be "very similar" in structure to those in the Baq'ah Valley tomb. (The site of Khirbet Nisya is being excavated under the direction of David Livingston under the auspices of the Associates for Biblical Research. I owe the information given here to Gary Byers [see also Byers 1995].)

The exclusively ornamental object types represented by the iron finds from Baq'ah Cave A4, Pella, and

Khirbet Nisya suggest usage more in keeping with Bronze Age practice than with that of the true Iron Age. The practice of steeling such items as bracelets is curious, since there is no obvious functional advantage in terms of hardness or strength to be gained by so doing. On the other hand, if the steeling were indeed deliberate, it might have been employed to impart desirable color or surface texture to the objects, producing a shinier, "jinglier" bangle than dull wrought iron (Notis, Pigott, et al. 1986:276). Alternatively, the shiny metal may have had an apotropaic function (Stager 1985:10). In any case, precedents for steeling in Palestine may exist in the form of the MBA "blade" from Pella cited above (Smith et al. 1984)[8] and a recently discovered pick from Mt. Adir in the northern Galilee, dated by the excavator to the twelfth century, but probably belonging to the eleventh (Amihai Mazar, pers. comm. 1988; and see Muhly et al. 1990:160).[9] The pick, upon examination, was found to have been carburized, quenched, and tempered (App. B, no. 28).

CYPRUS: PALAEPAPHOS-*SKALES* CEMETERY

At Palaepaphos in southwestern Cyprus a major cemetery, called the *Skales* Cemetery, was found containing some 55 tombs ranging in date from Cypro-Geometric (CG) IA through CG III, with a few as late as Cypro-Archaic and Hellenistic (Karageorghis 1983). Most of the CG tombs are rectangular chamber tombs with dromoi, and most contained multiple inhumation burials, though two were cremations. Of interest to us here are 29 tombs of the CG I and II periods (late eleventh to early ninth centuries). Nineteen of the tombs belonged exclusively to the CG I period: nine CG IA (late eleventh century); three CG IB (early tenth century); and seven CG IA–B or just CG I. In addition, two tombs had mixed material ranging from CG I into II and one contained three burials with pottery of CG I, II, and III types respectively, of which the individual metal finds could not be sorted out (Karageorghis 1983:290) and hence will not be considered here. Eight more tombs belong to the CG II period exclusively; while two span the CG II–III periods and will not be considered here. Several of these tombs exhibited a fair amount of wealth, containing bronzes, quite a bit of gold, iron, and a little silver (Stech et al. 1985:198, table II).

Since much has been made of this site as being somehow advanced in its use of iron both functionally and technologically (see, e.g., Snodgrass 1982:286; Karageorghis 1982:299; Stech et al. 1985:192), it is of some interest to examine the remains from the earliest of the tombs to see whether innovations can be detected. I am leaving aside for the moment consideration of tombs dating CG IB, CG IA–B, and CG I without specification, since the material from these contexts either does or could postdate the eleventh century. It should be noted too, that in preliminary publications there was a tendency to lump all of the *Skales* ironwork in the eleventh century (e.g., Karageorghis 1982:299; Snodgrass 1982:286). The final publication, however, with full description of the tomb contents and discussion of chronology, makes it clear that this was not at all the case (Karageorghis 1983).

All nine of the tombs belonging exclusively to the CG IA period contained some metal.[10] All had objects of bronze; five had iron as well, and eight had gold. Of a total of 79 metal objects belonging to this period, 55, or 69.6%, are bronze; 10, or 12.7%, are iron, and 14, or 17.7%, are gold. These figures are, in fact, quite close to those previously observed for Cyprus in general in the eleventh century (Waldbaum 1978:45, fig. IV.5c). In terms of function, there is 1 iron weapon (a dagger); 4 tools (3 knives and a spindle); 4 ornaments (1 fibula, 3 pins); and an attachment. This compares with 5 bronze weapons (spears); 5 tools (needles); 37 ornaments (fibulae, rings, pins); 6 bowls, a tripod, and a tripod-cauldron. All the gold objects are ornaments. Two of the iron knives, the dagger, and the attachment come from a single tomb (89), which contained the remains of at least five burials and also yielded 2 spears, 6 fibulae, 4 needles and a ring in bronze, 3 gold objects, and a large quantity of pottery (Karageorghis 1983:324).[11] Unfortunately, none of the iron artifacts from this earliest group were among those analyzed (Stech et al. 1985:193–195). The dagger and one-edged knives are not new types in Cyprus since examples of similar artifacts can be found as early as the twelfth and early eleventh centuries at several sites. A number of them have bronze rivets or other fittings, a characteristic which has often been taken as a sign of transition from bronze- to ironworking. Use of bronze fittings such as rivets on otherwise iron artifacts has been shown, however, to continue as a technique long after the period of iron's introduction and is not typologically significant (Waldbaum 1982:327–329 and see pp. 339–341 for list of bimetallic knives, daggers, and other implements from Cyprus).

Much of the rest of the material from *Skales* to be considered here is designated CG IB, CG IA–B, or CG I and is likely to fall in the first half of the tenth century; some, however, comes from two tombs dated CG IIA or CG IB–IIA (late tenth century).[12] Eleven out of twelve of these tombs contained some metal; three had only bronze; one, bronze and iron; one, bronze, iron, and silver; three, bronze, iron, and gold; two, bronze and gold but no iron; and one, only iron (two knives) (Stech et al. 1985:198, table II). There is a total of 103 metal objects of which 72, or 69.9%, are bronze; 20, or 19.4%, are iron; and 11, or 10.7%, are gold or silver (mostly gold). These figures differ somewhat from those published previously for tenth century Cyprus in general (Waldbaum 1978:45, fig. IV.5d), in that there seems to be a somewhat greater proportion of both iron and bronze and a somewhat smaller proportion of gold.

The functions of the artifacts can be categorized by material as follows. In iron there are 3 weapons (2 swords from Tomb 76 and a dagger from Tomb 43), 12 tools (10 knives, an axe, and a sickle), and 5 ornaments (1 fibula, 3 pins, 1 ring). This breakdown compares with 4 bronze weapons (spears), 1 tool (an awl), 43 ornaments (including rings, pins, earrings, but mostly fibulae), and 19 vessels (17 bowls, 2 strainers), plus a "knot," a tripod, and 3 obeloi.

All the gold and the single piece of silver are ornaments. The richest tomb in this group is 76, which contained 14 bronzes, 12 iron artifacts, and 4 gold pieces as well as 170 ceramic vessels for some three burials. Among the iron objects are 2 swords, 6 knives, a sickle, an axe, and 2 pins. The most noteworthy change from the situation in CG IA is the increase in relatively large iron tools as opposed to the insignificance of bronze tools.

A number of the iron artifacts from this group have been analyzed metallographically (see Appendix B). They include 2 knives from Tomb 49 (CG I; App. B, nos. 11, 12), 4 knives from Tomb 76 (CG I; App. B, nos. 15–18), and 2 objects called "awls" by the analysts but identified as pins in the final publication, also from Tomb 76 (App. B, nos. 13, 14; Stech et al. 1985:193–195 and cf. Karageorghis 1983:217, nos. 28a, b). One of the knives from Tomb 49 was found to be mildly carburized, though it could not be determined whether deliberately or not; the other analyzed knife from Tomb 49 showed slight evidence of carburization. One of the knives from Tomb 76 was not carburized; one was mildly carburized; the other two were extensively carburized. One of the two pins ("awls") was mildly carburized and the other was not carburized. None of these artifacts showed evidence of quenching or tempering, though the surfaces are so corroded that evidence for this might have been lost (Stech et al. 1985:196). At any rate, it appears that most of the knives were carburized to a varying extent, suggesting some attempt to manipulate the material to advantage, although full-scale heat treatment does not seem to have been practiced.

GREECE, EUBOEA: LEFKANDI CEMETERIES

At the Greek site of Lefkandi on the large offshore island of Euboea, several cemeteries containing material of the Early Iron Age (SubMycenaean, Protogeometric, and SubProtogeometric) came to light. Burials were for the most part in individual cist or shaft graves. Most were cremations, though a few inhumation burials were found. The wealth of the offerings in individual tombs varied from sparse to quite lavish, with some tombs containing imported materials from the Near East, Cyprus, and Egypt, including gold, faience, ceramic, and bronze vessels in addition to pottery brought in from nearby Attica (Popham et al. 1980; Popham et al. 1982a; Popham et al. 1989, 1993). Although there was a settlement mound nearby, occupation material for these periods is largely missing; however, Late Protogeometric (LPG) pit and leveling debris revealed a considerable quantity of bronze foundry refuse, indicating that casting of sizable objects such as tripods took place here in the later tenth century (Popham et al. 1980:93–97; 1979:pls. 12, 13). The following discussion will focus on the tombs.

There are 44 tombs from the eleventh century: 22 SubMycenaean (SM) or first half of the eleventh century; 12 Early Protogeometric (EPG); and 10 Middle Protogeometric (MPG), excluding the, thus far, unique Heroon (Popham et al. 1982b; Popham et al. 1993). The latter two periods together fall within the second half of the eleventh century. Twenty-six tombs were attributed to the Late Protogeometric (LPG) or tenth century (Popham et al. 1980:418–421; Popham et al. 1982a; Popham et al. 1989). The finds from the Heroon should probably be included in the early part of the tenth century as well.[13]

More than half of the eleventh century tombs contained metal: thirteen of the 22 tombs dated to SM, seven of the twelve EPG tombs, and four of the ten MPG tombs. There were 97 metal artifacts from those tombs, of which 76 (78.4%) are bronze; 16 (16.5%) iron; and 5 (5.1%) gold (Popham et al. 1980:418, table 1).[14]

Breaking this down even further, of those thirteen tombs dated to the SubMycenaean period (early eleventh century), ten contained bronze alone; one, bronze and iron; one, bronze and gold; and one, bronze, gold, and iron. There was a total of 53 metal objects found in the tombs: 45 bronze objects (or 85% of the total), 4 iron (7.5%), and 4 gold (7.5%). All the metal is ornamental in character. The iron artifacts consist of 2 pins, a spiral, and a fragment. In the second half of the eleventh century (EPG and MPG), comparable to CG IA, only three tombs contained bronze alone; five contained bronze and iron; two, iron alone; and one, bronze, iron, and gold. From these tombs comes a total of 44 metal artifacts: 31 bronze (all ornaments); 1 gold (a spiral); and 12 iron (4 fibulae, 6 pins, 1 knife, and 1 dagger, the latter two being the only tools or weapons so far found in eleventh century contexts). In comparative terms, this breakdown by metal type amounts to 70.4% bronze, 27.3% iron, and 2.3% gold. It is interesting to note that the *percentage* of iron present in these late eleventh century tombs (27.3%) is more than twice that cited above (12.7%) for the CG IA tombs at *Skales* in Cyprus, though the percentage of gold is much lower. *Skales* and Lefkandi each produced a single iron dagger for the period, and while there is only one knife from Lefkandi and three from *Skales,* this does not seem a significant difference. At both sites iron was still being used for ornamental purposes in this period.

Of the 26 LPG tombs, fifteen are known to have contained metal:[15] four with bronze only, four with iron only, two with iron and bronze, one with iron and gold, one with bronze and gold, two with iron, bronze, and gold, and one with iron, gold, and lead (Popham et al. 1980:419, table 2; Popham et al. 1982a:236–242; Popham et al. 1989). There are more than 78 metal artifacts, including 17 bronze objects, or 21.8%; more than 31 iron, or 39.7%; more than 28 gold, or 35.9%; and 2 lead, or 2.6%.[16] Relative proportions of metals at this one site are quite different from those previously reported for either Greece or the Aegean Islands in the tenth century (Waldbaum 1978:48, fig. IV.7d, 53, fig. IV.11d), showing considerably less bronze and iron and more gold than the former and less bronze and more iron and gold than the latter. It is interesting to note, in any case, that percentages of iron are greater than in contemporary Cyprus.

In terms of function, the gold and lead pieces are all ornamental, although the number of different forms in gold is greater than in earlier periods. Most of the bronzes are also ornamental, although one tomb (T39) contained a curious set of wheels as well as an Egyptian jug and a fibula (Popham et al. 1982a:219, 237, 239–240). There is a considerable shift in the types of iron produced: the more than 9 pins and a fibula are in keeping with earlier usage. There are in addition, however, 2 swords, a dagger, a spear, a spear butt, 10 arrowheads, an axe, a knife, and a needle. In other words, most of the iron from this period consists of tools and weapons.

The same general picture can be seen in the Heroon, a large, apsidal building, dated to the early tenth century, in which had been buried the cremated remains of a male warrior, an inhumed female skeleton (presumably his consort), and a pit containing the skeletons of four horses (Popham et al. 1982b:171–172; Popham et al. 1993). Included with the female burial were 2 gilt coils near the head, a necklace consisting of a gold pendant and 39 gold beads, 2 large sheet gold disks on the breast with a lunate sheet below them, 1 gold and 1 electrum finger ring, and 10 pins—5 bronze, 2 gilt iron with gold caps, 2 iron with bone heads, and 1 fragmentary plain iron. An iron knife with ivory pommel lay near the head (Popham et al. 1993:20–21). The cremation had been placed in a bronze amphora decorated with figurative scenes and stopped at the mouth with a bronze bowl (Catling in Popham et al. 1993:81–96, pls. 18–21). This burial was also accompanied by an iron sword, razor, and spearhead (Popham et al. 1982b:172–173; Popham et al. 1993:19). Remains of 2 iron bits were found with the horse burials and 4 fragments of bronze, 1 of iron, and 2 of lead were found in the fill of the building (Popham et al. 1993:71–72, 76–77, pls. 32, 34). While some of the bronze and gold items are believed to be heirlooms (Snodgrass 1983:82; Catling in Popham et al. 1993:86–87), the sword, razor, spearhead, and knife at least may be added to the general picture of increasing use of iron for utilitarian purposes that is seen in the other tenth century burials.

Unfortunately, although extensive analyses were done on the copper-base objects from Lefkandi (Jones in Popham et al. 1980:447–459), no similar work was done on the iron finds, so we cannot compare the level of technological expertise with that from Cyprus.

GREECE: NICHORIA

A final site that must be looked at is Nichoria in the southwestern Peloponnese. Unlike the other sites discussed, this one provided evidence for stratified occupation rather than burials in the Dark Ages. Unfortunately, however, the site is geographically and culturally somewhat out of the mainstream and the evidence for close dating of the remains for this period is slim (McDonald et al. 1983:3, 318–322) and has been questioned (Snodgrass 1984:152–153; Morris 1989:511–512). The periods we are interested in encompass Dark Age (DA) I, dated ca. 1075–975, and DA II, dated ca. 975–850. Unfortunately again, DA I, of most relevance to us, is least well known, since stratigraphic preservation of remains from this period was poor, and very few finds could therefore be definitely associated with it (McDonald et al. 1983:319). In any event, only 7 bronzes and a single iron artifact could be attributed to DA I: 1 ring, 2 awls or gravers, 2 needles, and 2 statuettes in bronze; and a "nail" in iron. Seventeen bronzes and 3 iron pieces are designated DA I–II, the bronze including a variety of ornaments, small tools, and scrap, the iron 2 knives and a piece of scrap. For DA II, which apparently descends into the ninth century, there are 32 bronze and 11 iron artifacts. Of the bronze, 9 pieces are ornaments, 1 is a weapon, 9 are tools or parts of tools, 3 are vessel rivets, and the rest various "fittings," "trappings," fragments, and scrap. The iron includes 1 pin, an axe, and a blade fragment, a socketed tool, 4 knives, a nail, and 2 pieces of scrap (Catling in McDonald et al. 1983: 274–276, tables 5.1–4, 283–285). Although the absolute quantities are not great, the variety of types in both iron and bronze may well be reasonably representative of what was available in daily use at this small site. While the picture of relative proportions of materials in use may not be wholly accurate, we do, at least, see a definite increase in iron use and iron diversity from DA I to DA II.

As with Lefkandi, extensive series of analyses were performed on the copper-base metals, but not on the iron (Rapp and Aschenbrenner 1978:166–181).

DISCUSSION

Although the material for the new sites in Greece, Cyprus, and Transjordan has been fully and carefully published and adds greatly to our knowledge of the situation in the period of transition from bronze- to iron-using, it still does not provide a fully balanced picture of the development of iron and its changing relationship to bronze in the first three centuries of the Iron Age. For three of the four sites considered here—the Transjordan cave, Palaepaphos-*Skales*, and Lefkandi—the metal finds come only from tombs. Cave A4 in the Baq'ah is—by definition—a burial cave, and the relevant material dates only to the twelfth century B.C.; the material from Palaepaphos-*Skales* is from a cemetery whose life span only begins in the late eleventh century, and continues into later periods. While there is an Iron Age settlement at Lefkandi, stratified habitation levels are lacking between ca. 1100 and the late eighth century, and all the metal artifacts studied come only from the cemeteries, which provide evidence for continuous occupation during that time. Nichoria does have the virtue of being a stratified Early Iron Age site. The site is provincial, however, and may not be entirely typical of developments elsewhere in Greece. Furthermore, the absolute chronology for the period in question is somewhat shaky.

The three cemetery sites, while they provide very useful and interesting material, cannot be considered to provide an accurate picture of the available metal repertoire. Cemetery material is usually rather specialized and selective in what it contains, and virtually never includes a completely representative sampling of available metal types. Burial goods in general tend to be skewed towards valuables—jewelry, valued personal weapons or knives, treasured foreign material such as gold, ivory, amber, or particularly well-made vessels in pottery or metal—but they are conspicuously lacking in such everyday items as tools (other than knives, which may also serve as personal weapons). Furthermore, metal of any kind, being generally more expensive than other materials, tends to be concentrated in tombs, and may appear to be more abundant than it would if more representative, stratified sites were included.[17] This observation is often lost sight of in comparing the material available for study from such areas as Cyprus, where most of the post–twelfth century material is from cemeteries, and that from Palestine in the same period, where there is a greater variety of sites (see Waldbaum 1978:74–78 for range of stratified sites versus cemeteries). In Palestine after the twelfth century, the repertoire of artifact types classified as tools is much broader than in Cyprus, but the apparent proportion of iron tools to those in bronze is lower than in Cyprus (Waldbaum 1978:40, table IV.2, 41, fig. IV.2b, 46, table IV.6, 47, fig. IV.6b). This makes perfect sense since the great majority of iron "tools" in Early Iron Age Cypriot tombs are knives, which often accompany their owners after death. The metal repertoires and relative proportions of bronze to iron in a contemporary Cypriot household and/or farmstead might very well differ considerably.

Another point to consider is that amounts and types of objects in tombs tend to vary with local burial practices and with the nature of the associated community. If local custom dictates against lavish burial, the amount and variety of metal in a given tomb will tend to be low, regardless of the amount of wealth available in the community. Similarly, if the burial ground belongs to a community of farmers, one would not expect graves containing warriors' panoplies. While these observations may seem self-evident, they are often forgotten in the enthusiasm for archaeological "firsts"—and we are often left to compare funerary 'apples and oranges to very little point. At the three tomb sites considered here, for example, we have at Lefkandi a coastal site with individual cremation graves containing, for their time and place, a fair amount of wealth; at Palaepaphos-*Skales*, a community that favors inhumation in multiple graves containing from two to five burials and rather lavish grave goods, and in Baq'ah Cave A4, a single burial cave containing a large number of burials (perhaps those of the whole community or a large kin group) but very little evidence of wealth. We are still very much in need of excavated settlement material, particularly from Iron Age Cyprus, before we can fully understand patterns of metal use and technological innovation.

DISSEMINATION OF IRON: DORIANS AND PHILISTINES?

The pattern of gradual increase in iron in the eastern Mediterranean over a period of several hundred years has been established for some time (Waldbaum 1968, 1978). The question of why this increase took place when it did and where it did is still controversial. Despite the lack of evidence for a Hittite "monopoly" on iron, the idea persists that the dissemination of iron after ca. 1200 B.C. was somehow owing to the breakup of this monopoly upon the collapse of the Hittite empire. Furthermore, iron was and is perceived to have been spread by peoples invading new territories who had somehow acquired the mastery of iron technology en route from their homelands to their new conquests. These include, of course, the Dorians in Greece and the Philistines in Palestine.

The notion of iron-bearing Dorians has long since been laid to rest. Snodgrass has demonstrated convincingly that the supposed northern homeland of the Dorians lagged behind Greece by some three hundred years in the adoption of iron, and that the coming of the Greek Iron Age is thus in no way dependent on technologically "superior" northern invaders (Snodgrass 1965).

The concept of Philistine mastery of iron, and even a Philistine "monopoly" over the material is more difficult to dispel. Despite the arguments that can be mustered against it (e.g., Waldbaum 1978:42; 1980:84–85), the idea still lingers, and it is therefore worth reviewing the evidence pro and con.

The main basis for the "Philistine monopoly" remains the Biblical text (I Samuel 13:19–22) in which the Israelites of the time of Saul (late eleventh century) possess no weapons and are forced to go to the Philistines to have their agricultural tools repaired because "there was no smith to be found in all the land of Israel." This has frequently been interpreted to mean that there were no *black*smiths in Israel, and that the tools and weapons in question must have been of iron, though the passage cited contains no reference to iron nor is the word translated as "smith" modified to indicate the material being worked. A fairly typical example of the reasoning behind this interpretation may be found in an article by Muhly:

> . . . the Biblical passage makes no mention of iron—nor of an ironworking monopoly for that matter. But the Israelites obviously had metal farm implements that needed repairing. On the basis of the surviving artifactual evidence, it is reasonable to assume that, by the end of the 11th century B.C. (the time of the reign of Saul), these farm implements were made of iron. (Muhly 1982:52–53)

And further:

> Iron artifacts from the 11th century are to be found at Israelite as well as Philistine sites, but *all of the weapons*—swords, daggers, spearheads—are found at Philistine sites. (Muhly 1982:52)

In other words, it is first assumed that iron is the preferred material for both tools and weapons by late eleventh century, presumably because of its supposed superiority to bronze (though Muhly and his colleagues elsewhere present evidence that this was not always so in Early Iron Age Palestine [Stech-Wheeler et al. 1981:257–259]); and then asserted that iron weapons are only to be found at Philistine-occupied sites at this time. But is this, in fact, the case?

I have shown elsewhere that the number of different types of tools found in bronze is greater than that for iron in both the twelfth and the eleventh century in Palestine and about the same in the tenth century (Waldbaum 1978:40, table IV.2). In fact, for the eleventh century there are some 14 different tool types in bronze, including such heavy tools as adzes, axe-adzes, plowshares, ox-goads, knives, and chisels, while there are only some eight varieties in iron including axes, chisels, knives, plowshares, and sickles. For weapons and armor, the types available in both bronze and iron in the eleventh century are about the same—swords, daggers, arrow-, lance-, and spearheads, and spear butt—with only armor scale being found in bronze alone. In other words, iron is by no means being used exclusively, or even predominantly for tools or weapons in eleventh century Palestine. As far as distribution goes, while it is true that few (but not no) iron weapons can be found at eleventh century Israelite sites, not many more can be found at Philistine sites (Waldbaum 1978:24–25; McNutt 1990:200–201 and see Muhly et al. 1990:166, 168–169 for an eleventh century iron arrowhead from the Israelite site of Kinneret). Furthermore, most of the weapons at all sites in this period are of bronze, which is by far the predominant material for both tools and weapons in the eleventh century (Waldbaum 1978:41, fig. IV.2a, b). This apparent preference for bronze is supported by analytical evidence showing that iron implements from Philistine sites, in contexts dating from the twelfth century B.C. to as late as the late eighth century B.C., were not regularly carburized (Stech-Wheeler et al. 1981:257–258; Muhly et al. 1990:170 and cf. Muhly 1982:53). While these investigators make every attempt to rationalize a Philistine iron-based technology, and with it a military sway over their enemies the Israelites, even to the point of producing analyses on late and somewhat irrelevant artifacts, several conclusions seem clear: (1) the Philistines do not seem to have been regular producers of steel; (2) bronze remained the metal of preference throughout Palestine in the eleventh century, perhaps because it was still more reliably "superior" to the unsteeled iron that was most commonly produced at the same time; and (3) there is no reason to presume a Philistine monopoly on iron, since its possession would confer no particular advantage on its holders.

The question of whether the Philistines were responsible for the introduction of iron into Palestine in the early twelfth century also deserves some consideration. Several sites with twelfth century Philistine occupation have produced some iron artifacts. These include a knife with ivory ring handle and an amorphous lump from Tell Qasile, Stratum XII (Mazar 1985:6–9, fig. 2.1, photo 3); a similar ivory ring handle with traces of an iron blade was found in the remains of a twelfth century shrine at Tell Miqne-Ekron. (A complete example [Fig. 2.4] and another ivory ring handle without blade came from an eleventh century Philistine temple at Miqne; a fourth, similar, handle was found in a later context [Dothan 1989:199; 1990:31, 33; Dothan and Gitin 1993:1053–1055; 1992:417–419].)[18] In a twelfth century tomb at Azor was found a bracelet, in another at Tell 'Aitun, a ring, and at Tell el-Far'ah (South), bracelets, rings, and a dagger (Waldbaum 1978:24; Dothan 1982:92, table 1; McNutt 1990:199, table 6).

Some of the earliest iron—and even steel—in the region comes from sites with which the Philistines are not associated. In fact, McNutt (1990:198–200) shows that significantly more iron artifacts come from "non-Philistine" twelfth century sites than from sites associated with Philistine settlement.[19] The carburized and quench-hardened pick from Mt. Adir in the Galilee, of twelfth or eleventh century date, is one conspicuous example (Davis et al. 1985); the steel bracelets from Cave A4 in the Baq'ah in Transjordan are another (Notis, Pigott, et al. 1986:262–267, 272–278) and there are also unanalyzed twelfth century iron artifacts from such sites as Madeba and Tell es-Sa'idiyeh in Transjordan (Waldbaum 1978:24; Pritchard 1980:20, 23) and Megiddo in the north (Waldbaum 1978:24) where there is little or no significant contact with the Philistines (see also Dothan 1982:92, table 1 for other

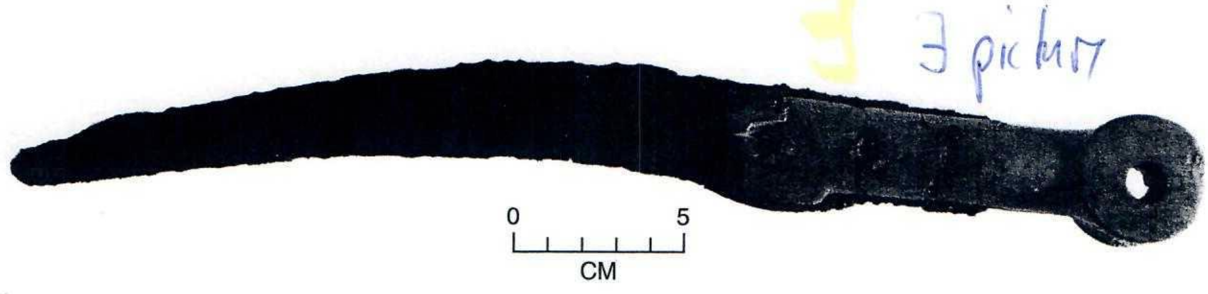

Figure 2.4 *Iron knife with ivory ring-shaped handle and bronze rivets from Tel Miqne-Ekron, Stratum V, eleventh century B.C. (Dothan 1989:154–163, figs. 2, 3). (Photo courtesy Tel Miqne-Ekron Excavations; photo by Ilan Stzulman.)*

sites). While the general atmosphere of the upheavals associated with the "Sea Peoples," and movements of peoples from the Aegean in the wake of these disturbances, may have in some way contributed to the initial spread of iron production in Palestine, and other parts of the eastern Mediterranean such as Cyprus (cf. Stech-Wheeler et al. 1981:266–267; Snodgrass 1982:293; Mazar 1985:9), these factors do not seem to have contributed significantly to developments east of the Jordan River (Notis, Pigott et al. 1986:277; McGovern 1986:340; McGovern 1987). In any event, it seems unlikely that the Philistines were responsible for the appearance of all early iron, and particularly steel, in Palestine.

WHY THE IRON AGE BEGAN: SOME RECENT HYPOTHESES

The revision of old assumptions and the better understanding of the historical background against which the adoption of iron took place has led to the proposal of new hypotheses to help explain the replacement of bronze by iron.

The first, and until recently, most popular hypothesis suggests that iron began to be exploited out of economic necessity. The political upheavals in the eastern Mediterranean ca. 1200 B.C. caused widespread disruption in trade routes and cut off access to raw materials, especially tin, which was assumed to have traveled long distances to the Mediterranean. The subsequent diminution in the metals trade would have forced the development of the more widely available iron ores (Waldbaum 1968:171–173; 1978:71–73; Snodgrass 1971:237–239; 1989:29). This hypothesis, while attractive for a number of reasons, is now being questioned in the light of new evidence.

In the first place, sources of tin have been identified in the Central Taurus mountain region of southeastern Turkey (Yener 1986a:183; 1986b:472; Yener and Özbal 1987; Willies 1990; Yener et al. 1991:546, 548). Thus far, there is evidence for exploitation of tin in this region only in the Early Bronze Age (third millennium B.C.) at the mining and smelting sites of Kestel and Göltepe (Yener et al. 1989; Willies 1990; Yener and Vandiver 1993a, b). However, the location of tin within the eastern Mediterranean, where it had not previously been recognized, raises the possibility, at least, of easier access to tin in the Bronze Age than had hitherto been believed.[20]

Even if tin did exist in usable form in the eastern Mediterranean, however, it need not necessarily have continued to be available during the period of political dislocation that ushered in the Iron Age. It remains possible that supplies were diminished by a disruption in trade, even if that trade were somewhat more local than has previously been assumed. There is, however, a growing body of evidence suggesting that tin continued to be available throughout the period in question. Recent analyses of bronze objects dating to the twelfth century B.C. and thereafter, from sites as widely scattered as Lefkandi in Euboea (Jones in Popham et al. 1980:447–459), Nichoria in southwestern Greece (Rapp and Aschenbrenner 1978:167–175), Kouklia in Cyprus (Pickles 1988:15–19), the Baq'ah Valley in Transjordan (Notis, McGovern, et al. 1986:278–283), Lachish (David Ussishkin, pers. comm. 1987), Tell Qasile (Mazar 1985:3), Beth Shan (Bonn et al. 1993), and elsewhere (Muhly et al. 1990:161) have shown no diminution of tin contents.[21] In fact, most of the bronzes tested from these sites contain tin well within normal range, and some even showed abnormally high tin contents, with average percentages of tin greater than those for the preceding Late Bronze Age at the same sites (Fig. 2.5, and cf. Fig. 2.2) (see Waldbaum 1989 for detailed discussion). While we still do not have enough analytical data from a large number of sites to be able to say with confidence that there was no tin shortage in the eastern Mediterranean generally, the evidence is beginning to accumulate in favor of this view. Other explanations must be sought to account for the increasing exploitation of iron after ca. 1200 B.C.

A second hypothesis, based on technological evidence, suggests that the discovery and consistent ap-

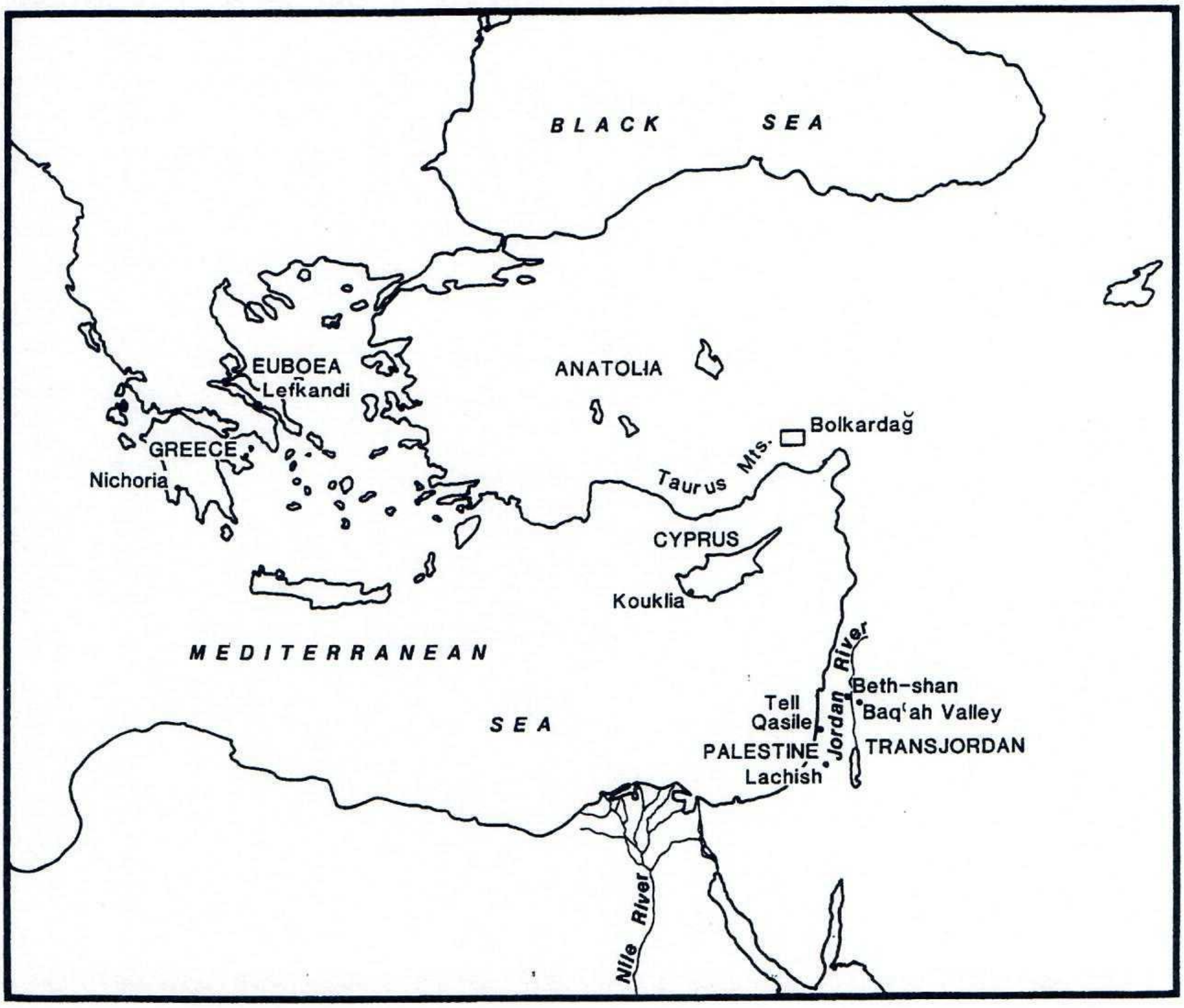

Figure 2.5 *Map of the Eastern Mediterranean showing Early Iron Age sites at which normal or high-tin bronzes have been found. (Prepared by the University of Wisconsin-Milwaukee Cartographic Services.)*

plication of the proper techniques for hardening iron took place in Cyprus. Iron was first adopted as a viable utilitarian material there and ultimately spread to the rest of the eastern Mediterranean (Maddin 1982:311; Pickles 1988:24). A proper consideration of this theory depends, of course, on analyses of iron artifacts to see, if possible, where steeling was practiced, when it was practiced, and what it was used for. If we are to isolate a single area as a possible originator of a new technology it is also necessary to compare data from all the areas in question and to ensure that the artifacts subjected to analysis can be well dated so that reliable comparisons may be made.

Unfortunately, the principal criterion cannot as yet be met. While several programs of analyses have been undertaken in recent years, so far, for a variety of reasons, they have been carried out only on material from Palestine and Cyprus. Analogous material from the Aegean, in particular, as well as from Anatolia and Syria in the critical transitional years from ca. 1200 to 900 B.C. has not been studied and cannot be added to the equation. It is possible to compare the situations in Palestine and Cyprus to some extent, bearing in mind that most of the Cypriot examples are from funerary contexts while most of the Palestinian ones are from stratified occupation remains.

CYPRUS

Metallographic analyses of several iron artifacts from Palaepaphos-*Skales* Tombs 49 and 76, dating to CG I (from the late eleventh into the tenth century), have been discussed above. Of these, about half, including four out of six knives tested, showed signs of carburization, although it was not clear in every case whether this had been accomplished deliberately or accidentally (Stech et al. 1985:193–196).

The analyses of the *Skales* iron can also be compared to analyses of material from several other sites in Cyprus. The earliest are two twelfth century objects from Hala Sultan Tekke—a knife handle and remnants of wire from a potsherd, neither of which showed signs of deliberate carburization (App. B, nos. 1, 2). Since neither item need have been steeled to function it is not possible to know whether the absence of carburization is deliberate or a function of early date (Åström et al. 1986:37). Artifacts from the Swedish excavations at Idalion, Lapithos, and Amathus as well as from Karageorghis' excavation at Kition have been examined (Åström et al. 1986; Maddin 1982; Maddin et al. forthcoming). Interestingly, the earliest artifacts, two knives and a dagger from LC IIIB (early eleventh century) occupation levels at Idalion, showed the most sophisticated treatment (App. B, nos. 3–5). These objects all showed extensive carburization, the two knives had been quenched, and at least one of them had been tempered. The dagger also showed evidence of rapid cooling (Åström et al. 1986:30–31). The results for the knives confirm those for analyses done earlier by Tholander (1971:17–22).

From Lapithos, an obelos from CG IA Tomb 417 (App. B, no. 6) had not been carburized; and a knife from contemporary Tomb 420 (App. B, no. 7) showed moderate carburization but no evidence of quenching or tempering (Åström et al. 1986:33). Several artifacts from CG II (tenth to early ninth century) had all been moderately to extensively carburized with the exception of another obelos. The carburized objects include a sword from Tomb 409 (App. B, no. 23) and four knives, two from Tomb 409 (App. B, nos. 24, 25), and one each from Tombs 411 and 429 (Åström et al. 1986:34). Several of the carburized objects had also been coldworked, but none showed evidence for quenching and/or tempering. Thus, in tenth and ninth century Lapithos there seems to be evidence for fairly consistent use of carburization and coldworking to strengthen objects that could benefit by such practices, though not of the quenching and heat-treating techniques that would impart still greater strength (for the beneficial effects of coldworking, see Rehder 1992). According to the analysts, the two obeloi would not have needed great strength to fulfill their function, so the absence of carburization may well be by choice (Åström et al. 1986:33–34).

Four artifacts from Amathus were also sampled. Two were from CG I contexts: an uncarburized obelos fragment (?) from Tomb 21.1 (App. B, no. 19), and a knife from Tomb 25.4 (App. B, no. 20), which was found to be heavily carburized and coldworked. A CG IIA (tenth century) knife from Tomb 19 (App. B, no. 21) was moderately carburized and possibly tempered; and another knife from CG II Tomb 21.2 (App. B, no. 26), tenth/ninth century in date, was carburized and coldworked (Åström et al. 1986:34–36). The pattern here is very similar to that from Lapithos.

Three artifacts from eleventh/tenth century Kition were sampled, a dagger tip, a knife blade, and an awl (App. B, nos. 8–10). The knife and the awl had been mildly carburized, the dagger moderately to extensively. Again, no evidence was seen for quenching or heat treatment (Maddin et al. forthcoming). It is interesting to note that several samples of iron artifacts from Phoenician contexts at Kition, postdating the three cited above, showed few or no signs of carburization, suggesting a technological change that apparently persisted into the Cypro-Archaic period, at least at Kition (Maddin et al. forthcoming).[22]

The analyses from Idalion, Lapithos, Amathus, and Kition, together with those from the *Skales* Cemetery, seem to show that by the late eleventh and tenth centuries in Cyprus carburization was practiced on a fairly regular basis in producing artifacts such as knives and weapons that could benefit from the additional strength and hardness. Only at Idalion, however, is there as yet any evidence for the use of quenching and tempering. These observations may, of course, be fortuitous, dependent as they are on the preservation of the surface layers of artifacts that are all too often fully corroded. Only future studies on better preserved objects will be able to clarify this problem.

PALESTINE

For Palestine, the picture is similar, though naturally it differs in detail. There is evidence for carburizing in the twelfth century in the bracelets from Cave A4 in the Baq'ah (App. B, no. 27), and perhaps for carburizing, quenching, and tempering in the pick from Mt. Adir in the Galilee (App. B, no. 28), if the early date is accepted. To these may be added a fragmentary and highly corroded knife from Tell Qasile Stratum XII, or late twelfth century, which showed some evidence of carburization, though possibly produced by accident (App. B, no. 29). These examples are roughly contemporary to the two from Hala Sultan Tekke, the earliest analyzed material from Cyprus, but there are so few of them in either case that any conclusions about precedence in steeling technology would be premature.

Only four objects from eleventh century Palestine have been analyzed so far, a knife from Tell el-Far'ah (South), Tomb 562 (App. B, no. 30), an axe from Tell Qiri, probably dating to the late eleventh century, (App. B, no. 31), an arrowhead from Kinneret, Stratum VI (App. B, no. 32), and a knife from Tel Miqne-Ekron, Stratum V (App. B, no. 33). All four of these artifacts had been carburized. The evidence improves with the tenth century. Eleven artifacts from Taanach were examined, including a sword blade, an arrowhead, two plowshares, a sickle or scythe blade, two armor scales, a chisel, two unfinished tools, and a plowshare scraper (App. B, nos. 37–47). Of these, five—the sword, one of the armor scales, one of the plowshares, the arrowhead, and the chisel—had not been carburized, while six—the scythe, the plowshare scraper, the other armor scale, the other plowshare, and the two unfinished tools—had been deliberately carburized (Stech-Wheeler et al. 1981:249–253). It is difficult to explain why, if carburizing was thoroughly understood, one plowshare and armor scale should be carburized and the others not, nor why such objects as a sword or a chisel should not have been carburized. The analysts do suggest that

> [s]words, arrowheads and armor scales need not be carburized to be adequate weapons; the relative effectiveness of iron or bronze weapons and armor is more or less the same and the greater ductility of wrought iron as opposed to steel would speed the mass-production of armor scales; the manufacturing process will proceed more quickly if the time is not taken for carburization. (Stech-Wheeler et al. 1981:254)

Further, they speculate that the highly corroded object identified as a chisel might have had some other function (Stech-Wheeler et al. 1981:255). It is interesting to note, however, that the same scholars point to a carburized and quenched dagger from Idalion as an example of appropriately applied technology:

> It is then reasonable to assume that the dagger was made of quenched steel. There is no surviving evidence of tempering, but a martensitic blade would . . . have been very brittle if not tempered. If, however, the dagger was used as a weapon rather than a tool, hardness may have been preferred to durability, and tempering deemed unnecessary. (Åström et al. 1986:31)

Also from tenth century contexts in Palestine were a knife from Ashdod, dated ca. 1000, and a tool blade and an axe from the late tenth century (App. B, nos. 34–36), none of which had been carburized; and from Tell el-Far'ah (South), two knives from Tomb 220, an arrowhead from Tomb 230, and a dagger from Tomb 240, all dated tenth–ninth century and of which only the dagger showed signs of deliberate carburization (App. B, nos. 51–54). A knife from Stratum V at Kinneret had been carburized and quenched, a sickle from Stratum IV had been carburized, but a spearhead tip from Stratum IV had not been carburized (App. B, nos. 48–50).

The evidence presented from Palestine is somewhat ambiguous. From these rather limited studies it appears that carburization was practiced with rather more regularity in the north than in the south, at least in the tenth century, and possibly earlier if the few samples from the twelfth century prove to be part of a larger pattern. It is curious that sites known to have been dominated by the Philistines in the twelfth and eleventh centuries should produce unsteeled iron in the tenth, although I have shown above that the association of Philistines with ironworking may be more tenuous than previously supposed. At any rate, cultural and/or regional differences may play a larger role in technological accomplishment than we can immediately perceive. This can be seen in Cyprus as well, where, for example at Kition, steel production seems to have been practiced in the eleventh/tenth century, then apparently dies out completely under Phoenician domination of the site (Maddin et al. forthcoming; Muhly et al. 1990:171). In this case, at least, technological "progress" did not advance in a straight chronological line.

It is probably too early to make entirely convincing comparisons between the technological achievements of Palestine and Cyprus. The very few analyzed specimens of twelfth or eleventh century date from each region are not sufficient to claim priority in steelmaking techniques for one or the other. By the end of the eleventh century or tenth century steelmaking seems to have been practiced in both regions, though not universally in either. It would be worth exploring in future whether the apparent regional variations noted above reflect genuine differences in practice.

Also missing, of course, are data from other regions, particularly the Aegean. While this area is generally discounted as an early producer of iron, it is paradoxically also credited as in some way providing a "stimulus" for the adoption of iron metallurgy in other areas such as Cyprus and Palestine (e.g., Stech-Wheeler et al. 1981:266–267; Snodgrass 1982:293). The finds from eleventh and tenth century Lefkandi now indicate a fair amount of iron use (and no "metal shortage"), comparable in many respects to what can be seen in Cyprus in the same period. What we are lacking is technological information, and until this is provided through systematic analyses we must remain in the dark as to the true relation among the Aegean, Cyprus, and Palestine in the age of transition from bronze to iron use.

A third hypothesis to explain the replacement of bronze by iron that has gained some credence is ecological. This hypothesis, proposed by the late Theodore Wertime, suggests that pyrotechnological activities making heavy demands on fuel over a long period, in conjunction with other kinds of human activity such as land clearing and agricultural terracing (Stager 1985:5–9), ultimately led to severe deforestation over much of the Mediterranean. Iron smelting, being significantly more fuel-efficient than copper smelting (Horne 1982:12), became economically more feasible despite technological difficulties and the greater labor intensity involved in producing iron (Wertime 1982, 1983). If it could be shown, therefore, that large parts of the Mediterranean were indeed undergoing heavy deforestation around the end of the Bronze Age and the beginning of the Iron Age, then the gradual switch from bronze to iron across a broad geographical range would be a reasonable response to a pressing ecological challenge.

At present, while there appears to be some evidence for deforestation in Greece and Palestine in the

Bronze Age and Early Iron Age, dated evidence on vegetation and land use patterns in the region for the time in question is sparse and cannot always be correlated with the period of change in metal technology (see Waldbaum 1989 for detailed discussion). Furthermore, the fuel efficiency of iron has recently been questioned (Muhly et al. 1990:162–163). More extensive and precisely dated studies from more regions are needed before we can draw any firm conclusions as to the validity of Wertime's hypothesis.

CONCLUSIONS

At present, there is not sufficient evidence to either support or refute conclusively any one of the hypotheses regarding the start of the Iron Age. Any hypothesis, new or old, has to account for the fact that iron was a known metal and smelting a known technique well back into the Bronze Age, though neither the metal nor the technique seems to have been appreciated for its utilitarian potential for a very long time. We still do not really know why the Iron Age began or whether one or more of the current proposals provides a satisfactory solution to the problem. We also do not know whether the proper technology for producing steel began to be consciously applied in just one area, from which it spread to others, or whether it developed empirically in several regions. Analytical data from Cyprus and Palestine are still insufficient and such studies are totally lacking from the Aegean, Anatolia, and Syria. More investigations must be undertaken on material from a broader geographic and chronological range, and an attempt must be made to include more examples of the earliest iron before this issue can be resolved. The possible role of the "Sea Peoples" and/or Aegean peoples in the spread of iron technology as they moved eastward into Cyprus and Palestine after the collapse of Bronze Age civilization in the eastern Mediterranean must be clarified. Did they already possess knowledge of working iron (in the metallurgical sense)? Did they provide some kind of "stimulus" to native metalworking industries as in Cyprus? Or is their presence in the area at the time iron was becoming more accessible mere coincidence? Again, the Aegean provides the missing link and metallurgical analyses the possible hammer with which to forge the chain of evidence.

New finds and new analytical studies are constantly changing our perception of the situation. The next few decades promise exciting new developments and, one hopes, a clearer understanding of the reasons for the adoption of iron in the eastern Mediterranean. For now it is important to persist in asking the right questions.

NOTES

1. Muhly (1992:697), McNutt (1990:99–101), and others have rightly pointed out the pitfalls of relying on tabulations of iron artifacts to provide an accurate picture of quantities of iron available at any given period. It is certainly true that known quantities of iron (or any other excavated material) change with increased archaeological activity as well as with more and better reporting and publication, and that the rapid corrosion of iron leads to its decline and disappearance from the archaeological record over time. It is also true that its often unattractive and formless appearance leads to underreporting in archaeological publications even when it is discovered (cf. Rothenberg 1982:295). These factors, however, do not change substantially in later periods of antiquity (e.g., after the transition from the Bronze Age to the Iron Age). Furthermore, many of these objections, especially with regard to completeness of publication, also pertain to bronze. Nevertheless, numbers and proportions of discovered and reported iron artifacts, in relation to those for artifacts of bronze, do rise significantly during and after this time of transition. Without any claims to absolute accuracy (which I, at least, never made, cf. Waldbaum 1978:12; 1980:69) it is still possible to make a rough assessment of the relative importance, usage, and distribution of iron with respect to bronze by examining the remains.

2. McGhee (1984:5) notes that certain Arctic peoples used meteoritic iron from a known meteorite fall in northwestern Greenland, providing at least one case in which utilization of meteoritic iron can be historically documented. I owe this reference to my colleague, Alice Kehoe.

3. Iron ores are widespread on the earth's surface and were present in most of the regions under consideration here. See Waldbaum (1978:59–66) for brief discussion of the distribution of mineral resources.

4. It should be noted that the tomb in which this object was found had been badly disturbed in antiquity; the excavator seems fairly confident that the "blade" belongs to the undisturbed area of the tomb, and that its MB date is secure (Smith et al. 1984:236). The possibility that the blade was intrusive, however, should not be entirely discounted (see, e.g., McGovern 1988:52).

5. Muscarella (1988:177) summarizes the evidence for a four-hundred-year gap in archaeological sites from central Anatolia following the destruction of the Hittite Empire (ca. 1200–800 B.C.). It is just this period, of course, that is crucial to the understanding of the spread of iron in post-Hittite Anatolia.

6. The North Cemetery at Knossos promises to produce important information on Early Iron Age metals on

Crete, but the metal finds from this site, which will be published by Snodgrass, have not yet appeared. Morris (1989:509–510) has a brief summary of some of the iron finds, while the contents of some of the tombs are enumerated by Catling (1979:45–49).

7. It should be noted that the quantities of objects in copper and iron listed in McGovern (1986:figs. 82–86) differ slightly from those given in the text (p. 59).

8. On the basis of the new finds of Early Iron Age iron from Pella, McGovern (1988:52) is inclined to view the Pella "blade" as intrusive in an MB context.

9. It should be noted that the archaeological context of the Mt. Adir pick has never been fully published; and until this is done the precise dating of this tool must remain uncertain.

10. The CG IA tombs containing metal are: 44, 51, 58, 61, 68, 78, 84, 85, 89.

11. These figures also speak against the view that Cyprus entered Snodgrass' "stage 3" in the adoption of iron as early as the eleventh century and about 100 years before Palestine (Muhly et al. 1990:172; Snodgrass 1980:344; 1982:290). This stage is defined as the period when "iron predominates over bronze as the working metal, although it . . . usually does not completely displace bronze" (Snodgrass 1980:337). In the eleventh century *Skales* tombs, at least, bronze still predominates over iron in every functional category as well as in absolute numbers. What the figures from Cyprus would look like if we had excavated habitation sites to compare with those from Palestine remains unknown.

12. The tenth century tombs being considered are: 43, 45, 48, 48A, 49, 50, 76, 88, 91, 92 (CG IB, CG IA–B, CG I); 53, 82 (CG IIA or CG IB–IIA).

13. Catling and Lemos (1990:4, 7, 95) assign the pottery from the use phase of the Heroon to MPG but favor an absolute date in the early tenth century.

14. The tombs included in this count are: EPG: S8, S10, S16, S20, S31, S32, S46; MPG: S51, P14, P16, T12B.

15. While Popham et al. (1980) and Popham et al. (1982a) provide catalogues of tomb contents for every tomb included in each publication, Popham et al. (1989) do not, preferring only to describe highlights. Similarly, the date of each tomb in this group is not indicated so that the actual number of tombs that fall within our range may be somewhat larger. The finds from the Heroon will be considered separately. The tombs included here are: T12A, T14, T17, T26, T39, T44, T48, T49, T54, T63; P3, P22, P23, P24, P31.

16. Popham et al. (1989:118) mention simply "gold rings, gilt coils and a group of iron pins" from the MPG/LPG tomb T49 without giving exact numbers. Numbers for bronze should probably be raised somewhat too, since discussion of fibulae on p. 120 implies that more were found than the four described.

17. For an interesting discussion of the effects of selective deposition of metal artifacts in tombs and a new, if not totally convincing proposal for the start of the Iron Age in Greece, see Morris (1989).

18. Although only two of the Miqne knife handles had iron blades or traces of blades preserved, all are being used to assess the amount of iron from the site. It is wise to keep in mind, however, that others of similar shape but with bronze blades are known from elsewhere in Cyprus and Palestine (Waldbaum 1982:332). The complete eleventh century knife is being analyzed by M. Notis and D. Belcher of Lehigh University.

19. Muhly (1992:697) criticizes McNutt's figures, saying that "the figures used by M. do not include any of the iron finds from the old excavations at Tell el-Far'ah (South) or the new excavations at Tel Miqne/Ekron and Ashkelon. Inclusion of such material would dramatically change the statistics." In fact, McNutt's tables 6 and 8 do include iron from Tell el-Far'ah (South) in her consideration of the twelfth and eleventh centuries (McNutt 1990:199, 201). As for Miqne, the fragmentary iron knife with ivory handle from the twelfth century, and the complete knife with similar handle and an iron "ingot," both from an eleventh century temple, are the only certain items of iron to be published from Iron I strata. Two more eleventh century ivory knife handles, with no traces of blade preserved, are assumed to have belonged to iron knives (Dothan 1990:28, 30, 31; 1989:199; Dothan and Gitin 1993:1053–1056). Thus far, the Leon Levy Expedition to Ashkelon, led by Professor Lawrence E. Stager, has not turned up any iron from Iron I Philistine deposits. While the situations at both Miqne and Ashkelon could change with further excavation, the few pieces recovered from Miqne to date are hardly cause for a "dramatic" change in McNutt's statistics. Furthermore, the cultic associations of the Miqne pieces are entirely in keeping with her observations that iron appears more frequently in ritualistic or ceremonial contexts at Philistine sites than at non-Philistine (McNutt 1990:198, 201). McNutt does, however, include an iron tool from Tell Qiri with her twelfth century iron (McNutt 1990:199); it should be taken with the eleventh century material (cf. Maddin et al. 1987:244–245).

20. Publications of the Taurus tin sources have unleashed a firestorm of controversy (see *inter alia* Belli 1991; Hall and Steadman 1991; Muhly et al. 1991; Pernicka et al. 1992; Muhly 1993 arguing against the significance of the Taurus as a tin source and Yener and Goodway 1992; Willies 1992; Yener and Vandiver 1993b in response to the above critiques). At present the weight of the evidence favors the existence of tin mining and processing in the Taurus at the Kestel/Göltepe locale during the Early Bronze Age. Whether this mine, or others in the region, produced sufficient quantities of tin to supply more than local needs, or whether it continued to be productive beyond the EBA, awaits the results of future research by Yener and her colleagues. It is interesting to note as well that there were other limited but significant tin sources elsewhere in the Near East including other areas of Turkey, the Caucasus, the former Yugoslavia, Egypt, and Cyprus in addition to the traditionally suggested sources of Afghanistan, central Europe, Southeast Asia, and Cornwall (Yener and Goodway 1992:80; Yener and Vandiver 1993a:212–213). The whole issue of tin supply and trade is, if anything, more complex now than in the past.

21. A local twelfth–eleventh century B.C. bronze industry whose remains have been found at Tel Dan in the northern Galilee, however, was apparently based primarily on

the remelting of scrap bronze without the addition of tin. Tested artifacts show varying and low amounts of tin, though a few objects had tin contents ranging from about 8 to 11% (Shalev 1993:60, 63–64).

22. It also must be noted that the dates for artifacts given in the manuscript available to me may be revised in the final publication. I owe this information to Tamara Stech (pers. comm. 1988).

APPENDIX A

IRON IN THE BRONZE AGE EASTERN MEDITERRANEAN: ADDENDA TO WALDBAUM 1980

Ref no.	Object	Date of Context	Provenance	Technical data	Publication
			SYRIA-PALESTINE (31 OBJECTS)		
1	blade?	MB	Pella, Jordan, tomb	carburized and quenched	Smith et al. 1984:234–236
2	fragments	LB	Lachish, temple		Ussishkin 1978:20
3	large, amorphous lump	LB	Lachish		David Ussishkin, pers. comm. 1987
4	anklet or bracelet	LB	Baq'ah Valley, Transjordan, Burial Cave B3		McGovern 1986:245, fig. 79.1, pl. 30a
5	"piece"	LB II	Jabal Nuzha, tomb		Dajani 1966:48
6	11 rings	13th c. B.C.	Timna, Hathor Sanctuary		Rothenberg 1988:147–148, figs. 54.1–10, 12, nos. 7–16, 18; and cf. Rothenberg 1982:295
7	2 tubes	13th c. B.C.	Timna, Hathor Sanctuary		Rothenberg 1988:148, figs. 54.11, 17, nos. 17, 23
8	3 rods	13th c. B.C.	Timna, Hathor Sanctuary		Rothenberg 1988:148, figs. 54.13–15, nos. 19–21
9	earring? gilded	13th c. B.C.	Timna, Hathor Sanctuary		Rothenberg 1988:148, fig. 54.16, no. 22
10	2 bracelets	LB 14–12th c. B.C.	Timna, Site 2, Area F		Gale et al. 1990:185
11	wire	13th c. B.C.	Timna, Hathor Sanctuary		Rothenberg 1988:152, fig. 58.24, no. 124
12	rivet	13th c. B.C.	Timna, Hathor Sanctuary		Rothenberg 1988:168, fig. 76.11, no. 497*
13	ring	LB	Kāmid el-Lōz, Lebanon, metalworking area of palace, phase P4a	mildly carburized	Frisch et al. 1985:111, no. 129, 146–148 (analysis), pls. 29.2, 34.6
14	pin fragment	LB	Kāmid el-Lōz, Lebanon, metalworking area of palace, phase P4a		Frisch et al. 1985:111, no. 130, pls. 28.2, 34.5
15	slag, 4 pieces of iron-arsenic speiss	LB	Kāmid el-Lōz, Lebanon, metalworking area of palace, phase P4a1	possibly from copperworking?	Frisch et al. 1985:108, no. 94, 144–146, 158, pl. 34.3–4
16	ring	LB 13th c. B.C.	Tel Nami, tomb		Michal Artzy, pers. comm. 1990
17	arrowhead	under deposit of LB II material	Tel Gezer, Locus 22,020, just outside the city wall		Dever 1993:50**
			GREECE (10 OBJECTS)		
18	nail?	MH	Asine, fill of tomb		Dietz 1980:86
19	ring	LH IIIA/B	Thebes		Varoufakis 1981:25
20	signet ring, bezel covered with gold foil	LH IIIA/B	Mycenae, Tomb 58	2.20% Ni	Athens National Museum 2856; Varoufakis 1982:315, pl. 30.2
21	ring, bezel missing	LH IIIA/B	Mycenae, Tomb 58	4.94% Ni	Athens National Museum 2866; Varoufakis 1981:29; 1982:316, pl. 30.6

APPENDIX A (CONTINUED)

Ref no.	Object	Date of Context	Provenance	Technical data	Publication
			GREECE (CONTINUED)		
22	signet ring with silver bezel, iron hoop	LH IIIA/B	Mycenae, Tomb 68	1.86% Ni, 1.29% Co	Athens National Museum 2986; Varoufakis 1982:315–316, pl. 30.5
23	ring bezel, laminated with lead	LH?	No provenance	0.78% Ni, probably 3.18% Ni originally	Athens National Museum 2347; Varoufakis 1981:29, fig. 2.3
24	ring, laminated with lead	LH?	No provenance	3.28% Ni, probably 10.77% Ni originally	Athens National Museum 2337; Varoufakis 1981:29 OR Athens NM 2377; Varoufakis 1982:316, pl. 30.7
25	ring fragment	LH?	No provenance	0.15% Ni	Athens National Museum, no. unspecified; Varoufakis 1981:29, fig. 2.6
26	slag, iron-arsenic	LH IIIB	Tiryns, workshop?		Kilian 1983:304, 306, fig. 31
27	"piece"	LH IIIB–C	Tiryns, Grave V(D)		Rudolph 1973:40, no. 22, pl. 18.5
			CRETE (3 OBJECTS)		
28	ring, silver and iron	MM II	Archanes, Sanctuary, on hand of a skeleton		Catling 1981:42; Varoufakis 1981:25
29	2 beads	LM IIIA	Archanes, Tholos Tomb A, inside a larnax on chest of burial		Heraklion Museum; Sakellerakis 1970:150, 153, nos. 202–203; Varoufakis 1981:25, fig. 1.3
			ANATOLIA (7 OBJECTS)†		
30	dagger with gold plated hilt	EBA	Alaca Hüyük, Tomb C		Stronach 1957:102, fig. 3.5; Muhly et al. 1985:71
31	ring	Hittite context	Boğazköy, Unterstadt 2, J/20 Haus 19 Raum 1		Boehmer 1979:35, pl. 21, no. 3466
32	3 rings	Hittite (called Phrygian in Boehmer 1972:155–156, pl. 55)	Boğazköy, Unterstadt 1		Boehmer 1979:35, nos. 1628–1630
33	long blade	late 13th/early 12th c. B.C.	Beşiktepe, Troad, found in a pit with transitional Myc IIIB–IIIC wares		Mellink 1984:446
34	studs on an ivory box	"no later than the 18th c. B.C."	Acemhöyük, on a floor of level III		Özgüç 1976:556††
			CYPRUS (1 OBJECT)		
35	wire, wrapped around a gold ring	LC IIB	Kition, Tomb 9		Karageorghis 1974:89
			TOTAL ALL AREAS: 52 OBJECTS		

(Notes appear on next page)

APPENDIX A (CONTINUED)

*This object appears in the catalogue of metal objects as bronze. Metallographic analysis by R. F. Tylecote, however, shows it to be iron (Tylecote 1988:190).

**The thirteenth century date of this deposit, and of the arrowhead, has been called into question (see Finkelstein 1994:278). It should be noted, also, that the article by Waldbaum cited in Dever's note 33 as published in 1991 (Dever 1993:53), and in his bibliography as 1992 (Dever 1993:54) was not at the time published. What Dever saw was, in fact, an earlier manuscript of the present article.

†It has been thought best to omit four objects from Korucutepe, ostensibly dating to the end of the LBA, but quite possibly extending as late as the eleventh century (Van Loon 1978:40; 1980:147–148, 276).

††In addition to iron studs the box was also decorated with bronze studs set in gold and lapis lazuli studs (Özgüç 1976:556).

APPENDIX B

ANALYZED ARTIFACTS FROM CYPRUS AND PALESTINE, CA. 1200–900 B.C.

This appendix does not include all the artifacts from Cyprus and Palestine that have been sampled and analyzed. Only those samples that can be dated by context between the twelfth and tenth centuries B.C., as well as a few for which the dates may descend into the early ninth century, have been included.

Ref no.	Object	Date of Context	Provenance	Technical data	Publication
			CYPRUS		
1	knife handle	12th c. B.C.	Hala Sultan Tekke	not carburized	Blomgren and Tholander 1976:123–126
2	"wire"	12th c. B.C.	Hala Sultan Tekke	not carburized	Åström et al. 1986:37
3	knife blade	LC IIIB	Idalion, no. 106	carburized, quenched, tempered	Tholander 1971:18, 22; Åström et al. 1986:30
4	knife blade	LC IIIB	Idalion, no. 1068	carburized, quenched; no evidence of tempering	Tholander 1971:18, 22; Åström et al. 1986:31
5	dagger	LC IIIB	Idalion, no. 517	carburized and quenched	Åström et al. 1986:31
6	obelos	CG IA	Lapithos, Tomb 417, no. 12a	not carburized	Åström et al. 1986:33
7	knife	CG IA	Lapithos, Tomb 420, no. 46	moderately carburized	Åström et al. 1986:33
8	dagger tip	11th–10th c. B.C.?	Kition, Area II, Room 4, between Floors II and I, no. 569	moderate to extensive carburization	Maddin et al. forthcoming
9	knife blade	11th–10th c. B.C.?	Kition, Area II, Bothros 2, Floor I, no. 829	mildly carburized	Maddin et al. forthcoming
10	awl	11th–10th c. B.C.?	Kition, Area II, Bothros 2, Floor I, no. 1041	mildly carburized	Maddin et al. forthcoming
11	knife blade	CG I	*Skales*, Tomb 49, no. 12	mild carburization, possibly not deliberate	Stech et al. 1985:193
12	knife point	CG I	*Skales*, Tomb 49, uncat.; Larnaca Mus. no. 416/79	very slight carburization	Stech et al. 1985:193
13	pin or awl	CG I	*Skales*, Tomb 76, no. 28a	mild carburization	Stech et al. 1985:195
14	pin or awl	CG I	*Skales*, Tomb 76, no. 28b	not carburized	Stech et al. 1985:195
15	knife edge	CG I	*Skales*, Tomb 76, no. 72	not carburized	Stech et al. 1985:195

APPENDIX B (CONTINUED)

Ref no.	Object	Date of Context	Provenance	Technical data	Publication
			CYPRUS (CONTINUED)		
16	knife end	CG I	*Skales,* Tomb 76, no. 132	mild carburization	Stech et al. 1985:195
17	knife hilt	CG I	*Skales,* Tomb 76, no. 133	carburized	Stech et al. 1985:195
18	knife point	CG I	*Skales,* Tomb 76, no. 134	thoroughly carburized	Stech et al. 1985:195
19	obelos fragment?	CG I	Amathus, Tomb 21.1, no. 46	not carburized	Åström et al. 1986:34
20	knife point	CG I	Amathus, Tomb 25.4, no. 4	heavily carburized and coldworked	Åström et al. 1986:34
21	knife blade tip	CG IIA	Amathus, Tomb 19, no. 31	moderately carburized and possibly tempered	Åström et al. 1986:34–36
22	knife blade	CG II	*Skales,* Tomb 77, no. 27	carburized	Stech et al. 1985:195
23	sword fragment	CG II	Lapithos, Tomb 409, no. 6	mildly carburized and coldworked	Åström et al. 1986:33
24	knife	CG II	Lapithos, Tomb 409, no. 17a	moderately carburized and possibly coldworked	Åström et al. 1986:33
25	knife	CG II	Lapithos, Tomb 409, no. 17b	carburized and coldworked	Åström et al. 1986:33–34
26	knife blade	CG II	Amathus, Tomb 21.2, no. 19	carburized and coldworked	Åström et al. 1986:36
			PALESTINE		
27	bracelets or anklets	Iron IA	Baq'ah Cave A4, nos. 55, 77, 147, 226, 202	carburized	Notis, Pigott, et al. 1986:273–275
28	pick	12th or 11th c. B.C.?	Fortress on Mt. Adir, Galilee, below earliest floor	carburized, quenched, tempered	Davis et al. 1985:41–42
29	knife blade	12th c. B.C.	Tell Qasile, Stratum XII	some carburization but possibly not deliberate	Stech-Wheeler et al. 1981:257
30	knife blade	11th c. B.C.	Tell el-Far'ah (South), Tomb 562	carburized	Stech-Wheeler et al. 1981:258
31	axe	late 11th c. B.C.?	Tel Qiri, Area D	carburized	Maddin et al. 1987:244–245
32	arrowhead	11th c. B.C.	Kinneret, Stratum VI	moderately carburized, estimated carbon content 0.4 %	Muhly et al. 1990:166
33	knife blade	11th c. B.C.	Tel Miqne-Ekron, Building 350, south room, Stratum V	corroded through but some remnant structure preserved; "probably a mild steel"	Michael Notis, pers. comm. 1993
34	knife blade	ca. 1000 B.C.	Ashdod	not carburized	Stech-Wheeler et al. 1981:257–258
35	pick or tool blade	late 10th c. B.C.	Ashdod	not carburized	Stech-Wheeler et al. 1981:257–258
36	axe	late 10th c. B.C.	Ashdod	not carburized	Stech-Wheeler et al. 1981:257–258
37	sword blade fragments	10th c. B.C.	Taanach TT 71	slight carburization, possibly not deliberate	Stech-Wheeler et al. 1981:249–250
38	plowshare	10th c. B.C.	Taanach TT 91	not carburized	Stech-Wheeler et al. 1981:250
39	plowshare	10th c. B.C.	Taanach TT 820	carburized	Stech-Wheeler et al. 1981:253
40	sickle or scythe fragment	10th c. B.C.	Taanach TT 322	carburized	Stech-Wheeler et al. 1981:250
41	plowshare scraper	10th c. B.C.	Taanach TT 387	carburized	Stech-Wheeler et al. 1981:250–251

APPENDIX B (CONTINUED)

Ref no.	Object	Date of Context	Provenance	Technical data	Publication
			PALESTINE (CONTINUED)		
42	armor scale	10th c. B.C.	Taanach TT 408	carburized	Stech-Wheeler et al. 1981:251
43	armor scale	10th c. B.C.	Taanach TT 602	not carburized	Stech-Wheeler et al. 1981:253
44	arrowhead	10th c. B.C.	Taanach TT 409	not carburized	Stech-Wheeler et al. 1981:251–252
45	chisel?	10th c. B.C.	Taanach TT 726	not carburized	Stech-Wheeler et al. 1981:252
46	unfinished tool	10th c. B.C.	Taanach TT 1879	carburized	Stech-Wheeler et al. 1981:252
47	unfinished blade	10th c. B.C.	Taanach TT 1880	carburized	Stech-Wheeler et al. 1981:252–253
48	knife blade	10th c. B.C.	Kinneret, Stratum V	thoroughly carburized and quenched	Muhly et al. 1990:166, 169
49	sickle	10th c. B.C.	Kinneret, Stratum IV	thoroughly carburized with "a well developed Widmenstätten structure"; more than 0.8% C	Muhly et al. 1990:167
50	spearhead tip	10th c. B.C.	Kinneret, Stratum IV	no trace of carburization	Muhly et al. 1990:167
51	knife blade	10th–9th c. B.C.	Tell el-Far'ah (South), Tomb 220	not carburized	Stech-Wheeler et al. 1981:258
52	knife blade	10th–9th c. B.C.	Tell el-Far'ah (South), Tomb 220	not carburized	Stech-Wheeler et al. 1981:258
53	arrowhead	10th–9th c. B.C.	Tell el-Far'ah (South), Tomb 230	not carburized	Stech-Wheeler et al. 1981:258
54	dagger blade	10th–9th c. B.C.	Tell el-Far'ah (South), Tomb 240	carburized	Stech-Wheeler et al. 1981:258

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