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Empire Without A Voice: Phoenician Iron Metallurgy and Imperial Strategy at Carthage

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Phoenician Iron Metallurgy and Imperial Strategy at Carthage

A dissertation submitted in partial satisfaction of the
requirements for the degree Doctor of Philosophy
in Archaeology

by

Brett Sanford Kaufman

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ABSTRACT OF THE DISSERTATION

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Phoenician Iron Metallurgy and Imperial Strategy at Carthage

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Doctor of Philosophy in Archaeology

University of California, Los Angeles, 2014

Professor Aaron A. Burke, Chair

Abstract

The role of iron in the emergence of Iron Age states in North Africa and the Near East has been poorly understood due to a paucity of contemporary, diachronic ferrous archaeometallurgical data. Excavations at Phoenician and Punic Carthage in the 2000s recovered one of the largest and most diverse corpora of Iron Age iron production material culture from North Africa and the Near East, spanning the entire history of Carthage from its Tyrian colonial foundations to its destruction by Rome (historical dates 814-146 BC). Analysis of the materials employing metallography, portable X-ray fluorescence spectroscopy (pXRF), and variable pressure scanning electron microscopy coupled with energy x-ray dispersive spectroscopy (VPSEM-EDS) indicates that Carthaginian smiths were smelting and smithing wrought iron and steel as an exchange good or tribute commodity to Tyre and the Assyrian empire, as well as producing, refining, and consuming tin and arsenical bronzes, leaded bronzes, lead, and cobalt. Archaeological evidence demonstrates a state industry of iron production, including the commissioning, decommissioning, and outsourcing of metallurgical precincts. There is an overwhelming difference exhibited between output capacity at industrial and household production sites. Epigraphic evidence in Punic illustrates the inherent economic and familial affiliations between the Carthaginian state and metalworkers. Ironsmiths, bronze casters, and goldsmiths were privileged engineers of one of the state’s most strategic industries, and were stratified in a hierarchy of technical specialties and ranks. In order to conserve fuel and succeed in properly vitrifying ore or bloom impurities into slag, they recycled industrial byproducts in the form of murex shells from purple dye production as a metallurgical flux and lined the furnaces with quartz-rich heat insulation. Carthage was one colony in the Phoenician commodity procurement network, whose task it was to convert iron blooms into final products. By the time this colony became independent of Tyre ca. 650-550 BC, the smiths of Carthage already had around a century of expertise in the production of iron and steel implements which gave the state a competitive advantage in the strategic arena of ferrous technologies and the formation of empire.

The dissertation of Brett Sanford Kaufman is approved.

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2014

For Perro

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Preface

This dissertation is an attempt to write an evolutionary history of empire formation at Carthage. Emphasis is placed on the 8th to 5th centuries BC, or what can be called in cultural evolutionary terms the colonial and formative phases of the city, as well as the beginning of the imperial phase. The later imperial phase and collapse (4th century to 146 BC) is treated in light of the end of the existence of Carthage as a political entity and also its transition into the enduring Orientalized legacy that it is today. Metals, metallurgical production material culture, and the inscriptions of Carthaginian metalworkers are the primary experimental and epigraphic data used to explain the rise and transformation of this Phoenician and Punic state. It is argued that the metallurgical remains at Bir Massouda (alternately spelled Massaouda or Messaouda) are part of an industrial zone that was organized centrally by the state, the data showing that over 90% of the metal produced was wrought iron and steel. The advent of iron technology is known to be crucial to the understanding of the states and empires that first utilized it, but available data until recently have been sparse and by and large synchronic in nature.

The metallurgical materials were excavated in the 2000s by a joint team from Universiteit Gent and the Institut National du Patrimoine. The artifacts recovered represent one of the largest known corpora of Iron Age iron production material culture, and span the entire lifespan of Carthage. Typologies include tuyères (long hollow ceramic shafts that deliver oxygen or carbon dioxide to the furnace) or other metallurgical (n=54) and glass (n=1) ceramics with slag still attached, loose slag (n=50, 17 subjected to analysis), ferrous and non-ferrous alloys, pigments, and corrosion products (n=20, with 14 copper alloys, one cobalt-copper-iron piece, two iron artifacts, three lead artifacts), flux in the form of murex shells, equipment such as an anvil and bloom or ore grinder, and furnace soils. This corpus is considered one of the largest due to the number of tuyères with slag attached. There are other contemporaneous sites that boast more massive slag heaps (cf. Chiarantini et al. 2009; Crew 1991), or many tuyère fragments (Veldhuijzen and Rehren 2007), but they do not contain the diversity of production material culture or number of metallurgical ceramics with residual slag.

Chapter 1 presents a synthesized view of the role of metals in Tyrian colonial expansion across the Mediterranean. The evidence gathered from across the Mediterranean and into the Atlantic indicates that for around three centuries Tyre demonstrated a protracted and calculated strategy of mineral resource extraction, ferrying the mineral commodities back to the Assyrian world. Chapter 2 offers the archaeological, historical, and scientific context of the Carthaginian materials, including a reconstruction of the Carthaginian constitutional political system from texts and epigraphic data. The transformation of Carthage from a typical colony to an empire is partially characterized by its industrial-level operations of ferrous metallurgy, its strategic location, and insofar as it began to defend the Phoenician colonies from Greek encroachment simultaneous with Nebuchadnezzar's 13 year siege of Tyre (585-573 BC) that created a political and economic vacuum in the Central and Western Mediterranean colonies. Chapter 3 details the excavation and analytical methods employed for the experimental data, including metallography, portable X-ray fluorescence spectroscopy (pXRF), and scanning electron microscopy coupled with energy dispersive X-ray spectroscopy (SEM-EDS). Chapter 4 contains the original experimental results that inform this research. It begins the discussion of the broad diachronic trends that can be explained from the metallurgical metadata. Chapter 5 is a revision of the translations of Punic metallurgical and occupational terms in light of the archaeometallurgical data. It is clear from consulting the archaeological and epigraphic data that a dedicated metallurgical precinct as seen at Bir Massouda must most likely be attributed to state planning.

Chapter 6 frames the results in an evolutionary lens in order to understand the ecological, political, phenomenological, and technological processes of empire formation at the imperial capital. The legacy of Carthage, the prototypical Orientalist regime and anthropomorphized through Hannibal, is one that outlived its political extinction. The Appendixes include microstructural and compositional data for each artifact analyzed, organized by typology and broad chronologies, including photography of specimens.

The fall of the Carthaginian Empire was one of the most meaningful events for the subsequent millennia of Western history. The trajectory of domination that propelled the Roman Republic to conquer the known world had its germination in the destruction of Carthage—a jointly romanticized and vilified empire that came to be seen as the very foil of *romanitas* (Lancel 1998). The Roman ethos that was codified in this victory would later serve as justification, inheritance, and even moral obligation of post-Renaissance European nations to acquire foreign territories (Dietler 2010). Yet the keen place that Carthage has occupied in the scholarship of historians, classicists, and in the imagination of propagandists is inversely proportional to its treatment by anthropologists. This is due to a number of factors:

> 1) *Artificial division.* Cultural historical analysis of the Carthaginian Empire has two main bodies of texts from which to draw, the Hebrew Bible and the Classical Greco-Roman literatures and histories. Both of these distinct research traditions have usually provided invaluable insights and interpretations for over 150 years contributing to our knowledge about the Phoenicians and Carthage. However, the history of scholarship dealing with Carthage has mostly been artificially divided between these two camps, with biblical scholars dealing primarily with the Phoenician expansion into the Central and Western Mediterranean, and classically trained scholars researching the fluorescence and

demise of Carthage. “Artificial” is the only appropriate word to describe this reality, as the formation of a Tyrian state, widespread establishment of colonies across the Mediterranean including Carthage, and the subsequent wild success of this latter colony over all others including the mother city represents an uninterrupted process of shifting political, economic, and military realities within one cultural milieu. The disconnect between “Phoenician” and “Carthaginian” or “Punic” is one that began with the Greek invention of the word “Phoenician,” continued with the Latin term “Punic,” and ultimately became arbitrarily canonized by modern scholarship (for discussions of Phoenician and Punic identity in both epigraphic and archaeological contexts not cited throughout the manuscript, see Schmitz 2012; Stager 2005). For this reason this manuscript is entitled “Phoenician Iron Metallurgy” as opposed to “Phoenician and Punic Iron Metallurgy.” A further impediment on an anthropologically synthetic view of the Phoenician and Punic World is the far-flung realms of Phoenician influence and the subsequent regional character of archaeological research. The goal of this research project is to synthetically bridge the inherently non-disparate fields of Phoenician expansion and Carthaginian empire formation by utilizing recently excavated materials in order to supplement previous interpretations with processes rooted in a perspective of cultural evolution (for some of the more influential arguments, presentations, and popular syntheses of the Phoenician and Punic world not cited throughout this manuscript, see Aubet 2013; Miles 2010; Moscati 1988).

2) *Biblical aversion.* There has been a general aversion in the last few decades to utilize biblical scholarship for anthropological research goals. Whereas many other Ancient Near Eastern texts are utilized in an either more or less critical fashion, historical data

derived from the Hebrew Bible have come to be viewed with the highest skepticism (Dever 2001). Uncritical discarding of historical data from the Bible recently came to be accepted popularly as the new paradigm, and it is incumbent upon critical scholars to foster a shift back to scientifically objective territory that regards all data as fit for analysis, regardless of whether or not it satisfies a given hypothesis. This erasure of data has only served to hamper investigation into human behavior in the Near East. It is scientifically unsound to discard datasets just because previous scholars have misused them, within reason. Intellectualizing departures from common sense such as this are particularly hazardous when trying to connect with the public.

3) *Textual paucity*. Old World archaeology, perhaps especially in the Near East, tends to fixate on textually or epigraphically attested phenomena and peoples, whether from an historical or anthropological point of view. New World archaeologists continue successfully to bridge the gap between ethnographies and archaeology in dealing with cultural evolution and empire formation (see Chapter 6 for New World analogies; Stanish 2003; Marcus and Flannery 1994). However, the case of Carthage is unique in that it is an Old World Empire, written about extensively by ancient sources, but of which no literature or histories of its own survived the Roman destruction of 146 BC. Nearly all that is left of Carthage, from an historical point of view, is propaganda written by its erstwhile enemies or allies. From an epigraphic point of view, all that is left of the Carthaginian voice are several thousand votive or funerary stelae from the child sacrifice precincts (Tophets) or cemeteries in the capital and across North Africa, listing lineages with an occasional nod to professions or titles. The fact that the majority of epigraphic evidence from Carthage (aside from the Urbanistic Inscription, Lancel 1995, 144) are

Tophet stelae ironically further compounds the Greco-Roman perspective of Carthaginian as barbarian, as this precinct of infant sacrifice was and still is the quintessential symbol of the inhumanity with which Carthage came to be affiliated. What remains, without a presumption of apologetics, is a silenced empire that was caricatured in antiquity, and ignored in modernity.

Targeted critiques of individual scholars are avoided. Rather, what is attempted here is a fusion of various intellectual trends that is approached reflexively (Tringham 2003, 107; Hodder 1999). Universal behaviors that can be observed via the study of empire formation and collapse are considered in the contextual light of the Carthaginian primate center using archaeological, epigraphic, metallurgical, and historical data. Comparative mechanics of empire are drawn from the New World (Johnson 1980).

Warmington wrote in 1969 that “there must have been a considerable force of metal workers, in view of the extraordinary production of hundreds of sets of arms per day in the last struggle of Carthage against Rome, but it is difficult to trace their activity in other ways” (Warmington 1969, 136). Excavations by the French in the 1970s and 1980s, and then the Dutch and Tunisians in the 2000s, have allowed for the verification of Warmington’s hypothesis.

The results demonstrate that a centrally organized authority commissioned, decommissioned, and outsourced metallurgical precincts throughout the entire lifespan of Carthage, from colony to capital to collapse (historical dates 814 BC-146 BC). Small-scale production of iron was carried out in households, but this level of intensity was dwarfed by industrial activities organized by the state at Bir Massouda (ca. 650-425 BC) and the Byrsa hill (ca. 500-200 BC). Epigraphic evidence in the Punic language illustrates a ranked hierarchy between smiths in terms of specialties and functions, as well as a clear affiliation between metalworkers and the state. Translations of Punic references to metallurgical activity are revised in light of the archaeometallurgical findings. The archaeological, archaeometallurgical, and epigraphic evidence considered together strongly suggest that metallurgical production at Carthage should be considered a “state industry.” More than 90% of the metal produced was ferrous, with some evidence for the non-ferrous recycling of tin bronze. Experimental results demonstrated the earliest evidence of tin and glass production at Carthage. Carthaginian smiths likely engaged in smelting (extraction of metal from an ore into an intermediate product called a bloom) on a limited scale, but mainly in smithing (further refinement of the bloom into wrought iron or steel metal), and forging (hammering the purified metal into objects) activities, which resulted in the manufacture of both wrought iron and steel. The first evidence of steel at Carthage is also demonstrated by the experimental results.

The vast majority of metallurgical material culture was excavated from contexts that range from 800-400 BC, but the bulk of activity and existence of what can be called a metallurgical precinct dates more precisely to ca. 650-425 BC. This approximately 225 year period is known to fall historically and archaeologically within the formative and nascent imperial phases of the Carthaginian state. The ratios of iron and steel to copper alloy production suggests that the iron output is too high for domestic consumption alone. Iron was likely an export and tribute product destined for Tyre and Assyria, as evidenced through epigraphic references to these practices explored in Chapter 1. It is hypothesized that it also may have been used as a barter item for food with local North African populations, much as it was traded for silver in Iberia (Sanmartí 2009). Some of the iron and steel, along with the small-scale recycling of copper alloys, would have been used to meet the needs of the burgeoning colony. However, of the 20 metal objects recovered over all periods, only four were made of iron, strongly indicating export practices.

It should not be seen as only an accident of discovery that one of the largest known corpora of iron and steel production was excavated at Carthage, as opposed to elsewhere in the Mediterranean. As the colony transitioned to an imperial capital by the mid-6th century BC, expertise in ferrous technology played a part in giving Carthage a competitive advantage over other candidates to assume a leadership role in the Punic world once Tyre's autonomy was removed by the Neo-Babylonians in the early 6th century BC. Carthaginian smiths were able to produce iron and steel by incorporating a recipe of recycling purple dye industrial byproducts in the form of murex shells as a fuel-efficient calcium-rich metallurgical flux. Further fuel efficiency was achieved by lining the furnaces with quartz, allowing a heat-insulating furnace environment (Docter et al. 2003, 60-65). Although the fuel efficient tactical metal of tin was used in high quantities from the 8th-6th centuries BC, the average tin content decreased dramatically in the Late Punic period preceding collapse. This is explained by Rome's ability to limit the flow of supplies to Carthage during the Punic Wars.

Vita/Biographical Sketch

Brett Sanford Kaufman received his BA from Brandeis University, and his MA from UCLA. He has previously published results of his research into the origins of bronze metallurgy in the Ancient Near East in the peer-reviewed journal *Archaeometry*. He has also published an article on colonial identity in the Punic world in the peer-reviewed journal *MAARAV: A Journal for the Study of the Northwest Semitic Languages & Literatures*. His research has been funded by the National Science Foundation's Graduate Research Fellowship Program. Brett is the Founding Co-Director of the Zita Project in the Archaeology, Anthropology, and Ethnography of Southern Tunisia, as well as the Associate Editor of the Cotsen Institute's *Backdirt Annual Review*.

Chapter 1. Between Assur and Gadir: Tyrian Metal Acquisition and Colonial Establishments

The first two Chapters of this research attempt to place Carthaginian metallurgy in the context of Phoenician expansion and Carthaginian state formation. It is crucial to illustrate that although the acquisition of metals was paramount for Tyre in order to maintain its independence under Assyria (for a critique see Aubet 2008; Frankenstein 1979), Phoenician colonies also served other functions such as to procure wood for shipbuilding (Treumann 2009, 1997) and fuel, as well as serving as political refuge. It is therefore useful to propose five major reasons for the establishment of a given Phoenician colony, meaning that colonies fulfilled at least one or more of the following aims: 1) acquisition of mineral resources and other luxury items from the Mediterranean and Africa, 2) creation of friendly ports of call or way stations in order to ferry metal resources back to the Assyrian world in a bid to justify the autonomous economic and political status quo that Tyre enjoyed for centuries, 3) political refuge, as in the case of Carthage (Elissa's flight) or Kition (i.e., Luli's flight, Yon and Childs 1997), or otherwise functioning as a pressure release due to traditional Malthusian demographic concerns (Trigger 1996, 36) as suggested by Aristotle for easing Carthaginian population pressure (see Chapter 2 below, section D.v.), and finally 4) tribute producers (i.e., Cypriot cities, and as will be discussed below, Carthage). A further category is added during Carthaginian times, namely 5) the establishment of naval bases (Pantelleria; cf. Spanò Giammellaro, Spatafora, and van Dommelen 2008) and fortifications or administrative centers for military purposes (i.e. Barcid Cartagena).

In terms of mineral importance, following the early Cypro-Phoenician establishments geared both for copper extraction and port capabilities, western Iberia (which this author identifies with Tarshish/Tartessos) was the crown jewel yielding important precious metals such as silver and gold, the tactical metal of tin, as well as copper, iron, and lead. Sardinia's iron and copper resources played a close second. These latter two regions are distinguished from strategic harbors of otherwise limited commercial value that merchant ships could call along the route back to Tyre, such as Sicily and Malta.

Much research has been carried out on Ibero-Phoenician silver, gold, and copper metallurgy (Renzi, Montero-Ruiz, and Bode 2009; Neville 2007; Ortega-Feliu et al. 2007; Renzi and Rovira 2007; Salamanca et al. 2006; Kassianidou 2003, 1992; Jurado 2002; Keesmann and Hellermann 1989). Although apocryphal, classical accounts detail the type of barter that characterized the trade in gold between sub-Saharan Africans and Phoenician sailors (Herodotus IV: 152; Warmington 1969, 40). It is informative that artistic manifestations of these precious metal commodities have been reviewed, but usually from an art historical perspective based on unprovenanced artifacts meaning that it is very difficult or impossible to achieve a high degree of chronological resolution of the objects (Markoe 1985). Despite the established and ever-growing knowledge of silver and copper metals and metallurgy in the Phoenician world, scholarship into the eponymous metal of the Iron Age has been lacking, partially due to the lack of a large body of evidence from any given site.

A. *Phoenicia, the Eastern Mediterranean, and Mesopotamia*

For [King Solomon] had a Ship of Tarshish at sea along with a ship of Hiram that would come once every three years, bearing gold, silver, ivories, apes, and parrots. I Kings 10:22

The Phoenician exploration of the 10th-9th centuries BC, and the colonial expansion of the 9th-8th century into the Mediterranean, was fueled by the incentive to import metal commodities into the

Near East (Aubet 2008; Gilboa, Sharon, and Boaretto 2008, 118; Niemeyer 2001; Frankenstein 1979). Tyre was the richest and most commercially influential city of the Phoenician homeland on the Levantine coast from around the time of King Hiram I (ca. 969-936 BC) to its destruction by Alexander the Great in 332 BC (Katzenstein 1997, 349). Throughout the 9th century BC, Neo-Assyrian kings looked to the Tyrian merchant kings, otherwise known as the "Kings of Sidon," to provide tribute in the form of both base and precious metals, including gold, silver, tin, and copper (Aubet 2008, 251). The gates of Balawat dated to Shalmaneser III's first regnal year (858 BC) record "the tribute of Tyre and Sidon, silver, gold, lead, bronze, purple-dyed wool I received," while another band depicts Tyrian servants carrying metal ingots (Katzenstein 1997, 163, 165). The "Monolith-Inscription" of Shalmaneser III's third regnal year (856 BC) records "the tribute of the kings of the sea-coast…silver, gold, lead, copper, copper vessels, cattle, sheep, brightly colored woolen and linen garments" (Katzenstein 1997, 166).

Conspicuously absent from these earlier tribute lists is iron, which is only mentioned in a later biblical text as belonging to the purview of Phoenician trade. Ezekiel 27:12 mentions trade from Tarshish; "Tarshish was a source of your commerce, from its abundant resources offering silver and iron, tin and lead, as your staple wares," (Katzenstein 1997, 157-158). The identity of Tarshish has been subject to a healthy scholarly debate, with possibilities ranging from Anatolia to Iberia (Belén Deamos 2009; López-Ruiz 2009; Burke 2006). The metals mentioned in this last passage do not help in determining geographical identity, as Anatolia, Iberia, Sardinia, and Etruria were rich in these metals to varying degrees.

Phoenician cities were left relatively unmolested by the Assyrians despite the former's shifting alliances with neighboring kingdoms such as Aram and Israel. This Assyrian policy of autonomy toward the coastal Canaanites left the latter free to conduct profitable חבר (*ḥbr*) shipping ventures into the central and western Mediterranean (Katzenstein 1997, 70). This uninterrupted self-governance was essentially granted so that the Assyrians could benefit from Phoenician expertise in shipping technologies and proximity to timber resources in Lebanon. The ecological reality of limited agricultural resources also served to keep Phoenician populations low, increasing their reliance on the hiring of mercenary troops as well as the goodwill of the succeeding Assyrian, Babylonian, and Persian empires. Biblical attestations of food shortages are indeed one of the key factors in explaining the alliance between Hiram and Solomon, in which the former sent metalworkers, masons, and raw materials to Jerusalem to construct the Judean king's palace and temple, and in return received twenty cities in northern Israel which were supposed to (but fell short) of bolstering agricultural production (I Kings 9:11). Whereas Assyrian armies perfected chariot warfare and executed land-based campaigns of conquest and tribute exaction, they were unable to match Phoenician shipbuilders and sailors in maritime endeavors. Phoenician sailors not only imported goods back to the coast, but were also charged with the riverine shipping of commodities to the Assyrian centers (Linder 1986). Sennacherib recounts that in the year 694 BC, Phoenicians built him boats at Nineveh and Tel-Barsip. Tyrian, Sidonian, and Cypriot sailors then manned these boats in a campaign against Merodach-Baladan (Katzenstein 1997: 256). In the Neo-Babylonian period under Nebuchadnezzar (592/591 BC), just a few years before this same king stripped Tyre of its autonomy, a ration list states that oil was given to "…100+90 mariners from Tyre" (Katzenstein 1997, 307).

This model of interaction provided multiple niches to the "Kings of the Sidonians." Firstly, even before the rise of Assyria, marine expertise allowed for the establishment of foreign trade networks and access to metals overseas which proved to be their long-term lifeline. This also served to make Phoenicians indispensable in the construction and sailing of the imperial navies. Second, direct access to resources due to their trade with such distant lands as Ophir and Tarshish, which yielded exotica in the form of ivories and precious metals, provided Phoenician craftsmen with a great deal of raw material to perfect their crafts for both Assyrian overlords and Levantine elites (Hussein 2011; Giumlia-Mair 1992; Markoe 1985; Winter 1976). Cinnamon residues in Phoenician bichrome vessels in the homeland indicate that Phoenician sailors of the 11th-10th centuries BC may have established trade relations with Southeast Asia, specifically India (Namdar et al. 2013). Intricate articles of jewelry of the tombs of Assyrian queens demonstrate Phoenician artistic motifs, blending Levantine, Mesopotamian, and Egyptian themes (Hussein 2011). The Chapter opening above of 1 Kings 10:22 discusses Solomon's relationship with Hiram; "For the king had at sea a ship of Tarshish with a ship of Hiram: once in three years the ship of Tarshish came, bringing gold, and silver, ivories, and apes, and peacocks." This historical text "converges" on (Dever 2001) or can be considered "relational" (Hodder 1982) to a Neo-Assyrian relief in the British Museum dated to the time of Ashurnasirpal II (883-859 BC) which portrays Phoenicians carrying apes as tribute to the king (Gadd 1934). An unprovenanced Hebrew ostracon dated on paleographic grounds to the second half of the 7th century BC records a Judean king commanding three silver shekels of Tarshish be given to the House of YHWH, and the Phoenician Nora Stone from Sardinia begins with a reference to Tarshish and is dated paleographically to around the end of the 9th to end of the 8th centuries BC (Schniedewind 2004, 97; Bordreuil, Israel, and Pardee 1998; Cross 1972).

The skills of Phoenician craftsmen were widely known, causing local allies such as the Judean state to employ them despite the latter's own access to copper resources in the Faynan region (Levy, Ben-Yosef, and Najjar 2012; Smith and Levy 2008). A likely local source as determined by lead isotope analysis for some Phoenician coppers from Tell Jatt has been established as the Wadi Arabah, or somewhere at or between Timna and Faynan, or Sardinia (Stos-Gale 2006). The transitional Iron I/Iron IIA (ca. 1000 BC) construction level (Crucibles Layer) of the administrative large stone structure in Jerusalem (probably King David's palace) contained metal production debris in situ, plausibly the result of Phoenician metalworkers who accompanied the "messengers to David, cedar trees, carpenters, and masons" sent by Phoenician King Hiram "to build David a house" (2 Samuel 5:11; Mazar 2009). Hiram, a smith of Phoenician and Hebrew descent, was in charge of all of Solomon's metalwork to construct the First Temple: "King Solomon sent for Hiram of Tyre. He was the son of a widow from the tribe of Naftali. His father was a man of Tyre. He was a copper smith, filled with wisdom, capacity, and knowledge to make all copper objects. He came to King Solomon and made all his wares" (1 Kings 7:14). Following Hiram's introduction is a detailed list of items he fashioned. This story may be allegorical, but it shows that the Bible writers of the 8th-6th centuries BC remembered that Phoenicians were the master smiths and metal traders in the period of the early Judean Kings. In terms of masonry and timber work, "you know that no one among us can fell trees like the Sidonians" (I Kings 5:20). The research from Faynan on the contemporary copper sources available to the Phoenicians also suggests the biblically-attested close relationships between Judeans and Tyrians from a resource perspective in the 10th-9th centuries BC (Levy, Ben-Yosef, and Najjar 2012; Smith and Levy 2008, 77). Whether or not the Judean monarchy was the state entity in control of the mines at Khirbat en-Nahas, sherds of Cypro-Phoenician Black-on-Red juglets indicate some form of Phoenician direct or down-the-line contact at the site.

The Phoenician colonies on Cyprus, archaeologically attested as the earliest Tyrian foundations westward, also provide a useful lens into the hierarchy of tribute in which the Tyrian state strategically placed itself. Evidence for connections between Cyprus and Phoenicia date to the 11th century BC (Smith 2008, 264). Josephus relates that Abibaal, father of Hiram I, conquered Itykaios, and Hiram I later quelled a rebellion there (Josephus, *Antiquities of the Jews* VIII, 146; Katzenstein 1997, 84). Itykaios is likely to be identified as Kition, and the archaeological strata support this notion (Karageorghis 1976). An inscription found in Cypriot Carthage documents tribute provision not only to the Tyrian king Hiram II, but also directly to Esarhaddon. An offering is made by the governor of Cypriot Carthage, referred to as "servant of Hiram king of the Sidonians," in the form of copper. Esarhaddon's annals also record tribute paid to him from a "king of Carthage" from the ten kings of Cyprus (Katzenstein 1997, 209-210, who identifies Cypriot Carthage as Limassol). It stands to reason that the Tyrians were therefore not only able to broker their own autonomy based upon commodities exacted from their colonies, but sometimes had enough control over these same colonies to extract double tribute to be paid to the Assyrians. Although most of the evidence from the Cypriot Iron Age points to copper production, it is likely that iron was also an integral part of the metallurgical industries there (Kassianidou 2012; Maddin 1982). Still, Phoenician control over the island's resources was sporadic, and it was only by the 5th century BC that Phoenician kings ruled in succession (Smith 2008, 262).

Some of the earliest archaeological indications of the early Phoenician mastery of metalworking come from the homeland. No production remains from smelting or smithing are known, but the proliferation of iron weapons and tools by the 10th-9th centuries BC attest to a rapid adoption of iron at Phoenician sites. Early excavations at Tyre and Sidon leave us little in the way of clear stratigraphic relationships; work at the cemeteries of Akhziv has yielded a different picture. The occurrence of iron spears, knives, and arrowheads dating to the 10th-9th centuries BC also serves to indicate the early application of ferrous technology to warfare (Mazar

2004, figure 32; 2001; see especially Dayagi-Mendels 2002). At the fortified Phoenician village of Horbat Rosh Zayit, by the 10th-9th centuries BC sickles, chisels, saws, ploughshares, daggers, and arrowheads were all made of iron, with bronze reserved for limited usage as weights and nose rings (Gal and Alexandre 2000, 127-39). The inscribed arrowheads of El-Khadr indicate a uniformity of military tradition among the Phoenicians in the Iron I based upon weapon typology and paleography (Cross 1980; Milik and Cross 1954).

B. *Iberia*

The Tyrian Empire was able to negotiate commercial relationships not only with Mesopotamian empires, but also local tribes in Iberia on which the Tyrians depended to assist them in accessing the mineral wealth of the Peninsula. In the 10th and 9th centuries BC, so-called “Orientalizing” influences in the Central and Western Mediterranean are usually referred to as “protocolonization” or “precolonization” initiated by Phoenician merchants plying foreign waters searching for mineral resources to exploit Valério (Valério et al. 2013; Valério et al. 2010; Dietler 2009; van Dommelen 1998). This period of the Levantine Iron I, IIA, and IIB corresponds to the Iberian (1100-700 BC) and Sardinian Final Bronze Ages (1200-900 BC; Bierling 2002; van Dommelen 1998). The earliest evidence of Phoenician settlers in the West comes from Huelva and the region of Tartessos by the 9th century BC, if not earlier (Aubet 2008, 247; Canales, Serrano, and Llompart 2008, 648). The most prevalent model describing this process of gradual Phoenician influence is one in which Phoenician traders tapped into preexisting trade networks in order to extract silver and other metals.

Relationships were forged with Iberian chieftains who were able to increase their own status by the acquisition of finished Phoenician products, including iron which was unknown to them before Orientalizing contact (Dietler 2010; Dietler and López-Ruiz 2009). Leaded bronze is also seen only following Phoenician contact; this alloy is easier to cast than pure copper and while it is absent in the Iberian Late Bronze Age, it is bundled with other Orientalizing cultural traits in the Early Iron Age (Valério et al. 2010, 1816, fig. 9). An ashlar retaining wall to prevent erosion from rainfall has been found in the Tartessian village of San Pedro dating to ca. 800 BC. This wall finds a parallel in Tyre which dates to ca. 850 BC, and may suggest technological exchange on friendly terms in the decades before intensified colonization (Ruiz Mata 2002, 267-9). Tyrians established their capital in the far west as if they were at home. The Gadir complex fit the Phoenician model of island center (like Tyre), with coastal mainland sister center of Castillo de Doña Blanca (like Ushu). The Tyrian state also may have signified their good intentions and a mutualistic commercial relationship to the Tartessians in western Iberia by the establishment of a temple at Gadir honoring Melqart, which would serve to symbolize the long-term economic commitment of the Tyrian officials to their local counterparts in addition to being a place where grievances and claims could be officially brought forth (Fentress 2007; Aubet Semmler 2002b, 230; and cf. Shaw 1989, for possible evidence of this type of interaction at 9th-8th centuries BC Kommos, Crete). Iberians adopted or imported Phoenician cultural elements at Castro dos Ratinhos including rectilinear dwellings, red slip pottery, iron, and ivory (Valério et al. 2010, 1812).

Recent excavations on the Andalusian coast have revealed that for every established Phoenician colony, a previously existing indigenous center stood nearby (Aubet Semmler 2002a, 103). Iberian centers of the Final Bronze Age were already operational during the 9th century at sites such as Almuñécar, Salobreña, Montilla in Andalusia; at Catujal, Tapada da Ajuda, Quinta do Almaraz, Lisbon, and Santarém on the Atlantic Portuguese coast; at Saladares, Vinarragell, and Peña Negra in Eastern Spain. One critique of this clear cut picture is that it does not account for the precolonization period, in which Iberian elites may have begun to funnel goods to wayfaring eastern sailors before the foundation of colonial establishments. It is certain that Phoenician merchants tapped into mineral trade networks and created new incentives for the Iberians. At Tartessian sites such as Cabezo de San Pedro, San Bartolomé, Huelva, and perhaps Almonte, silver working installations can be found that date just before the arrival of Phoenicians, with accelerated developments following colonial contact (Ruiz Mata 2002, 265, 95). The site of La Peña Negra is a prime example of a metallurgical production type-site that antedates Phoenician colonization (Neville 2007, 31).

Whereas most Phoenician sites show evidence of at least localized, small-scale iron production, the Iberians were unquestionably the entity behind the actual mining and smelting of silver. Iberian sites of the 8th and 7th centuries BC such as Cerro Salomón, Quebrantahuesos, and Corta Lago have revealed extensive evidence of cupellation (Neville 2007, 140-1). The latter site may have begun producing silver in the pre-Phoenician Late Bronze Age (for additional information on Iberian mining cf. Rothenberg and Blanco-Freijeiro 1981; Allan 1970).

Phoenician prospectors and colonists sparked large-scale silver production among the Iberian chieftains. Silver smelting or other types of production are rare in Phoenician settlements, with minimal evidence coming from Doña Blanca (Neville 2007). The settlement at Sa Caleta on Ibiza is one example of Phoenician silver smelting, as the island has galena ores and evidence of household production was found dating to the less than 75 years of its existence (Neville 2007, 32). The Balearic Islands, with limited ore outcrops of copper, galena, and iron, boast some early indigenous metalworking (ca. 1750 BC), but far before the time of the Phoenicians (Giardino 1995, 317). It is likely that finished iron objects, the technology of which was unknown to 8th century Iberians and therefore valued as exotica, were traded by Phoenicians to the latter for their silver products. Evidence for iron production at Phoenician colonies contemporary with their indigenous silver producing counterparts is widespread, coming from such settlements as Abdera, Cabecico de Parra, Morro de Mezquitilla, Cerro del Peñón, La Fonteta, and Santa Olaia (Neville 2007, 136; Niemeyer 2002). Significantly, as at Carthage (excluding a few pieces of slag from under the *Decumanus Maximus*) in the 8th century BC iron workshops at Morro de Mezquitilla are distinctly not found in households (Schubart 2002).

The major silver producing regions that attracted the Phoenicians were the Iberian Pyrite Belt down the Rio Tinto to Huelva, as well as Aznalcóllar. Tin ore was ubiquitous in northwest Spain (Neville 2007, 139). Due to the need for great amounts of timber fuel to smelt the ores, production centers are often found removed from the mines and close to timber stands (Aubet Semmler 2002b, 237; Jurado 2002, 245). It stands to reason that the metals driving this trade were the gold and silver deposits found in the Sierra Morena and the Northwest, feeding down the Guadalquivir to Gadir (Aubet Semmler 2002c, 202). However, the clearest evidence of precolonial contact is found in the lack of Iberian iron production, but precipitation of local consumption by Iberians of iron “prestige-objects.” This technology, unknown to the Andalusians in the Final Bronze Age, is well attested at the Phoenician settlements of Morro de Mezquitilla and Cerro del Villar during the 8th century BC. At Morro and Tejada, changes in smelting technology are apparent following Phoenician contact, with iron content increasing in copper alloys compared to all previous periods studied (Craddock and Meeks 1987, 190, table 1).

In Portugal, copper, tin, and gold made their way from the hinterland mines to the coast. One of the more tantalizing pieces of evidence for the presence of Near Eastern populations comes from the Beira Alta region of Portugal, at which fragments of a small curved iron knife were found, as well as at Almada where additional curved iron knives are found. These strata have been respectively radiocarbon dated (calibrated) from 1310-1009 BC, and 994-783 BC (Sanmartí 2009, 55). Adoption of Phoenician technological practices was selective and gradual as indigenous Portuguese communities adapted what seems to be their own well-developed non-ferrous metallurgical traditions before Phoenician iron was introduced (Valério et al. 2013; Valério et al. 2010).

Phoenician colonists along the Andalusian coast constructed large warehouses, likely used to keep crude or recyclable metals for export (Aubet Semmler 2002d; Niemeyer 2002). Agricultural activity certainly took place, but the *raison d'être* for the establishment of these centers would only be commercially viable for the Tyrian state if high returns on their investment into colonial and mercantile infrastructure could be obtained, the likes of which could only be derived from precious metals. Gadir emerged as the most important Phoenician city next to Tyre in this period, as it was the geographical nexus between the metal hinterlands and the Mediterranean (Ruiz Mata 2002).

The Phoenician colony at Ibiza ca. 650 BC represents another bridgehead between east and west, and points to a long-term entrenchment of a mutually beneficial system of commerce (Ramón 2002). The success of this endeavor indicates state planning integrating Phoenician sailors and merchants, local elites and miners, and an expertise in extractive and productive metallurgical technologies at every stage of the *chaîne opératoire*.

C. ***Sardinia, Sicily, Etruria***

Iron implements from as far afield as the Portuguese Atlantic coast (Margarida Arruda 2009; Aubet Semmler 2002a, 104), to bronze artifacts from the Sardinian S. Antioco and Phoenician-style brooches on the eastern coast of Sicily (van Dommelen 1998, 75) demonstrate that the tribute system of metal supply to the Assyrians was not unidirectional. Local elites in the indigenous areas desired, acquired, and consumed Phoenician metal craft as well as the Assyrians. Indeed, in this precolonial or prospective period, most of the Orientalizing artifacts are found archaeologically in close geographical proximity to regions of metal ores. Nora and Bithia were likely the earliest Phoenician settlements on Sardinia (Cross 1972), with some evidence of "Levantine" amphora used for copper storage dating from the end of the 9th to the first half of the 8th centuries BC at Alghero, close to Nora (Bernardini 2008, 539). Sardinia (LoSchiavo 1986) and Tuscany are both rich in metal resources (Costagliola et al. 2008; Corretti and Benvenuti 2001), and Etruscan mining districts such as Colline Metallifere witnessed similar Phoenician contacts as those in Sicily (van Dommelen 1998, 79). Etruscan smiths at the Gulf of Baratti produced about three tons of iron a year from the period 600-100 BC (Crew 1991, 113). A transition in metallurgical preferences from copper to iron is witnessed in Etrurian Populonia at massive beach slag heaps that spanned from the 9th to 7th centuries BC (Chiarantini et al. 2009). Sicily is not rich in metal resources, and less is known about the extent to which Phoenicians influenced metallurgical trends on the island (Procelli 2008, 464-5). The trade was not unidirectional, as Etruscan *bucchero sottile* was found in tombs on the Byrsa Hills at Carthage dating to the end of the 7th century BC (Lancel 1995, 60).

There is evidence to indicate that the Tyrians were busy planting the proverbial seed of goodwill in their precolonizing or prospecting phase. As mentioned above, Tyrian-type architectural features are found in what may be a pre-colonial phase at San Pedro, Castro dos Ratinhos, Gadir, and Kommos.

It is likely that a similar precolonization phase occurred between the Phoenicians and the Nuraghic populations of Sardinia. This centuries-long process resulted in neither outright hegemony by the Phoenicians or Carthage (although Carthage did control the island militarily until after the First Punic War), nor are there archaeological indications of violent resistance. Instead, practices of "hybridity" and "entanglement," or in other words a mutualistic mechanism of culture and commodity exchange, were the hallmarks of the colonial/indigenous interactions (Dietler 2010; van Dommelen 2006, 2005, 2002, 1998, 1997; Tronchetti and van Dommelen 2005). Prospecting or precolonization is evident via Phoenician imports into the island of the 10th through 8th centuries BC. These are associated geographically with regions containing metal ores, for example at S'Imbenia and S. Antioco (van Dommelen 1998, 75; Bernardini 1986, 105-6). Copper, lead, and iron resources are found throughout the island, at locations such as in Nurra, and the regions of Iglesias, Sulcis, Ogliastra, Sarrabus, and other scattered parts such as Nuoro (Giardino 1995, 308). The island of Corsica is also relatively rich with metal ores, including many copper sources, as well as lead-copper and a few iron sources. There is even some evidence for the occurrence of tin ores (Giardino 1995, 309).

D. *Shipwrecks*

Shipwrecks along the Iberian coast provide evidence of the material types utilized for the metal trade. The wreck at Rochelongue dating to the end of the 7th century BC contained stockpiles of scrap metal, clearly destined for melting and recycling (Aubet Semmler 2002a, 108; de Motes 1966). The wreck at Bajo de la Campana, also of the 7th century BC, contained tin, lead, and copper ingots (Polzer and Reyes 2009, 2008). Two additional wrecks just south of Bajo de la Campana have been found at La Playa de la Isla, containing as cargo metallic lead ingots

(Neville 2007, 32; Negueruela et al. 1995). A 3rd century BC wreck is known from Marsala in Western Sicily (Frost 1974, 1973). Although no metals are known to come from the wrecks, the *Elissa* and *Tanit* vessels must be mentioned as representing one incredibly important facet of Phoenician trade: wine (Greene 1995). These wrecks date to the last half of the 8th century BC (Ballard et al. 2002; King and Stager 2001, 180-1).

Despite such a limited number of ships discovered, their cargoes of copper, tin, and lead scrap and ingots are advantageous to our discussion, as they suggest that Phoenicians were indeed operating at every stage of the metallurgical *chaîne opératoire*. It has been poignantly suggested that the demand for iron in Iberia gradually accelerated due to the removal of scrap bronze in commercial circulation by Phoenicians throughout the Iron Age, further cementing the need for Iberians to rely on new Phoenician imports (Aubet Semmler 2002a).

The Tyrian state established a vast commodity procurement network that stretched from Lebanon westward through the Straits of Gibraltar to Portugal and Morocco, southward through the Red Sea into an unknown destination in Africa, and eastward perhaps as far as India. Phoenician traders were the movers of this mercantile cooperative network which enfranchised local elites through the provision of otherwise unobtainable luxury commodities, mostly in exchange for rights to silver mines, silver, and establishment of warehousing colonies. Each of these colonies, including Carthage, operated with a specific function in the greater scheme of tribute provision back to Tyre and ultimately to Assyria.

Chapter 2. Carthage: From Colony to Capital

Most military states remain safe while at war but perish when they have won their empire; in peace-time they lose their keen temper, like iron. (Aristotle, Politics VII.xiii.15; Rackham 1932)

In order to understand the formation of empire at Carthage, its nascent centuries as a Phoenician colony must first be examined. The reasons and mechanisms of Phoenician expansion as detailed in Chapter 1 were to acquire metal resources, create ports of call, provide political refuge and tribute, ease demographics, and later Carthaginian establishments acted as fortifications or administrative centers. Carthage certainly fits this model in terms of a port of call, political refuge, and tribute producer. Geographically it is clear that Carthage provided an excellent port of call, placed as it was in the Central Mediterranean and close to Sicily. Textually, the famous story of the flight of Elissa (Dido), daughter of Tyrian King Mattan, to found Carthage *de novo* in 814 BC attests to a situation of elite exile (Figure 1). Although the exact dates and historical details have not been corroborated archaeologically in the case of Carthage, royal frictions in the Tyrian court did sometimes lead to flight as seen in the Assyrian reliefs of the flight of Eloulaios (Luli) during one of Sennacherib's campaign (Katzenstein 1997, 132).

Topographically, Carthage likely contained two natural harbors several meters in depth, although the number and placement of the harbors before the 4th century BC and even afterwards is far from clear (Gifford, Rapp, and Vitali 1992). Eventually two distinct harbors were dug out of the low-lying coastal land between the Tophet and the Byrsa. These were the rectangular commercial harbor (constructed in the 4th century BC) and circular military harbor (with unclear temporal origins but with a final phase of construction around 200 BC; Lancel 1995, 182-92; Gifford, Rapp, and Vitali 1992, 586; Hurst 1979; Hurst and Stager 1978).

Based upon radiocarbon dating, Carthage was certainly a functional settlement by the first half of the 8th century, and perhaps by the end of the 9th century (Docter et al. 2008; Docter et al. 2004, Table 1). Like many other 8th century Phoenician sites in Iberia, Carthage produced iron. However, unlike the other ones Carthage has provided one of the largest corpora of artifacts linked to ferrous metallurgical production from the entire Ancient Near Eastern Iron Age. From the period 800-500 BC, 36 tuyères or other metallurgical ceramics with slag still attached to the nozzle were excavated in the Bir Massouda precinct of Carthage by the joint excavations between Universiteit Gent and the Institut National du Patrimoine (Figures 3 and 4; Docter et al. 2006; Docter et al. 2003). Hundreds of samples of loose, unattached slag were also excavated. Based upon scale, and the overwhelming proportion of iron over other metals (Chapter 4), it is most probable that this iron production was not geared only toward local consumption, but also for the provision of tribute to Tyre. The iron could then be utilized as Tyre saw fit; paid to Assyria or Babylonia, traded for as an exotic commodity with indigenous Mediterranean elites for silver, left in Carthage to trade with Numidians for food (Sanmartí et al. 2012; Kallala et al. 2010), or used by the Tyrian government or Carthaginian colonials in other ways. An examination of the history of excavations at Carthage, the context of the metal remains, and an investigation into the Carthaginian political system is provided in order to frame this state industry geared toward strategic metal production in geopolitical context.

A. *History of Excavations at Phoenician and Punic Carthage*

The study of Phoenician and Punic Carthage was relegated to Greek, Roman, and Hebrew historical sources preserved since antiquity until the mid-19th century AD when French and British archaeologists began to conduct excavations in the Byrsa and lower towns (Figure 2;

Lancel 1995; Beulé 1861; Davis 1861). This work had been preceded by the Danish consul-general in Tunis who executed the earliest topographical survey of Carthage with the goal of documenting archaeological remains (Falbe 1833). Contemporary archaeological—otherwise known as antiquarian—research questions were usually wholly informed and inspired by textual "convergence" with archaeological remains (Dever 2001). From its very beginnings archaeology in Carthage has often accorded well with the textual sources, with Beulé encountering 1.5 meters of a burnt destruction layer separating Roman and Punic remains that resulted from the Roman razing of the city described most convincingly by the eye-witness Polybius, as well as Appian (Lancel 1995, 444; Beulé 1861, 55). In 1949, General Duval, the Commander-in-Chief of the French forces in Tunisia, pinpointed a partial course of the city's tripartite fortification wall described by Appian (Lancel 1989).

In 1881 Tunisia was placed under French protection under the terms of the Bardo Treaty (Lancel 1995). Until the 1970s, French scholars would be responsible for the vast majority of archaeological discoveries in Carthage. In order to acquire inscriptional evidence for the publication of *Corpus Inscriptionum Semiticarum* (CIS), the Académie des Inscriptions et Belles-Lettres tasked E. Sainte-Marie to excavate and acquire Punic texts from the hills of the Byrsa, such as Saint Louis and Juno (Brown 1991; Sainte-Marie 1884). He began excavating in 1875, and within the year found over two thousand stelae. Immediately following and overlapping Sainte-Marie's excavations, the first chaplain of the White Fathers, Père Delattre, began work in the Punic necropolis that would become the Musée National de Carthage, uncovering marble statues in the Punic cemetery then known as Sainte-Monique (Lancel 1995). This plot started out as the Ottoman Bey’s palace on the northeast side (where there are now storerooms in the middle of the summit), and later the Cathedral of St. Louis was built on the southwest side. Hundreds more stelae were excavated by Reinach and Babelon in the area of Sainte-Marie's project in 1883 (1886).

Throughout the 19th and 20th centuries AD, many Punic stelae were found out of context due to their reuse as building materials by the Romans—the Tophet was mined for building fill until as late as the 2nd century AD (Brown 1991; Wilson 1975). Only with the discovery of the Tophet, or sacrificial precinct of Tanit, was the original context of the stelae discerned. The “Tophet of Salammbô” was discovered on Christmas Eve, 1921, by the first excavators of the site, F. Icard and P. Gielly (Lancel 1995; Icard 1923; Poinssot and Lantier 1923).

Early Punic (EP)	
EP I	760-675
EP II	675-530
Middle Punic (MP)	
EP/MP	530-480
MP I	480-430
MP II.1	430-400
MP II.2	400-300
Late Punic (LP)	
LP I	300-200
LP II	200-146

Table 1. Archaeological strata and historical chronology of Carthage, after Bechtold (2010)

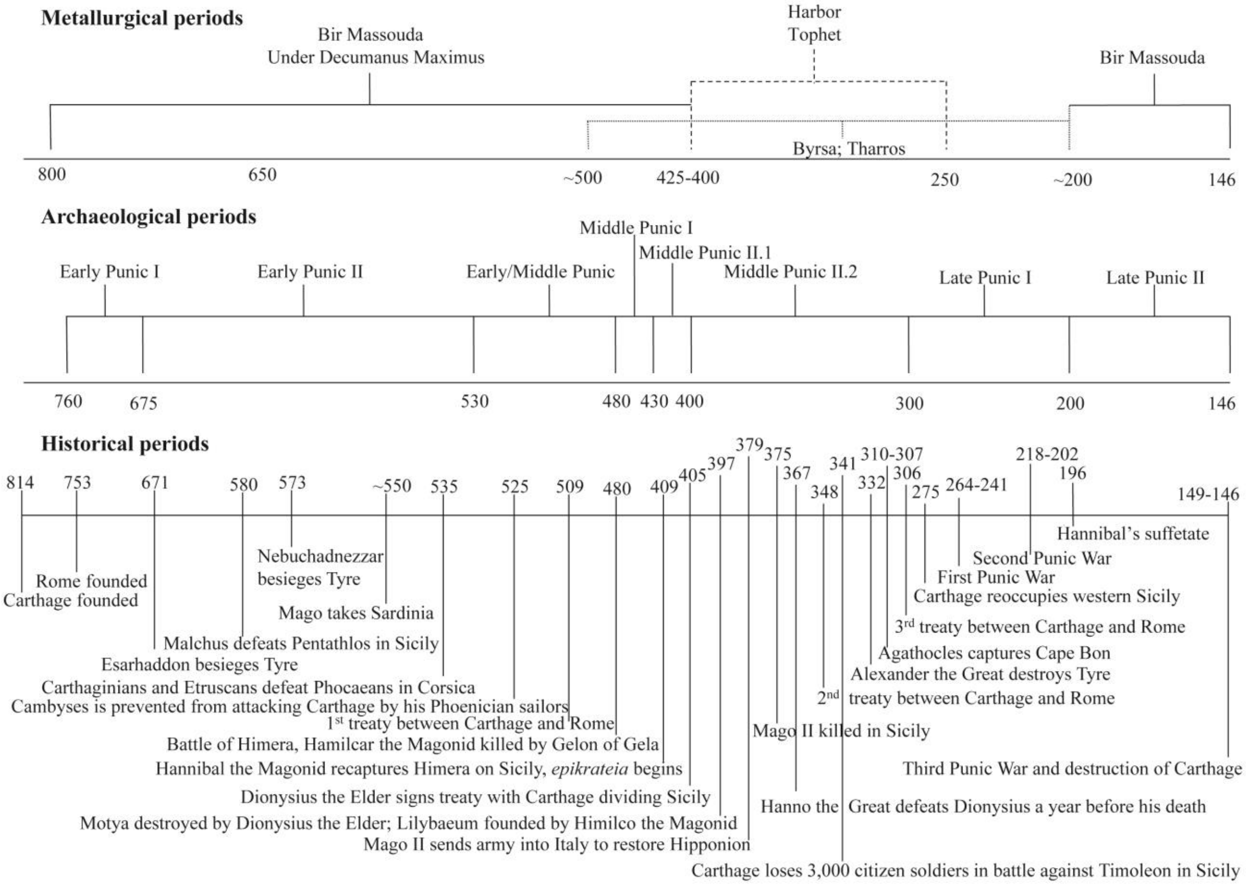

Figure 1. Chronological schematic synchronizing major metallurgical, archaeological, and historical periods at Carthage (all dates BC; scale is relative, not temporal)

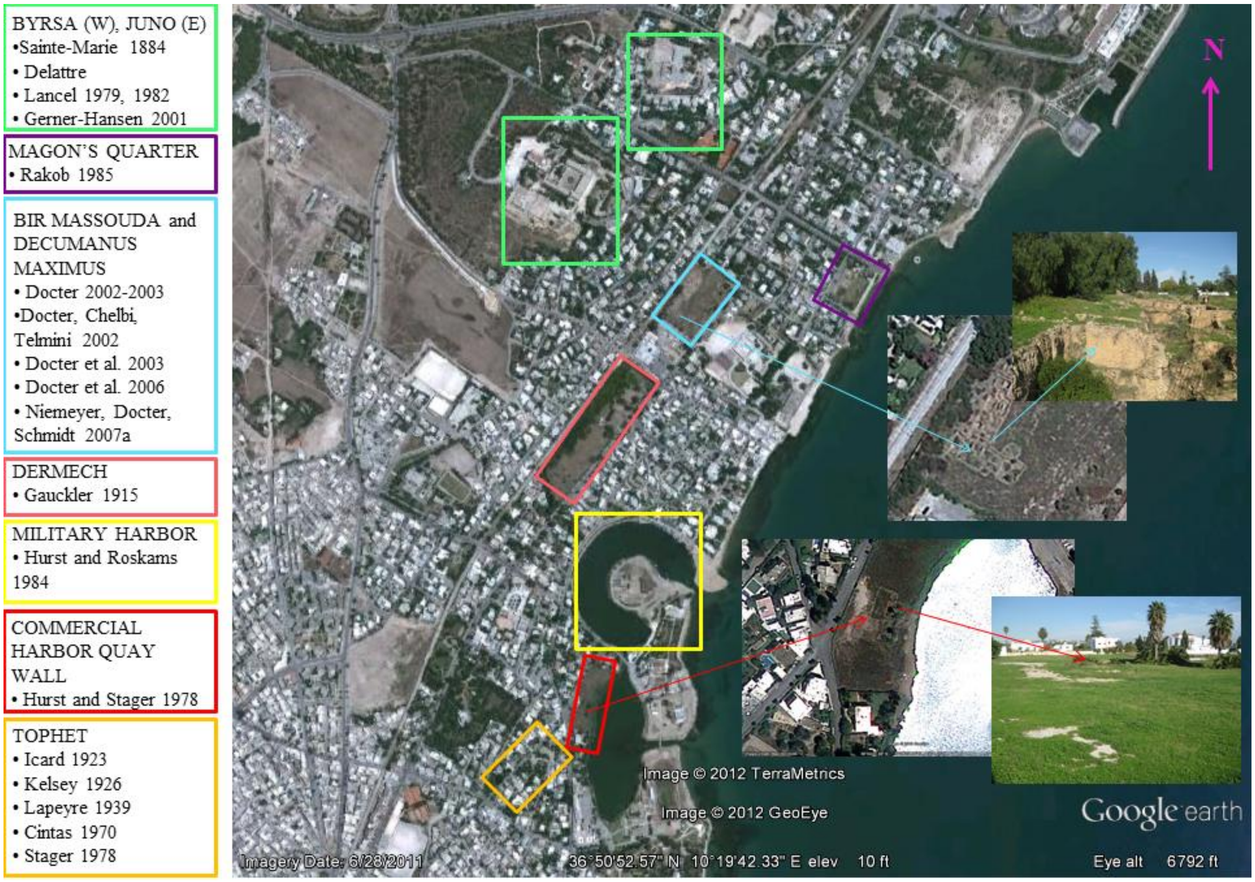

Figure 2. History of excavations at Phoenician and Punic Carthage

Figure 3. Remains of furnace L. 8217 at Bir Massouda, ca. 7th century BC

Representing the most spectacular convergent nexus between text and archaeology at Carthage, archaeological interest in the Tophet, spanning the 8th to 2nd centuries BC, was to persist. Pallary (1922) identified the burnt osteological remains found in numerous urns of the Tophet to be those of human infants, sparking scholarly debate that continues today as to the historicity of the classical and biblical accounts, as well as to the scientific methodologies employed in the analysis (cf. Smith et al. 2013; Xella et al. 2013; Schwartz et al. 2012; Smith et al. 2011; Stager and Wolff 1984).

Count Byron Khun de Prorok purchased the land of the Tophet from Icard, and helped raise funds to continue excavations (Lancel 1995; Brown 1991; Prorok 1926). The American

F.W. Kelsey, of the University of Michigan, also excavated the Tophet in 1925 (Kelsey 1926). Donald Harden produced the three tiered stratigraphy of the Tophet still employed today (i.e. the Tanit I-III system; Harden 1937, 1927). An adjacent part of the Tophet was purchased by L. Carton, who died before he could begin excavations. His widow enlisted G.G. Lapeyre, another White Father, to undertake excavations which resulted in the discovery of thousands more stelae and urns (Lancel 1995; Lapeyre 1939). Following World War II, P. Cintas resumed excavations at the Tophet, finding evidence of additional ritual functions such as the “Cintas Chapel.” Moreover, Cintas discovered the walled border of the precinct (Cintas 1976, 1970; Picard 1945). The number of excavations at Punic Carthage was greatly increased due to the International Campaign to Save Carthage of 1972 brought about by UNESCO and the Institut National d'Archéologie et d'Art de Tunisie (Ennabli 1992). Another American team extended Kelsey's excavations of the Tophet, led by L. Stager of the University of Chicago's Oriental Institute (Lancel 1995; Stager 1978).

In addition to Americans, the UNESCO-inspired excavations also brought French, British, Swedish, Danish, Canadian, Italian, and Polish scholars and teams to Carthage that uncovered Punic remains. Until the 1970s, scattered excavations brought to light tombs in the area of the Byrsa and Dermech (Gauckler 1915), stelae and urns at the Tophet, some destruction layers and parts of the city wall. Concerted efforts by the aforementioned international teams assisted in the scientific recovery of the commercial and military ports of Late Punic Carthage, as well as their industrial complements and quay walls (Hurst and Roskams 1984; Hurst and Stager 1978), the necropolis, remains of the acropolis, market area, small-scale craft production, cisterns and luxury villas of the Byrsa and the slopes of Juno (Hansen 2002; Lancel 1982, 1979), and a more refined stratigraphy of the Tophet (Stager and Wolff 1984). A few Punic cisterns and one grave were also excavated along the north slope of the Byrsa (Hansen 2002). Furthermore, the most comprehensive survey of the Carthaginian hinterland to date was conducted by J. Greene (Docter 2007; Greene 1986).

B. *Carthaginian Metallurgy in Archaeological Context*

From 1985 to 1996 German excavations from the University of Hamburg began to uncover Phoenician and Punic phases, including the so-called Magon's Quarter abutting the sea wall and under part of the Roman *Decumanus Maximus*. The Phoenician and Punic levels under the *Decumanus Maximus*, dating from the 8th through 2nd centuries and restructured many times throughout, revealed careful town planning in the later periods as well as sophisticated drainage systems, bathrooms, dwelling spaces, and small-scale metallurgy (Niemeyer, Docter, and Schmidt 2007a, 2007b; Docter 2002-2003; Docter, Chelbi, and Maraoui Telmini 2002; Lancel 1995; Rakob 1985). The era best represented, with evidence of imperial prosperity, comes from the 5th through 3rd centuries BC. The Hamburg team also began excavations in Bir Massouda, a plot of land northeast of Dermech in between the ports, Tophet, and Byrsa.

The most recent excavations were those conducted at Bir Massouda, by Universiteit Gent, University of Amsterdam, and Institut National du Patrimoine. These yielded the material under analysis for this manuscript (Docter 2010, 2009, 2008, 2007; Docter et al. 2006; Docter et al. 2003). The site of Bir Massouda is significant in that it was an area utilized for multiple purposes throughout the history of Carthaginian settlement. The area is surrounded by a wall, and contains burials, domestic dwellings, and metallurgical production reaching industrial proportions, all dating to different periods.

Figure 4. Remains of furnace and tuyères with unlabeled loci 8091 (800-500 BC), 8092 (800-400 BC), and 8098 (750-400 BC) from Bir Massouda

Metallurgical innovations and production are required for many purposes, including a contribution to warfare. Iron, steel, and/or bronze weapons, tools, and nails are essential for an aspiring empire in terms of military equipment and shipbuilding activities. Therefore, the way in which metallurgical production is executed—including resource acquisition, material commodities dedicated such as fuel, ores, transportation, and labor (Kaufman 2013, 2011), as well as state commissioning of production zones—is essential to the study of imperial strategy at the primate center.

Excavations at the site of Bir Massouda in Carthage conducted by the joint Belgian-Dutch-Tunisian research expedition documented centuries of strata in which furnaces, flux in the form of recycled murex shells from purple dye production, tuyères (Figure 5), slag, anvils, hammerscales (iron-rich debris expelled by forging activities), and alloys and corrosion products were abundant from ca. 760–500 BC. Production was reduced throughout the 5th century and completely halted by 425/400 BC (Figure 6), the space then repurposed for domestic structures (Docter et al. 2003). A thick layer of hammerscales were found capping parts of the metallurgical area, suggesting that forging activities were prevalent (Docter et al. 2003, 44). Some of these scales seem to have been trapped in the slag as well (Appendix II12). Bir Massouda was then transformed into a residential quarter and the metallurgical precinct was transferred to an in-use cemetery on the Byrsa Hill (Lancel 1985), although small amounts of what seems to be non-ferrous slag are contemporarily evident at Bir Massouda perhaps indicating household production. It is noteworthy that metalworking was conducted on a large-scale in a metallurgical precinct, and on a seemingly personalized scale in the household.

The new metallurgical precinct at Byrsa continued in this capacity until the loss of Carthage of its territorial holdings following the Second Punic War with Rome in 201 BC, at which point metallurgical production at Bir Massouda recommenced (Figure 1). Until these materials were excavated, the only known remains of metallurgical production at Carthage were from the 5th through the first years of the 2nd centuries BC on the Byrsa, along with a few pockets at the Harbors and next to the Tophet (Lancel 1985, 1982, 1981; Hurst and Stager 1978), leaving major gaps in the metallurgical sequence (Figures 1 and 2). There is some additional scattered evidence of metalworking from northwest of the Tophet (3rd century BC), the west side of the channel in the area of the commercial harbor (400-350 BC), some metallurgical remains from the Ilôt de l’Amirauté in the military harbor contemporary within this latter half century, as well as slags and tuyères from a 7th century BC dump at *rue Ibn Chabâat* (Essaadi 1995a, 1995b; Hurst and Stager 1978). The Hamburg excavations led by Rakob also found tuyères and slag in a mixed fill dating widely from the 8th-4th centuries BC (Niemeyer 2001; Keesmann 1994; Rakob 1989).

Various scholars such as F. Rakob, H.G. Niemeyer, and Roald Docter conducted excavations at a major residential area from the Magonid period (5th-3rd centuries BC) known as Magon's Quarter (Niemeyer, Docter, and Schmidt 2007a, 2007b), recovering some ferrous implements. In addition to some Early and Middle Punic slag that the Hamburg team recovered from household contexts under the *Decumanus Maximus*, hundreds of representative loose slag samples spanning all periods (see Chapter 4), dozens of tuyères with slag attached, furnace material including carbonized remains, a basalt anvil, and alloys and corrosion products from Bir Massouda were excavated and inform the archaeometallurgical analyses presented here. There have been three previous archaeometallurgical analyses of Carthaginian iron (Keesmann 2001, 1994; Tylecote 1982a).

Multiple examples of metal workers attested from the votive Tophet stelae indicate that Carthage was home to "metalworkers" (Mosca 1975). These technicians held specialty titles such as "ironsmith," "iron forger and smith," "master smith," "bronze caster," "gold vessel specialist and goldsmith" (cf. Chapter 5; also Wolff 1986; Heltzer 1983).

Tunisia is not rich in iron ores, although there may be some scattered sources like most places in the world (Wolff 1986). It is more plausible that before Carthage became an independent entity with territorial and commercial aspirations of its own, it was an integral part of the Phoenician metals provision network to Tyre and was a hub receiving iron ingots or blooms in various stages of the *chaîne opératoire* (Tylecote 1982a). Since there is no current

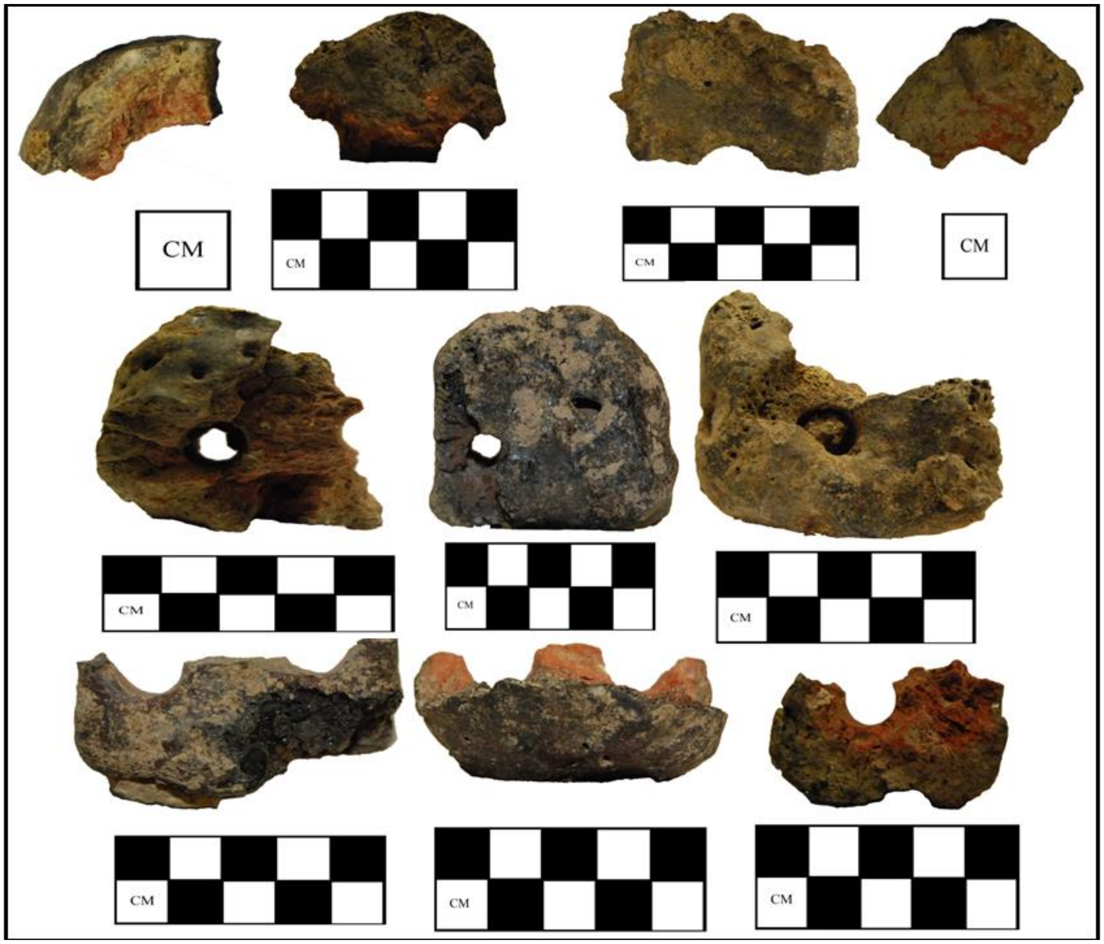

Figure 5. A selection of tuyères with slag attached from Bir Massouda [left to right: top row 8091 18719, 8069 16627, 8091 38018, 8091 17482; middle row 8089 17486, 8091 30191, 8092 17473; bottom row 8091 38027, 8069 16621, 8069 16622]

way to determine provenience of iron ore, it is most parsimonious to assume that the iron ores came from Sardinia (Giardino 1995). Etruria may have been another hub of metals trade for Carthage, and it is well known how close a commercial relationship was shared between the two states as attested textually (Aristotle, Politics, III.v.10; archaeologically with the gold Pyrgi tablets; Moretti Sgubini 1999, 65), and with ferrous archaeometallurgical evidence in general attested in Tuscany (Corretti and Benvenuti 2001). Centuries of intimacy with iron production granted the Carthaginians a competitive edge in ferrous technology that could be effectively employed in the creation of weapons and other iron or steel implements (a further discussion of state-run organization and production is reserved for the conclusions, Chapter 7).

Mechanisms of empire formation are rooted in the development of political systems, and much is known of the Carthaginian political system from epigraphic and textual evidence. From the traditional founding of the city in 814 BC, Carthage seems to have subsisted as an ordinary colony serving as a port of call as well as a production center of finished wrought iron and steel goods. Firm archaeological evidence of a port system comes in the 4th and 3rd centuries BC when the large commercial and military ports were constructed (Hurst and Stager 1978). The bulk of the archaeological evidence from the Archaic or Early Punic era (Table 1) comes from the Bir Massouda metallurgical zone and also household contexts from under the *Decumanus Maximus*. The latter contained evidence of domestic occupation, and the former of a dedicated metallurgical precinct, interspersed with burials. XRF analyses of the slag from Bir Massouda point to around 92% iron production, with 8% copper, tin, and lead production (Chapter 4). This proportion of iron is too high for mere domestic consumption, and most likely represents tribute production for Tyre. Therefore, before or around the time that Carthage attained political independence from Tyre, it served mostly as a port of a call, tribute provider of iron and purple-dye wares, as evidenced by the murex shells used for metallurgical flux.

C. *Carthaginian Independence*

The first we hear from the classical sources regarding Carthaginian independence comes from Diodorus Siculus (V:16:1-3), who explains that Carthage founded its first colonies on the Balearic Islands ca. 654 BC (Katzenstein 1997, 293). However, it is not until the historical and archaeological “convergence” of the Babylonian siege of 573 BC does Carthage emerge as the most dominant Phoenician city. Nebuchadnezzar invested Tyre for thirteen years (585-573 BC), cutting it off from its foreign and local holdings and sources of wealth (Diakonoff 1992). Although it continued to be independent or mostly autonomous until its destruction by Alexander the Great in 332 BC, its power by now had been curtailed. It is during the Babylonian siege that classical authors begin to discuss Carthaginian military activity. In ca. 580 BC, Greeks under the command of Pentathlos of Cnidos attempted to drive the Phoenicians from Lilybaeum on Sicily (Warmington 1969, 41). This would have placed the Phoenician shipping routes to Iberia in peril. Shortly afterward, Carthage sent an army under Malchus (likely a mishearing of מלך, *mlk*, “king”), to repel the Greeks (Lancel 1995, 112). He was successful, and there is seen archaeologically a bolstering of defense on Sicily. By 580 BC, a defensive wall was built for Motya, and between 575-525 BC a causeway was constructed between the island and mainland (Warmington 1969, 43; Whitaker 1921, 142). A number of other military actions conducted by the Carthaginians were undertaken over the next centuries, which indicates not only their independence, but imperial and aggressive aspirations (Figure 1).

There is no question that the Carthaginian military outstripped its Phoenician ancestors and contemporaries. Naval prowess was buoyed by terrestrial operations, including the hiring of mercenaries (Fariselli 2002) and recruiting of subject troops from North Africa to Spain, whilst maintaining an officer corps comprised of citizens. Following a number of geopolitical circumstances after which Carthage secured its position as the champion of the Phoenician peoples, the technology of iron extraction came to be held as a strategic endeavor and was continually controlled by the state and applied to warfare.

D. ***The Carthaginian Political System as Reconstructed from Text and Epigraphy***

"…not only are many of the Greeks bad, but many of the Barbarians are refined—Indians and Aryans, for example, and, further, Romans and Carthaginians, who carry on their governments so admirably." (Strabo, quoting Eratosthenes, Geography I.4.9; Jones 1997)

The most reliable and detailed textual source for reconstruction of the Carthaginian political system is Aristotle's *Politics*, written in the 4th century BC. By this time, Carthage had developed a constitution that was unique in many ways from their Mediterranean counterparts. The full text of the constitution is not known, but the government was comprised of a Senate, known as the One Hundred and Four and populated by men with the title of judge (II.viii.2). An additional Council of Elders was subordinate to the Senate, which Aristotle names the Supreme Magistracy of the Hundred (II.viii.4). One of the most striking features was the Popular, or People's Assembly, praised by Aristotle as a democratic achievement "that does not exist under the other constitutions" (II.viii.3). The state was led executively by kings and generals through the Magonid period, after which point greater democratization brought about leadership by judges and generals.

i. *Kings, Generals, Judges*

Kingship was the oldest form of rule among the Phoenicians, accompanied by a Council of Elders (Lancel 1995, 113). Carthage remained subordinate to the Tyrian system until Nebuchadnezzar's siege ending in 573 BC, and it is precisely during the siege (ca. 580 BC) that the classical sources first mention an independent Carthaginian leader engaging in military action (Warmington 1969, 42). There is further evidence of governmental shifts during this time. After a tradition of some 1,300 years of kings at Tyre, the office of judge[1], שפט (*šp*ṭ), was established in the city in the early 6th century BC, perhaps with two judges serving as executives at once (Lancel 1998, 188; Katzenstein 1997, 340; Sznycer 1978). At Carthage, it seems that judges began to play a more directly leading role in the 4th or 3rd centuries BC at which point they adopted executive powers in an office known as the Suffetate.

Kings and judges seemed to have also played a role in the military top brass. Many ancient Greek writers used the term βασιλεύς for Carthaginian leaders, indicating hereditary kingship (Warmington 1969, 139). However, Latin authors would interchange between *basileus*, *rex*, and *sufes*. The first Carthaginian champion, Malchus, to emerge and defend Phoenician establishments in western Sicily following the encroachments of Pentathlos of Cnidos, was referred to as *Dux*, or general (Justin XVIII: 7; Lancel 1995, 111, 117). Aristotle makes it clear that rulers at Carthage, including kings and generals, had to fulfill two main prerequisites, neither having to do with lineage: wealth and merit (II.viii.5). He sees this is a third, hybrid type of system, merging both oligarchy (wealth) and aristocracy (merit). Warmington (1969, 137) suggests that a landed aristocracy rooted in a tradition of merchant princes gave birth to a warrior class, the two spheres representing the fundamental division in Carthaginian society and politics known in later Barcid times. The idea of Phoenician merchant princes is one generally drawn from Phoenician scholarship (Katzenstein 1997, 272). Hannibal, following his role as commander-in-chief of Carthaginian forces, briefly assumed the Suffetate (jointly with another unknown judge) in 196 BC (Livy XXXIII: 46.3; Lancel 1998). Hannibal angered many officials

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[1] Perhaps more accurately translated as "governor" or "senator," but to reduce confusion the traditional term "judge" will be employed throughout this research. See Chapter 5 for a discussion of the various meanings of "judge," including as a personal name. This title is also used by other Northwest Semitic groups such as the Hebrews, as the biblical authors describe the society of the Iron Age I (1200-1000 BC) being led by judges.

and eventually had to flee to exile due to the fact that he changed the rules of judgeship, canceling life-long tenure. This indicates that at least in the years preceding Hannibal, and perhaps since its inception, this title was virtually irrevocable. Epigraphic funerary evidence supports this, with a title of judge often inscribed on Tophet stelae (Kaufman 2009). In the first half of the 2nd century BC, two sons of the same father are inscribed as judges on a Punic inscription in Sardinia (Katzenstein 1997, 341; Donner and Röllig 1968, KAI 66), perhaps indicating that a title of judgeship could be hereditary. These judicial titles could mean that their bearers were likely members of, or eligible to serve in, one of the legislative or judicial houses, or Boards. Aristotle writes that officers of the Supreme Magistracy of the Hundred "are in power after they have gone out of office and before they have actually entered upon it" (II.viii.4). The top judges had powers to summon the Senate and the People's Assembly (Diodorus Siculus XXV:16; Polybius III: 33l Warmington 1969, 140). For a compendium of royal or aristocratic titles found epigraphically, including Phoenician kings across the Mediterranean, see Filigheddu (2008).

Some scholars have acknowledged the confusion evident throughout the textual tradition and the epigraphic data, calling into question whether there was ever a king, or if the seemingly interchangeable role of the king, head judge, and commander-in-chief were ever distinct from one another (Lancel 1995, 117; Gsell 1921, 194). Generalship seems always to be associated with kingship in the earlier periods as in the 6th century BC, and later among the Magonids and Barcids (Lancel 1995, 113).

ii. *Senate, Council of Elders, Tribunals*

The major lawmaking entity of Carthage was the One Hundred and Four, or Senate. The Senate met in a building near the agora or forum, the location of which is unknown archaeologically, and the judges would publicly dispense justice outdoors (Appian, *Lib.*, 128; Diodorus Siculus, XX: 44.5; Warmington 1969, 132).

Subordinate to this body was the Supreme Magistracy of the Hundred which included officers who were appointed to this assembly by Pentarchies, or Boards of Five. These Pentarchies were tribunals or courts comprised of judges, and were founded in 396 BC (Lancel 1995, 114). It is important to emphasize that before the position of judge was synonymous with the executive branch, it was an official title that enabled its holder to fill senatorial and judicial functions. By the time of the Punic Wars in the 3rd century BC, a permanent senatorial committee of thirty members was established, the members of which sometimes accompanied the generals abroad where they acted as ambassadors (Livy XXX: 16; Warmington 1969, 141).

Receiving no pay for their governmental duties, the title of judge was a mark of honor and distinction. It enabled its holder to influence politics, perhaps soemtimes with an eye toward protecting commercial investments. Boards of judges also acted as lawgivers, adjudicating lawsuits brought to the state. Instead of different branches of courts holding specific types of trials, such as at Sparta, all lawsuits were brought before these fixed Boards (Aristotle II.viii.4; also III.i.8). One of the most striking features of Carthaginian democracy was the People's Assembly. Matters and proposals could be referred to this body when the king and elders unanimously agreed to do so. Furthermore, if a specific issue failed to reach consensus between these latter two, it would be put forth to the people (Aristotle II.viii.3).

iii. *People's Assembly*

This assembly possessed the unprecedented power of allowing any citizen to speak and petition against proposals brought to it by the other governmental bodies (Aristotle II.viii.3). Even when the king addressed the assembly, any citizen had the right to debate. Hannibal appealed to the People's Assembly to revoke lifelong tenure of the judges, and succeeded in creating annual elections without the possibility of serving two consecutive years (Livy XXXIII: 46; Lancel 1995, 119). The People's Assembly also had the power to elect generals from the First Punic War onward (Diodorus Siculus XXV:8; Polybius I: 82,12). Lancel (1995, 118) points out that whereas Aristotle praised this assembly's incorporation of everyman in the 4th century BC, Polybius labeled this as a flawed constitutional infrastructure dangerous to the state by acquiescing to the common masses rather than keeping decisions in the hands of a supposedly cool-minded elite in times of crisis (Polybius VI: 51).

iv. *Citizenship and Other Titles*

Specific functionaries operating in the Carthaginian government are known to scholarship through text and epigraphy, but surely many more existed that exceed our knowledge. Textually, there are references to a state treasurer, censor of morals (Livy XXXIII; Nepos, *Hamilcar*, III: 2; Warmington 1969, 140), and epigraphically to functionaries such as accountants (Lancel 1995, 120; Sznycer 1978, 585). Epigraphically, there are also multiple declarations of citizenship. There are some nine instances of "Citizen of Tyre" at Carthage and Sabratha in Libya, "Citizen of Carthage" in Tyre, and "Man of Sidon, Priest" in Sardinia (Kaufman 2009; Stieglitz 1990; Bordreuil and Ferjaoui 1988). Citizenship at Carthage was not limited to Phoenician ethnicity, as two of Hannibal's officers were part Syracusan but also Carthaginian (Livy XXIV: 6.2; Polybius

VII: 2.4; Lancel 1995: 120). There are also further epigraphic attestations of scribes, priests (Charles-Picard and Charles-Picard 1958), a chief valuer (Lancel 1995, 120; CIS I: 132), as well as judges.

In the last decades of the city's existence, a school of Pythagoreans was established. One Carthaginian is known to have held a reputable academic position abroad in Athens. Hasdrubal became head of the Academy at Athens in 129 BC, seventeen years after the Roman destruction (Cicero, *Tusc*., III: 22.54; Diog. Laert. IV: 67; Warmington 1969, 152).

v. *Constitution*

Besides the aforementioned aspects of the Carthaginian constitution, a few other principles are known to us from Aristotle. Kingship was not limited to bloodline (II.viii.2). One man could hold multiple offices simultaneously, considered a distinction among Carthaginians but held as inefficient by Aristotle (II.viii.8). Attempts to distribute wealth were embedded in the constitution, as common people would often be sent abroad for political appointments in the colonies, with the goal to "heal the social sore and make the constitution stable" (II.viii.9; Neville 2007, 206). Beyond political appointments, Aristotle praises the Carthaginian policy of establishing their citizens abroad in colonial enterprises in order to "make them well-off" (VI.iii.5), a Malthusian reasoning in the sense that it implies that the state sought to decrease an apparent surplus of citizens in lower socioeconomic classes who could be granted state tenders abroad, providing opportunities to increase their fitness by establishing themselves elsewhere (Trigger 1996, 36). Politicians were allowed to engage in business (and control over the affairs of this business was likely the highest incentive for them to hold office), unlike other Mediterranean oligarchies (V.x.4). According to Aristotle, the constitution was noteworthy for its general concern of the common people (IV.v.11), as demonstrated by the existence of the People's Assembly. The fact that a tyrant never arose in Carthage before or during his lifetime was "proof of a well-regulated constitution" (II.viii.1). As if this was a challenge made by Aristotle, just years after the philosopher's death, Bomilcar did attempt to seize absolute power (308 BC) and was consequently tortured and killed by the people (Diodorus Siculus XX: 43-4; Warmington 1969, 125).

vi. *Military Tradition*

It is clear that a full treatment of the textual sources dealing with the Carthaginian military is not suitable for the current research, as the bulk of classical historians from the Greeks to the Romans were mostly fixated on this aspect of Carthaginian society. Instead, a limited treatment is offered here dealing with the salient features of the Carthaginian military insofar as it relates to their legal system. As Tyre relied heavily on mercenaries to defend its walls (Ezekiel 26:10-11; Katzenstein 1997, 156), Carthage too sought the bulk of its armed forces from soldiers for hire and subject populations (Fariselli 2002), likely also enticing native troops to join voluntarily. The officer corps seems to have been comprised of Carthaginian citizens, likely stemming from certain families of the landed aristocracy that sought wealth abroad, but through naval rather than merchant seagoing endeavors. With the advent of Malchus, land forces began to be employed in earnest. From a constitutional standpoint, military honors were granted officially. An armlet was issued to a Carthaginian citizen for every campaign in which he served (Aristotle, *Politics*, VII.ii.6), promoting valor and loyalty by encouraging service members to exhibit a conspicuous display of belonging and bravery. Warmington (1969, 143) hypothesizes that, unlike the Roman consuls, Carthaginian generals took the field for several years and were therefore highly experienced. Their tactics were based on a tempered approach and conservative policies of engagement, as failure in battle often resulted in crucifixion.

It is likely that an early focus on iron production as a Phoenician colony allowed the Carthaginians over many centuries to refine this technology. Iron and steel production offered the state a chance to develop a competitive advantage regarding ferrous technological approaches to warfare. It seems fairly clear, based on the archaeological evidence, that following independence, the Carthaginian state took over from the Tyrian state in controlling the production of metals in the Punic World just after a period often termed the "crisis of the 6th century BC."

E. *Carthaginian Expansion and the Punic World*

It is useful to clarify what is meant by "Punic." According to traditional cultural historical scholarship, it would be ideal to assign Punic material culture to specific ethnically or linguistically similar descendants of Phoenicians. However, centuries of commercial relationships between Phoenicians and indigenous groups obviously created genetically and culturally diverse groups whose identities continued to be rooted in their city or region of origin rather than on a monolithic ethnic, racial, or ethno-linguistic identity (Kaufman 2009).

Scholarship has tended to define the cultural context of the Punic world as an extension of Carthaginian policy, expansionary aims, and colonial strategy—an essentially political definition. The Punic world is defined as the areas in the western Mediterranean inhabited largely by descendants of Phoenician settlers, and includes the Spanish Levant or Andalusia, as well as the southwestern part of Iberia (including Cádiz), Ibiza, Malta, western Sicily, Sardinia, and the Maghreb. It is very difficult to quantify what percentage of certain sites would be Punic, and what parts indigenous but also adopting Phoenician-Punic material culture (van Dommelen and Gómez Bellard 2008). For example, the term "Punic" is rarely used to describe actual demographic components of Hannibal's army in works such as Polybius, Livy, and Appian. More frequently we hear of "Punic perfidy" as cultural traits of the Punic world (Lancel 1998), whereas the troops themselves are Carthaginians, Libyophoenicians, Balearic Islanders, Celtiberians, etc. It may be stated that to attempt to find Punic people is a misstep. We are rather dealing with a situation of "hybridity" (van Dommelen 2006, 2002, 1998, 1997; Tronchetti and van Dommelen 2005) and "entanglement" (Dietler 2010), in which a cultural complex developed differentially in the various Punic regions and according to the specific mercantile, Semitic/indigenous, environmental, and political contexts over multiple centuries (see Vella 2005, for a good treatment). This world then produced Punic Carthaginians, Punic Libyophoenicians, Punic Balearic Islanders, Punic Celtiberians, Punic Maltese, etc. The lack of surviving texts in most of these regions, not to mention from Carthage and her environs itself, limits our ability to further quantify the "Phoenician" core of these people groups—an ethnonym that itself was laminated over the coastal Canaanites by Greeks.

For our purposes, the task can be clarified by affiliating Punic settlements with earlier Phoenician foundations which were then incorporated into a generalized Carthaginian sphere of influence, assisted by linguistic, cultural, and likely often kin-based familiarity. At Carthage itself, affiliation with the state itself was an important mark of identity as seen in the inscriptions in Chapter 5. Working forward with the 6th century BC Carthaginian mixed model of economic mechanisms and military intervention, by the 3rd century it is theoretically much easier to define the Carthaginian world based upon distinct Carthaginian material culture such as coinage (cf.

Robinson 1956) although important Roman sites built over Carthaginian foundations often catalyzed into modern cities, making excavation and identification of the earlier strata untenable.

The emergence of Carthage as an imperial entity seems to have followed the Phoenician model of exploiting and adapting to local conditions that would yield commercially or politically profitable relationships to the city. Contemporary with the so-called "crisis of the 6th century BC," when large-scale abandonment or destruction of many urban centers combined with intensified fortification of others are characteristic of the time, Greek desires to capitalize on this relative vacuum began to come at odds with renewed Phoenician interest in the colonies under the Carthaginian, rather than the Tyrian, banner. Now, in addition to the acquisition of mineral and timber resources, Carthage began to employ land forces in tandem with naval strength.

Results from across the Central and Western Mediterranean show a more or less consistent pattern during the 6th century BC. Firstly, large scale abandonment of urban centers and cessation of mining activities were the hallmark of the mid-6th century BC. This was followed by the appearance of Carthaginian material culture, reinforced by textual references. The Middle Punic period at Carthage itself is also distinguished by widespread import capabilities spanning the entire Mediterranean Basin as seen in the amphorae assemblage at Bir Massouda (Bechtold 2008, figure 10), and substantial imports continue into the Late Punic as well (Bechtold 2010). By the 4th century, rural intensification skyrocketed in Iberia, the Balearic Islands, Sardinia, Sicily, Malta, and North Africa. Despite a relative lack of archaeological (and textual) evidence from the 6th through 4th centuries BC, a synthesized picture has begun to emerge in the recent years that allows for the beginnings of a holistic understanding of the Punic territories.

The earliest Phoenician settlements are those established at the turn of the 9th and 8th centuries BC at Doña Blanca and Morro de Mezquitilla, on the Andalusian coast, and also Huelva (Aubet 2008, 247; Canales, Serrano, and Llompart 2008, 648). La Fonteta is another candidate for an earlier Phoenician foundation, with some evidence indicating 9th century Phoenician/Iberian contacts (González Prats, García Menárguez, and Ruiz Segura 2002). Generally across Iberia, botanical evidence indicates a variety of timber types, cereal cultivation of barley and some wheat, lentils, as well as figs, olives, grapes, plums, almonds and walnuts. Faunal evidence shows cattle, pig, chicken, goat and sheep, fish, shellfish, horse, and game such as deer, rabbit and cranes. Different sites of course contain differing amounts of the above products (López Castro 2008). The mid-6th century BC witnessed a crisis in settlement, as most towns and villages were abandoned. These were reoccupied, most heavily during the 4th century BC during which many new sites were established. The Phoenician-Punic archaeology of Iberia is one of regionally variant interactions between the Phoenician or Carthaginian settlers on the coast and the Iberian and Tartessian inhabitants of the interior.

It is unclear how much violence Carthage actually employed during the “crisis.” What is more plausible based upon the available evidence is that internal frictions caused abandonment, desertion, and the Carthaginians capitalized on these new local conditions, much as their Tyrian predecessors did. In places like Sardinia, it appears that Carthaginian colonists settled together with indigenous Sardinians forming van Dommelen’s “hybrid” culture, but also employed military tactics (Bernardini 2008). Whereas the Tyrians always had a navy ready to assist the Mesopotamian empires, Carthage also employed land forces. But the Carthaginian method of expansion was in some ways similar to the earlier Phoenicians. Instead of tapping into new local trade networks, Carthage was able to resurrect previous networks to her advantage (Neville

2007, 164). Neville (2007) is correct that it is unlikely that Carthage adopted a uniform policy of conquest, as this is a monolithic explanation that can hardly account for any imperial formation in the human past or present. Instead, a combination of control of political economy, backed by force, is more likely (Stanish 2003; Earle 1997). The use of direct force with a citizen and mercenary army (Fariselli 2002) in order to implement hegemonic policy is what begins to distinguish Carthage from Tyre, as opposed to using a citizen or mercenary army merely for defense, or to combine with (or resist) neighbors in rebellion against the Mesopotamian empires.

i. *Iberia*

A shift in the types and preponderance of metals and mining activity represents one hallmark of the "crisis." In the Early Iberian Period (550-400 BC), iron weapons are predominant in tombs whereas in the preceding periods they are totally absent (Sanmartí 2009, 66). The mineral rich zone of Huelva witnessed a cessation of construction activity in the settlements, along with a decrease in population as of 550 BC and a drop in Greek imports (Neville 2007: 163). Sites along the metal procurement chain on the Rio Tinto were abandoned, such as Peñalosa, and San Bartolomé de Almonte, but others such as Tejada la Vieja reflect the building up of fortifications and intensification of agriculture and herding instead of metal production. La Fonteta also probably absorbed refugees from El Cabezo Pequeño del Estaño, a fortified wall also being constructed there (over the former metallurgical zone; Neville 2007, 165). Sites like Tharsis and Aznalcóllar continue producing silver, but to a far less extent. One of Neville's interpretations of the precipitation of the "crisis" is the possible exhaustion of easily accessible silver mines. Conversely, both Frankenstein (1979) and Neville suggest an over-saturation of silver in the Assyrian market and a corollary collapse in price. At the Portuguese Atlantic site of Abul, a sanctuary dated to the 6th-5th centuries BC may be attributed to Carthaginians. Other sites across northwest Iberia show evidence of renewed Mediterranean contacts from the 6th-4th centuries BC, with the sudden and ubiquitous appearance of Carthaginian contact through material culture such as pottery and polychrome glass (González-Ruibal 2006, 128).

There is direct evidence for the substitution by Carthage of the former Phoenician long-distance trading routes in Iberia. Carthaginians settled at Ibiza, Villaricos, and Almuñécar. Many sites in Iberia had been abandoned peacefully, but others were destroyed in conflagrations. La Fonteta was abandoned in ca. 545 BC, and La Peña Negra was destroyed (Neville 2007, 165). If Diodorus Siculus is correct about the 654 BC date for a colony on Ibiza (Katzenstein 1997, 293), the Carthaginians had already established colonies of their own during the height of Tyre's power, and it is most plausible that they capitalized on these foundations to expand their influence and protect their allies in the economic and perhaps military vacuum created after Tyre's fall to the Babylonians. Further abandonments occurred ca. 570 BC at Cerro del Villar, and at end of the 6th century BC at Abul in Portugal (Neville 2007, 166-167). Evidencing the transfer of power from abandoned centers to newly invigorated centers, Malaga was founded at the beginning of the 6th century as well.

Not much can be stated definitively about Iberian indigenous mechanisms of adaptation to this "crisis," but we do know that instead of scattered small settlements, we see the rise of large, fortified, *oppida* centers. Although the commercial activity of 6th century Iberia pales in comparison to the previous centuries, enough of an infrastructure remained for Carthage to seize the opportunity. Sites like Gadir, Tejada la Vieja, and for a time La Fonteta, all maintained their independence and show nucleation of population and construction of fortifications. Rather than a purely invasive model wherein a previously nonexistent Carthaginian military sprang up to conquer, or one in which all destructions are seen as evidence of internecine struggle, 6th century BC Iberia is most plausibly explained by following Burke's (2008, 101) model of fortification. In this approach, it is recognized that in order to construct monumental structures, a certain degree of stability is required for elites to organize large-scale construction activities. The "crisis of the 6th century BC" should be seen as being characterized both by internecine struggle and Carthaginian protectionism of Punic and Iberian allies as the political, economic, and military landscape was altered as a result of Tyre's removal from the list of major players. In the aftermath of a reorientation in trade and political economy, alignment with the nascent Carthaginian Empire would have been sought differentially and according to shifting political allegiances and commercial needs.

ii. *Ibiza*

Prehistoric settlement in Ibiza came to an end in the 13th century BC, to be settled anew by the Phoenicians/Carthaginians in the 7th century. Two villages were settled at the Bay of Ibiza. The major town throughout the Phoenician-Punic settlement is underneath modern-day Ibiza town. Evidence of lead-silver metalworking was excavated there, and analyses have demonstrated that the mineral resource was exploited on Ibiza itself (Gómez Bellard 2008). Around the mid-6th century BC, a Carthaginian imprint begins to be seen. It appears that Carthage established a settlement at Ibiza, Sa Caleta, by the end of the 7th century (Gómez Bellard 2008; Ramón 2002).

Exploitation of silver and lead ores was perhaps a driving factor, as well as agricultural output. Cremation was abandoned as a practice as inhumation was adopted, resulting in a large cemetery at Puig des Molins near Ibiza town. Carthaginian and central Mediterranean typologies mark the accompanying grave goods. This period is also when the rural landscape of the island began to be exploited, perhaps by an influx of Punic settlers from Carthage. Although the data on flora and fauna is not as robust as might be desired, evidence indicates that olive oil and wine were the main products grown in Ibiza, the farms being organized centrally from Ibiza town. Salt and high-quality ceramics were secondary items produced for export. Domesticates included pigs, cattle, sheep/goats, equids, and dogs. Rural settlement was established on a large scale by the 4th century BC, and consolidated by the 3rd century. Roman control of the island following the Second Punic War resulted in a booming agricultural economy throughout the 2nd century BC, turning down at the end of this century (Gómez Bellard 2008).

iii. *North Africa*

It is difficult to find natural harbors along most of Algeria and Morocco, but the Tunisian and western Moroccan coasts had harbors and were utilized by Phoenician colonizers. Cape Bon, where Carthage is located, boasted some of the best agricultural land in antiquity. Southeast of Cape Bon is the fertile coastal plain, or Sahel, where many settlements were also located. Extending southwest of Cape Bon running into Algeria is the Mejerda Valley, which was utilized extensively for cereal cultivation (Fentress and Docter 2008). Urban bias in archaeology has skewed settlement data in North Africa, but this has begun to change over the last decades. There appears to have been a villa system in place as evidenced by Fantar's (1984) excavation at Gammarth, as well as textual descriptions of Megara, both places close to Carthage. Despite limited knowledge of the urban layout of Carthage, some aspects of the rural realities are fortunately clear. The Carthage Survey established a few valuable facts about the Carthaginian hinterlands within a 30 km radius of the city (Greene 1986). In the 7th-5th centuries, or formative phase, Punic sites are scarce, numbering only seven. Compared to later periods (4th century, 9 sites, 3rd/2nd centuries, 50 sites), this indicates a reliance on Numidian agricultural production (likely exchanged for finished iron products), or on imported cereals. Iron production inland at Numidian Althiburos in the 10th or 8th centuries BC indicates contacts between the autochthonous population and Phoenician settlers including ferrous technological transfer, although let it be said that we still do not know enough about the development of African ferrous metallurgy to conclusively disregard the possibility for independent discovery in earlier periods (Sanmartí et al. 2012; Kallala et al. 2010). A level dated to the end of the 9th century BC at Althiburos provided one tantalizing iron implement. Close to the Carthaginian core in Althiburos, the beginning of the 6th century BC witnesses gradual Punic influence, including perhaps actual Carthaginian settlers as evidenced by a Punic cistern, and even a defensive wall by the 3rd century BC (Sanmartí et al. 2012, 33, 6-7).

Modern build-up limits our knowledge of what suburban Carthage could have produced in terms of garden or estate products, as described by Mago (Krings 2008; Greene and Kehoe 1995; Greene 1986). Phoenician and Punic settlements and epigraphic finds are known from modern-day Libya, at sites such as Lepcis Magna with Phoenician, Punic, and Neo-Punic occupations from the 7th century BC onwards (Carter 1965), and Sabratha (Kaufman 2009).

The Carthaginian diet, or broadly their agricultural hallmarks, comprised of emmer wheat (which goes out of fashion during the Roman occupation), salted olives and olive oil, opium poppy seeds (and perhaps opium extract), and flax. Furthermore, the famed Carthaginian propensity for fruit growing was verified with evidence of grapes and wine (Greene 1995), figs, pomegranates, mulberries, peaches, plumbs, and almonds (van Zeist, Bottema, and van der Veen 2001, 59). There is also evidence of wild blackberries, hawthorns, a jujube species, with limited amounts of blackberries. Further pollen evidence indicates the planting of manna ash. Imported foods include stone pine, hazelnut, and walnut.

By the Late Punic period, the population of the hinterlands did not likely exceed 87,000 people. At Djerba, until the 4th century BC, there was very little rural exploitation (Fentress and Docter 2008), similar to the situation in Sardinia (van Dommelen 1997). But it is only in the 4th century BC that colonial settlements really took root, with many established in the 3rd and 2nd centuries BC. With the increase in agricultural exploitation, cattle decreased in the areas around Carthage and gave way to goat and sheep. Wild bird populations of geese and duck dropped, giving way to domesticated birds. The island of Djerba (earliest pottery is a 6th century Ionian cup) was mostly urbanized until the 4th century BC, when rural sites began to become the predominant feature of the island. In the 3rd century BC there was a marked increase in rural sites, achieving as many as 93 farms in the 2nd century. The Sahel was also a fertile location of mostly oasis agriculture. Pliny describes farms there as layered: olives growing beneath palms, pomegranates and figs beneath the olives, and grain and vegetables beneath these (18.51; Fentress and Docter 2008). Pliny attributes this to a markedly Punic style of agriculture.

In Algeria and Morocco there were some abandonments at the end of the 6th century BC akin to the situation in Iberia. At this time, Mogador in Morocco and Rachgoun in Algeria both witnessed abandonment (Neville 2007, 166). There is abundant evidence for Punic style cemeteries, with the only published one being in Cherchel (Algeria). Olives were cultivated in the area around Lixus in Morocco in the 7th century by Phoenicians. By the 3rd and 2nd centuries, barley, wheat, sorghum, grapes, legumes (chickpeas, lentil, fava beans, vetch), and flax were grown there. All of this data comes from Lixus, and no rural survey has been carried out. At Lixus, cattle were the early domesticate as at Carthage and gave way to sheep and goat. Pigs were increasingly utilized in the Punic period.

The overall trend seems to be that early Phoenicians were not engaged in subsistence farming activities for the first centuries of their colonization, but relied on trade. During the 6th century this changed, with substantial increase in Punic agriculture taking off in the 4th through 2nd centuries BC (Fentress and Docter 2008). The southernmost known Phoenician establishment is on the island of Mogador, most probably within the sphere of Gaditanian influence in the 7th and 6th centuries BC, as opposed to being affiliated with Carthage (Aubet 2001, 301-2). Lixus was occupied from the 8th century BC, and may have had a mint in Punic times from the Hercules/Melqart temple (González-Ruibal 2006, 124; Aranegui 2001; López Pardo 1992).

iv. *Sicily, Pantelleria, Malta*

Due to the fact that the Sicilian channel represents a choke point for east-west Mediterranean maritime travel, the western coast of Sicily and Malta represented a point of early importance for Phoenician settlement and commerce. The earliest settlement of Motya was joined by many other Sicilian sites with natural harbors and fertile valleys leading up into the mountains. Sicily became a focal point of military aggressions between Greek colonies in the eastern part of the island, and Carthaginian interests in the western part throughout the 5th and 4th centuries BC. Carthage really took control of the Punic colonies in the 5th century, and by 405 BC a treaty dividing the island between Syracuse and Carthage was penned (Figure 1; Spanò Giammellaro, Spatafora, and van Dommelen 2008). Archaeological finds at sites in the interior are not as clear cut in defining political hegemony (known as the Carthaginian *epikrateia*), as Punic, Greek and indigenous wares abound throughout the periods, especially at interior hilltop settlements. However, the bulk of rural settlements were established in the 4th century BC and a great deal of Punic pottery—notably North African amphorae—circulated throughout the island.

The volcanic island of Pantelleria sits right in the middle of the channel between Sicily and Cape Bon, making it an ideal advanced naval outpost. Agricultural potential of the island was utilized in the 4th century BC as well, with two thirds of all amphorae being Punic North African. 256 cisterns of Punic construction were discovered on Pantelleria. The acropolis of San Marco represents the major Punic site of the island. Although the exact date of earliest Phoenician settlement is disputed, it is clear that the site at Rabat-Mdina was an early nucleated site. To date, 19 rural settlement and 642 burials dating to the Phoenician-Punic period have been found (Spanò Giammellaro, Spatafora, van Dommelen 2008).

The Maltese countryside was also intensively exploited from the 4th-3rd centuries onward, but lacked mineral wealth that would have attracted intensive Phoenician or Carthaginian occupation (Spanò Giammellaro, Spatafora, van Dommelen 2008; Vella 2005, 444). It is hard to pinpoint an exclusive Phoenician or Carthaginian Punic presence in the island population, as Greek, Roman, and indigenous traits accompany the material culture through all periods (Sagona 2008, 488). But Sagona (2008, 513, 525-32) places permanent Phoenician colonial activity by the last half of the 8th century BC (no well-contextualized evidence can be dated before ca. 750 BC; Vella 2005, 439-40), with a distinctive Punic occupation from ca. 500-300 BC.

v. *Sardinia*

Carthage took control of the island by the last half of the 6th century BC. Archaeological evidence is furnished by the destruction of a ritual center at Cuccureddus of Vallasimius ca. 530 BC, destruction of the settlement of Monte Sirai ca. 520 BC, and the accompanying influx of Carthaginian material culture including gold workshops (Bernardini 2008, 573). All rural sites were abandoned in the late 6th century. The 4th century saw the establishment of mostly farms, cemeteries and cult sites. There are a number of Tophets found on the island, and many sites have indigenous *nuraghi* incorporated into Punic architecture (van Dommelen and Finocchi 2008). From the 5th to 3rd centuries BC at Tharros, a metallurgical facility with furnaces, slag, and Carthaginian coins was most likely a Carthaginian mint (Attanasio, Bultrini, and Ingo 2001; Manfredi 1997).

Sardinia was originally characterized as having "capillary" settlement types, meaning almost all of the island would be covered by sites but would contract during certain periods. There seems to be a general retraction of rural sites from the 6th to 5th centuries BC, gaining ground in the 4th century BC, but not fully fluorescing until the Roman period (Bernardini 2008, 586; van Dommelen and Finocchi 2008). The only Punic town that has been exhaustively excavated is Neapolis. It is unclear how to define the many agricultural centers—were they urban or redistributive? Naked wheat, grapes, sheep, pigs, cattle, dogs, deer, ducks, foxes, and wild boar make up the bulk of floral and faunal evidence. The earlier Phoenician sites contain more game animals than domesticates, which is not surprising as other early Phoenician sites also show that the early colonists relied on native agricultural output (van Dommelen and Finocchi 2008) likely supplemented by hunting. It is likely that the mineral wealth of Sardinia, in addition to its strategic position, was highly attractive to the Carthaginian state in the formative phase of empire.

The emergence of Carthage as an international power is one that began in the last half of the 7th century BC, as it founded its own colonies such as on Ibiza, and initiated industrial production of metallurgy. By the first quarter of the 6th century BC, as Tyre's power was abruptly cut short, it focused its expansionist and protectionist policies via the formation of a military class. If this class had previously existed, it now gained notoriety and began fostering a military tradition. It is at this time when we can begin to actually distinguish between Phoenician and Carthaginian. This began not as a linguistic, ethnic divide, or political divide alone, but rather as one between the old Phoenician merchant class and the nouveau Punic generals at Carthage itself. Whereas it was the overarching Tyrian mercantile genius that allowed for the Phoenician world to maintain its distinct commercial character across the Mediterranean and Near East through a monopoly of sorts in the transport and refinement of mineral resources, certain elements within Carthage realized that in order to maintain this wealth it was necessary to establish and deploy an army, and forge new alliances. Investment in centralized industrial ferrous technology and commissioning of metallurgical precincts is seen as a behavioral mechanism of the Punic state to promote their role as the new political center of the Phoenician world. As the Tyrian state can be called a mercantile cooperative empire, Carthage began to fashion itself into a mercantile coercive empire.

Chapter 3. Methods

A. *Excavations and Materials*

The materials considered in this study were excavated from 2000-2004 in the Bir Massouda area of Carthage. They are comprised of 54 metallurgical ceramics with residual slag attached (although more than around hundred were excavated, some are currently in Tunis), 17 pieces of loose slag not attached to ceramic components, 14 copper alloys, one piece of cobalt rich material that may be a glass or pigment, three lead pieces, four iron pieces, one ceramic associated with glass production, soil recovered from the furnaces, lithic components of the metallurgical infrastructure such as a basalt anvil and a likely bloom or ore grinder, as well as 22 copper alloy and iron ore and slag standards to establish general margins of error for the unknown archaeological samples (Tables 2-4). The excavations were executed by the University of Amsterdam, the Archaeological Department of Ghent University, and the Tunisian Institut National du Patrimoine (INP; for additional excavation information, cf. Maraoui Telmini 2012; Docter and Bechtold 2011; Docter 2010, 2009, 2008, 2007, 2002-2003; Bechtold 2008; Maraoui Telmini et al. 2008; Docter et al. 2006; Docter et al. 2003; Docter, Chelbi, and Maraoui Telmini 2002). The materials have been assigned periods based upon the field reports and chronological interpretations of the materials provided by Roald Docter. Materials from the household contexts under the Decumanus Maximus were dated based upon the excavation reports also provided by Roald Docter. When rounded dates such as “800-500 BC” are given, they represent the *terminus post quem* and *terminus ante quem*, respectively, of the range of the excavated phases and are not intended to indicate absolute dates. Although the ceramic seriation associated with the Early Punic metallurgical remains does span 800-400 BC, Docter indicates that the metallurgical precinct was mostly in operation between ca. 650-425 BC. At this point the metallurgical zone activities were halted and a residential quarter was constructed. Although four tuyères with slag date to 200-146 BC from the Roman destruction layer and are therefore most likely dated to the end of the Late Punic era and the fall of Carthage, they are from a destruction layer meaning their use context is unclear. It is possible that they are residual metallurgical infrastructure from earlier periods, but whatever the case they do not provide evidence for the resurrection of a centrally organized precinct.

Radiocarbon sequences have established the first absolute dates at Carthage (Docter et al. 2008; Docter et al. 2005), and relative chronologies were clarified by recent excavations (Bechtold 2010). Selected samples from representative artifacts from sound contexts were taken from the field. Any attempts to record the tonnage of slag from Bir Massouda would be speculative.

B. *Sampling*

A number of techniques and methods were used in order to extract analytical data from the various artifacts. The three major corpora represented in this research are 1) tuyères (or in some cases unidentified ceramics which could be tuyères, crucibles, etc.) with residual slag still attached to the ceramic components, 2) unattached or loose slag, and 3) alloys and corrosion products. All of the artifacts were collected or had representative samples taken in the archives of the Department of Archaeology of Universiteit Gent, Belgium. They were stored there since being exported from Tunisia. All archaeometallurgical artifacts were divided by chronological phase, i.e., Early Punic, Middle Punic, and Late Punic, in order to determine the extent of the entire corpus of metallurgical material culture remains.

The complete tuyères with slag attached were not sampled, but exported whole. Some of these artifacts are well-preserved, with the ends of the tuyères and slag maintaining the original shapes. Others were in a fragmentary state due to site formation processes or fracture during use (Schiffer 1983). Representative samples were taken from loose slag. In many cases the slag chunks were hammered, rendering a pea-sized sample to be brought for export. The alloys and corrosion materials were also subject to standard metallurgical representative sampling practices: both before and after sampling, artifacts were photographed in order to document the original piece and the subsequent change. Artifacts were secured by a padded vice, and a jeweler's saw was used to take "V" shaped samples and/or edge sections. Cross sections were also sometimes removed. Sampled artifacts were stored in Eppendorf vials or conservation paper.

The samples were thereafter exported to the Cotsen Institute of Archaeology. Laboratories that provided support in sample preparation and analysis of all archaeological samples and modern standards included the Molecular and Nano Archaeology Laboratory (MNA), and the GCI Conservation Institute Laboratories at the Getty Villa. Mounting and grinding procedures for all artifact types also follow that of Kaufman (2013), namely that samples were mounted in a two-part epoxy resin, ground with 240 then 600 PSA backed grit, followed by polishing with monocrystalline diamond suspension and/or non-crystallizing colloidal silica suspension of 6 µm, then finished with 1 µm and/or 0.02 µm.

C. *Instruments and Settings*

Analytical methods employed were portable X-ray fluorescence spectroscopy (pXRF), variable pressure scanning electron microscopy coupled with energy X-ray dispersive spectroscopy (VPSEM-EDS), and metallography using light optical microscopes. Supplemental methodological information to that provided here is in preparation for publication in a series of articles.

i. *X-Ray Fluorescence* (XRF) *Spectroscopy*

Portable x-ray fluorescence spectroscopy (pXRF) was used for analysis of the tuyères with slag, loose slag, lead alloys, and furnace soil. Slag and ore standards, as well as bronze standards, were used to estimate margins of error. The instrument used is a Thermo Niton XL3t Goldd+ from ThermoFischer Scientific. Settings for the tuyères with slag, loose slag, slag and ore standards, and the furnace soil was the "mining Cu-Zn" mode, 120 seconds duration (maximum time 121 seconds), divided into four parameters for detection of elements in weight percentage (wt%) of 30 seconds each (main, high, low, light). In Appendixes I and II, one spectrum was chosen from these four parameters to show certain characteristics for individual specimens, or else generically to show the components typically found throughout the corpus. The instrument has a silver source and therefore is not appropriate for measuring silver values. There was occasional spectral interference between the silver Kβ line and the tin Kα line, but the differences are easily resolved by viewing the spectra. The furnace soil was also analyzed on "Soil" mode, 90 seconds duration (maximum time 91 seconds), divided into three parameters for detection of elements in parts per million (ppm) each (main, low, high). For the lead alloys and Getty bronze standards (published by Heginbotham et al. 2010), the "General Metals" mode was used, with 120 seconds duration (maximum time 121 seconds), divided into three parameters for detection of elements: 60 seconds high, 30 seconds low, 30 seconds light. Sometimes a toggle spot was used for analysis, other times the toggle was disabled. Each ore and slag standard average was generated from two spots on pXRF. Three significant digits are often reported for the pXRF data, but this is only because it is what the instrument provided and not because the detection limit is actually that resolute.

ii. *Polarized Light Microscopy* (PLM)

Metallographic polarized light microscopy was conducted with a Nikon Epiphot-TME Metallograph microscope, as well as a Leica DMRM. Mostly optical light was used, but for some of the micrographs differential interference contrast (DIC) and/or a red compensator plate was used in order to increase the depth contrast of the image, as well as polarization and dark field settings. Micrographs were mostly taken with a 14 MP eyepiece digital camera UCMOS series microscope camera, UCMOS14000KPA-U-NA-N-M-SQ=NA with ToupView 3.2 image software USB 2.0 DC 5V 250 mA P/n tp6140001, but also in some cases with a Nikon digital camera D3000.

These methods were employed in order to discern the microstructure of both slags and alloys and corrosion products. It was conducted on all of the alloys and corrosion products excluding lead, one iron alloy and bloom, all of the loose slag, and 10 of the tuyères with slag.

iii. *Scanning Electron Microscopy* (SEM) *and Energy Dispersive X-Ray Spectroscopy* (EDS)

Scanning electron microscopy (SEM) with energy dispersive x-ray spectroscopy (EDS) was performed on alloys and corrosion, on selected samples of loose slag and tuyères with slag, and on bronze standards and the iron ore and slag standards. The instrument located at the Molecular and Nano Archaeology (MNA) Laboratory in the School of Engineering and Applied Science at UCLA is a FEI Nova^{TM} NanoSEM 230 scanning electron microscope with field emission gun (FEG) and variable pressure capabilities, equipped with a Thermo Scientific NORAN System 7

X-ray Energy Dispersive Spectrometer (EDS). For the alloys and corrosion, and bronze standards, a gaseous analytical detector (GAD) detector in variable pressure was used for the detection of backscattered electrons (BSE), providing images with compositional contrast; atoms of heavier elements elastically scatter electrons more strongly compared to those of lighter elements, resulting in higher signal intensity for elements with higher atomic numbers making them appear brighter. Accelerating voltage was kept to 15 keV, usually a spot of size of 5 was employed, chamber pressure was set at 50 mPa, and working distance around 8 mm. Aperture settings were adjusted in order to increase peak intensities. Five average spots were taken at 1500x magnification for the alloys. Although it would be ideal to quantify the average iron content of slags, this is impractical due to characteristic heterogeneous nature of slag. Buchwald and Wivel (1998) show that within nine spots analyzed in one iron/steel bar, the FeO content of the slag ranged from 5.33-56.12 wt%. As many spots as possible were taken on the slag surfaces with pXRF in order to generate a semi-quantitative composition, but no attempt to quantify using EDS was made except for targeted spots.

Efforts were made to capture only metal spots on the alloys, but often corrosion was unavoidable. For artifacts that were completely corroded, the alloy average should be close to the original barring leaching into the soil matrix which is discussed in the Appendixes. Oxygen, carbon, chlorine, calcium, potassium, aluminum, and phosphorus were excluded from the alloy readings as these mostly represent post-depositional inclusions. Sulfur was included as this can be left from the smelt, although often it may be introduced from the soil. No elements were excluded from the slag compositions, except for the standards wherein only the known quantities were included. Tuyères with slag, loose slag, and the iron and ore standards were also analyzed using the same settings, namely low vacuum, a spot size of 5, and usually an accelerating voltage of 15 keV for compositional readings with adjustments made in intensity and aperture for imaging.

D. *Analysis of Standards*

A number of standards were employed to approximate margins of error for both the pXRF and SEM-EDS (Tables 2-4). Twelve certified reference standards from Heginbotham et al. (2010) were employed to correlate the experimental data from Bir Massouda to the standards as best as possible by knowing the approximate margin of error of each measurement, using “General Metals” mode, “Main” 60 seconds, “Low” 30 seconds, “Light” 30 seconds. Following the protocol of their published study, the polished areas on the 12 samples were analyzed, once with the toggle spot, and once without. The results obtained had excellent correlation with the certified values (Table 3). The values reported here wherein the percentage was unknown precisely in the Heginbotham et al. (2010) publication, but was simply “less than” (<), should be considered qualitative at best.

However, other precise values indicated levels that often reached 99% and sometimes 100% correlation. Measurements were rounded up or down, except when exceeding 99%, in which case they were always rounded down. Eight other bronze standards were used to estimate margins of error on the EDS. Metal heterogeneity necessitated averaging over five or ten areas on the standards. Five or ten areas on each standard were analyzed at either 1500x or 3000x magnification, respectively, and the results averaged. The alloy reading in wt% was then compared against the known standard alloy wt%. Arsenic content was not significantly high enough in any of the standards to be useful to establish a margin of error. Therefore, a commercially purchased realgar (As4S4/AsS) specimen was used, the molecular formula for which yields predictable ratios of arsenic to sulfur (Kaufman 2013: table 4). The analysis of the realgar specimen was conducted in 2010, whereas the rest of the standards presented here were analyzed in 2010 and 2013, allowing for calculation of drift. The margins of error for varying elements are presented in Tables 2 (bronze standards) and 3 (Getty standards).

Elemental values as recorded by pXRF and SEM-EDS were expressed as oxides for direct comparison to the values of the standards. For pXRF, the powder of the standards was used. For SEM-EDS, the standards were pelletized. Only elements experimentally verified and recorded on the standard certifications were included, and all others were excluded, including carbon.

E. *Analysis of Tuyères with Slag*

Since the pXRF technique is the first, non-invasive analysis in a methodological chain, the samples were not polished or otherwise prepared. Many of them were fractured, and a fresh cross section of the bulk was exposed for analysis. Since none of them were polished, at best the results generated by this exercise can be considered semi-quantitative, but were applied uniformly throughout the analysis.

On slag specimens, either one spot was analyzed, or two or three were averaged when enough surface was exposed. This is indicated in Table 5. Spectra were also acquired from the ceramic tuyères, and this demonstrated that sometimes the iron content of the ceramics was indistinguishable from the iron content of iron-poor slags. Since iron makes up about 5% of earth’s lithosphere, earth’s inner core likely being nearly pure iron, low iron contents are expected in the majority of mineral or clay bodies (Anderson 1986; Charles 1980). In this case, it was found that the occurrence of manganese, characteristic of the iron slag, allowed for conclusive distinction of the metal slag from the attached ceramics in addition to ocular observation. Aluminum was recorded, however due to the low absorption energy of this element using pXRF the spectra are considered qualitative. We expected that magnesium was present in the samples, as this is a common element in iron and copper slags as an impurity. Often when using SEM-EDS, aluminum, calcium, and potassium would be present in phases where they would not be expected, such as in a fayalite lath on high magnification to avoid confusion between spots. This was likely due to the electron beam of the instrument being about one micron which creates difficulties in attempting to resolve the compositions between phases. Slag is highly porous, so samples were cleaned with water, sprayed with alcohol, and/or an air blaster was used in order to reduce contamination between the different sized grits and polishing suspensions trapped in the pours.

Presence of magnesium was verified with EDS in most cases. Microstructurally, olivine/fayalite laths are observed. Titanium was also not detected in any of the slags using pXRF, but it was often detected in the ceramic tuyères. SEM-EDS confirmed the presence of titanium contents, sometimes in high amounts such as in L.8091 17466 with certain phases exceeding 22 wt% Ti making it unclear whether this was really a metallurgical tuyère or instead used for glass production. As mentioned above, margins of error were estimated using standards. For example, the instrument recorded polymetallic slag L. 1121 17470 containing 0.194 wt% of tin (Appendix I2); tin with 0.53 wt% in one standard had a margin of error of 3% for this element (Table 3, Standard E). Dust was intentionally not cleaned off of the specimens in order to preserve any delicate remains for future analysis, except for the spots under pXRF.

Photographs were taken in order to show one key feature in each artifact, be it the combination or interface of slag and ceramics, the internal mechanics of the tuyère such as the toggle holes, the slag formation due to human intervention such as clearing holes for multiple use, slag hoods, etc. These images can be found in Appendix I. Of all the tuyères with slag, the following were mounted, ground, and polished for metallographic, or electron microscopic analysis, either the entire artifact when small enough, or a representative sample: 1060 17478, 1078 38051, 1112 38082, 1121 17470, 8091 12679, 8091 17466, 8091 38042, 8091 38118, 8092 17479, 8091 17480.

On SEM-EDS, 1060 17478 was analyzed at 20keV. 8092 38014 is an artifact that appears to have both a slag and a corroded iron object attached to a ceramic sherd. It was not included in any of the analyses. 8092 38022 and 8094 (750-575 BC) 38103 are almost certainly iron slags with ceramics attached but were not included in the analysis. There were also at least four tuyères with no slag attached found, but not included in the analysis for the sake of methodological continuity (only tuyères with slag): one tunnel preserved from 1078, one tunnel preserved from 1060, one tunnel preserved 8091 38109, and two tunnels preserved 8052 (750-400 BC) 16620.

F. *Analysis of Loose Slag*

Selection procedures for analysis:

It was found that utilization of pXRF combined with verification of slag microstructure using metallographic microscopy is sufficient for determination of slag. All metalliferous-looking artifacts that were clearly not the remains of an iron artifact were selected for pXRF to determine whether or not they were slag specimens (Table 6, Figure 7). In order to identify as many slag specimens as possible, if there was any doubt, it was checked with pXRF. If there was still a doubt, the specimen would be mounted to verify any slag phases in the microstructure. Some slag specimens with visible differences but included in the same locus and artifact bag (e.g., 8339 34955) were divided into two different artifacts (A, B). This division was later justified by vastly different iron contents, indicating that these are likely slags from different smelts or smithing episodes, although due to the heterogeneous nature of slag it cannot be ruled out conclusively that they were from the same episode. A number of porous materials were mounted, but upon inspection with an optical light microscope were excluded when no slag microstructure was found.

Based upon chronology, artifacts were further divided based upon composition to see if further analysis was warranted. Furthermore, some of the slag found in Middle Punic contexts was clearly used for fill or leveling to build the residential structures, and was excluded. Many specimens were not included in the analysis for the following reasons: 1) they did not fit into a clear chronological divide, which would have “muddied the waters” of attempting diachronic analysis; 2) some specimens were not mounted in order to preserve samples for future analysis, the archaeometric equivalent of preserving baulks. Because they were not mounted, it is also impossible to conclusively verify if they are indeed slag. That being said, they are likely slags based upon examination with the naked eye; 3) many of them are from leveling layers or fill and cannot be assigned to a conclusive period. The specimens from sound contexts and that are most likely iron slags as determined from ocular observations are included in Figure 8 for qualitative determinations. 1074 37985, probably an iron slag, was excluded from Figure 8 because it was dated too broadly, from 450-146 BC. The same is true for 8068 38070, dated 800-450 BC. Artifacts used for Figure 8 are as follows (locus and artifact number provided, but in some cases only locus was assigned): 800-530 BC – 1121 38094 (this one dates specifically to 760-600 BC), 2565 45059, 2566 45060, 2569 45062, 4448 38450, 4460 38465, 8212, two specimens from 8217, 8218, 8222, two specimens from 8227, 8237, 8240, 8241 – the following date from 700-

500 – 1117 (this one dates specifically to 600-500 BC), 1250 (this one dates specifically to 650-500 BC), 8069 38071, 8091 17485, 8091 38101, 8091 38189, 8091 38193, 8091 37986; 750-400 BC – 8086 38233, 8089, 8089 38105, 8092 37908, 8092 38076, 8092 38099; 530-300 BC – 8205; 300-146 BC – 1210 32105, 1231.

Upon mounting and grinding, some artifacts proved not to be slag based on microstructure and composition. A number of slag specimens were excluded from analysis because their dates as determined from excavations are too broad to yield comparative value. Furthermore, a number of other slags had temporal overlap with the periods used for analysis.

A balance between 1) the greatest number of artifacts, and 2) no temporal overlap was identified. The equilibrium dates from Bir Massouda, as represented in Table 6 and Figure 8 (loose slag), are periods BC 800-600, 550-475, and 330-300. The samples from under the *Decumanus Maximus* range from 700-550 BC, and are therefore partially contemporary with the 800-600 BC slags from Bir Massouda representing the first phase of metallurgical activity in the precinct. All of these slags were subjected to pXRF, metallography, and the following selected for SEM-EDS: 3348 34318, 8210A, 8210D, 8339 34955B, 8339 38255A, 8360 34930, KA91 496-17.

Since SEM-EDS was the most quantitative technique employed in the current analysis, only compounds that could be verified both by composition and known, standard microstructures were defined conclusively, such as primary and secondary wüstite, and fayalite. All others are generally presented.

G. *Slag Research in Context*

One of the principal theories regarding the adoption of iron in the Ancient Near East is that large scale deforestation during the collapse of the Late Bronze Age and the transition into the Early Iron Age (ca. 1200 BC) denuded the timber stands available for charcoal fuel production used in the metallurgical process (King and Stager 2001, 111-2; Waldbaum 1989). This premise builds on a qualitative assumption that iron ore is easier to smelt than copper ores. However, despite the growing palynological and climatological data that inform scholarship on the fuel side of this relationship (cf. Kaniewski et al. 2010) studies generally have lacked quantifiable thermodynamic consideration of the actual metal ore smelting process. Most research into slag has been focused on qualitative molecular characterization of the slag, in order to deduce whether this byproduct resulted from primary smelting, secondary smelting, crucible smelting, melting activities, etc. Compounds that make up iron slags such as silicates or oxides are usually extrapolated based upon a range of quantitative elemental techniques including XRF, ICP-MS, WDS, and EDS, found throughout a number of helpful analyses. A great deal of excellent research has been conducted on slag, with just some of the more recent notable publications listed herein (cf. Eliyahu-Behar et al. 2012; Fouzai et al. 2012; Charlton et al. 2010; Radivojević et al. 2010; Blakelock et al. 2009; Humphris et al. 2009; Iles 2009; Eliyahu-Behar et al. 2008; Paynter 2006; Shalev, Shilstein, and Yekutieli 2006; Veldhuijzen 2003; Buchwald and Wivel 1998; Ingo et al. 1994; Gordon and Killick 1993; Killick et al. 1988; Bachmann 1982; Hedges and Salter 1979).

However, the lack of a method that would identify definitively the molecular compounds using methods such as Raman spectroscopy has meant that research into one of the most potentially powerful explanatory models relating to slag has been overlooked—namely, that of furnace temperature achieved. When an ore is smelted, fluxes are often added to reduce the temperatures necessary to isolate the iron, including calcium and manganese, in addition to naturally occurring silicon in the ore which would induce self-fluxing (Craddock 1995, 244). These processes leave distinct molecular formations that comprise the slag. This is one future avenue that research into slag could possibly explore.

H. *Analysis of Alloys and Corrosion*

Although the sampling, preparation, and analysis employed for this research is largely based on Kaufman (2013), a number of additional procedures or alterations were conducted. Etching, for example, was conducted to accentuate microstructural features of the alloys. Color etching was executed by first preetching the mounted samples in a 10% aqueous solution of ammonium peroxydisulfate, 98%. The color tint etching was then obtained by soaking the mounted samples in a bath of a saturated solution of sodium thiosulfate ($Na_2S_2O_3$), in distilled water to which a few grains of sodium metabisulfate ($Na_2S_20_5$) were added, a variation of Klemm's Reagent II, following Scott (2010). Samples were then repolished for conservation purposes in order to inhibit accelerated corrosion following color etching from the various acid baths.

L. 7466 40820 is considered a leaded tin bronze due as its lead content of 5.01 wt%, and the lower limit for leaded bronzes is usually placed at 5 wt% (Scott 2010, 174). Many of the arsenical coppers are just barely arsenical with over 0.50 wt%, but are counted as arsenical copper following Tylecote (1962) who considers intentional additions to be those exceeding 0.5 wt%. Therefore, some of the alloys presented in Table 7 could be considered questionably ternary, but may only have arsenic due to recycling. Regardless, application of a thermodynamic model or to identify trade routes and metal consumption practices could be justified only on comparable alloys—meaning pure copper, tin bronzes, or arsenical coppers. This is why the leaded artifacts have been excluded, as their mechanical properties are vastly different than the mechanically similar copper alloys which are so similar that they are essentially “interchangeable” (Tables 7 and 8; Lechtman 2007, 335; Budd and Ottaway 1991).

Some copper alloys are sulfur-rich, notably 4460 38465. Although many corrosion components were excluded from analysis such as chlorine, calcium, and phosphorus as these are not added intentionally and were accrued by post-depositional formation processes, sulfur falls into the category of sometimes being an unintentional impurity and/or corrosion product due its presence in the ore. Sulfur can be trapped in the alloy matrix remnant from the smelt.

Accelerating voltage was 10 keV for one of the spots of the five averages of 2504 45010. 7466 40820 is heavily corroded, and five spots were taken from the metal-rich sections. Corrosion was examined and found to be incredibly tin-rich, meaning that the alloy average reported in Table 7 is a conservative one because of tin segregation and leaching away from the alloy bulk. Corrosion layers closer to the external portions show essentially the bleeding out of high amounts of both tin and lead into the soil, with the metal core remaining more intact. The lead weight 2420 42777 is a cubic artifact, so one spot was taken on each face. One of the six spots had substantial silicon, phosphorous, and aluminum contents, presumably from post-depositional soil interaction. Their contents are not presented as they likely do not represent the intended alloy (unless we are dealing of course with “Punic perfidy”). This is why the lead content is not higher.

Some alloys found in a Punic septic pit were not available for analysis, and do not appear to come from a context specific enough for this investigation (Docter et al. 2006).

I. *Analysis of Furnace Soil*

Furnace soil was taken to be sampled in order to attempt further reconstruction of furnace environment. Samples were analyzed using pXRF, measuring both ppm and wt%. No carburized remains were found in the sample. No indications of metallurgical activity were found in the analysis.

Table 2. Bronze standards in wt% on VPSEM-EDS

BNF C71.34-3																	
Element	Al	Si	P	S	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Zr	Ag	Sn	Sb	Pb	Total
Standard wt%	0.01	0.04	0.02	0.16	0.03	0.05	0.29	0	0.01	86.88	1.55	0.18	0	0.025	8.2	0.07	2.47	99.985
EDS wt%	0.02	0	0.03	0.39	0.03	0.06	0.28	0.02	0.19	84.48	1.86	0.13	0.03	0.03	9.36	0.53	2.58	100.02
Accuracy	50%	NA	67%	41%	100%	83%	97%	NA	5%	97%	83%	72%	NA	100%	88%	13%	96%	

CTIF B32																		
Element	Al	Si	P	S	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Zr	Ag	Sn	Sb	Pb	Total
Standard wt%	0.07	0.07	0.04	0.03	0	0	0.10	0	1.49	74.85	1.15	0.01	0	0	5.92	0.13	16.10	99.96
EDS wt%	0.05	0.02	0.16	0.10	0.01	0	0.10	0.01	1.41	72.31	0.68	0	0	0.07	7.88	0.32	16.87	99.99
Accuracy	71%	29%	25%	30%	NA	100	100%	NA	95%	97%	59%	NA	100%	NA	75%	41%	95%	

CTIF UE15																		
Element	Al	Si	P	S	Cr*	Mn	Fe	Co	Ni	Cu	Zn	As	Zr	Ag	Sn	Sb	Pb	Total
Standard wt%	0	0.06	0.29	0.03	0	0.01	0.15	0	0.24	87.1	0.17	0.09	0	0	10.75	0.61	0.5	100
EDS wt%	0.12	0.02	0.13	0.05	0	0	0.11	0.03	0.36	86.34	0.03	0.1	0.03	0.1	11.23	0.77	0.59	100.01
Accuracy	NA	33%	45%	60%	100%	NA	73%	NA	67%	99%	18%	90%	NA	NA	96%	79%	85%	

CTIF UE53																		
Element	Al	Si	P	S	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Zr	Ag	Sn	Sb	Pb	Total
Standard wt%	0.02	0	0.01	0.03	0	0	0.17	0	1.01	84.04	3.45	0	0	0	4.78	0.53	5.95	99.99
EDS wt%	0.05	0	0.04	0.05	0.01	0.03	0.13	0.01	1.07	84.87	2.52	0	0	0.04	5.89	0.65	4.64	100
Accuracy	40%	100%	25%	60%	NA	NA	76%	NA	94%	99%	73%	100%	100%	NA	81%	82%	78%	

CTIF UZ51																		
Element	Al	Si	P	S	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Zr	Ag	Sn	Sb	Pb	Total
Standard wt%	0	0.01	0.02	0	0	0.01	0.1	0	0.16	83.42	14.5	0.09	0	0	1.52	0	0.19	100.02
EDS wt%	0.02	0	0.01	0.01	0.01	0.01	0.11	0.01	0.16	80.88	16.6	0	0.02	0.01	1.92	0.09	0.13	99.99
Accuracy	NA	NA	50%	NA	NA	100%	9%	NA	100%	97%	87%	NA	NA	NA	79%	NA	68%	

IARM 94B																		
Element	Al	Si	P	S	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Zr	Ag	Sn	Sb	Pb	Total
Standard wt%	10.8	0.03	0.01	0	0.02	0.07	3.99	0.01	4.31	80.60	0.14	0.01	0	0.02	0.003	0.01	0.004	100.027
EDS wt%	9.17	0.03	0.01	0	0.01	0.08	4.36	0.03	4.81	80.92	0.47	0	0.02	0.02	0	0.03	0.04	100
Accuracy	85%	100%	100%	100%	50%	88%	92%	33%	90%	99%	30%	NA	NA	100%	100%	33%	NA	

MBH 32X SN3																		
Element	Al	Si	P	S	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Zr	Ag	Sn	Sb	Pb	Total
Standard wt%	0	0.11	0	0.05	0	0.73	0	0	0.55	81	0.43	0	0	0	15.1	0.51	0.33	98.81
EDS wt%	0.03	0	0.01	0.13	0	0.01	0.06	0.02	0.52	78.63	0.87	0.04	0	0.06	18.91	0.47	0.25	99.94
Accuracy	NA	NA	NA	38%	100%	1%	NA	NA	95%	97%	49%	NA	100%	NA	80%	92%	76%	

CTIF UE13																		
Element	Al	Si	P	S	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Zr	Ag	Sn	Sb	Pb	Total
Standard wt%	0.01	0.17	0.23	0.29	0	0	0.45	0	0.11	83.9	0.6	0.23	0	0	13.7	0.29	0.22	100.2
EDS wt%	0.10	0.16	0.14	0.08	0.02	0.04	0.49	0.02	0.19	81.76	0.19	0.43	0.02	0.05	15.60	0.48	0.23	100.00
Accuracy	10%	94%	61%	28%	NA	NA	92%	NA	58%	97%	32%	53%	NA	NA	88%	60%	96%	

*Only two spots were taken for Cr on this sample

Table 3. Getty bronze standards in wt% on pXRF

A - Chinese coin (unknown date)

Element	**Fe**	**Ni**	**Cu**	**Zn**	**As**	**Ag**	**Sn**	**Sb**	**Pb**	**Bi**
Getty standard wt%	0.55	<0.35	71	<0.79	0.47	<0.15	4.1	0.22	24	<0.12
XRF wt%	0.653	0.075	71.458	< LOD	nd	< LOD	3.782	0.217	21.21	0.069
Accuracy	84%	21%	99%	NA	NA	NA	92%	99%	88%	58%
XRF wt% with toggle spot	0.706	0.086	72.888	< LOD	nd	< LOD	3.962	0.232	20.614	0.079
Accuracy with toggle spot	78%	25%	97%	NA	NA	NA	97%	95%	86%	66%

B - Italian upholstery tack (17th century?)

Element	**Fe**	**Ni**	**Cu**	**Zn**	**As**	**Ag**	**Sn**	**Sb**	**Pb**	**Bi**
Getty standard wt%	0.22	0.35	82	9.3	<0.25	<0.15	4.6	0.12	3.3	<0.12
XRF wt%	0.239	0.341	81.323	9.338	nd	< LOD	4.481	0.122	3.346	< LOD
Accuracy	92%	97%	99%	99%	NA	NA	97%	98%	99%	NA
XRF wt% with toggle spot	0.243	0.335	81.828	9.405	nd	< LOD	4.452	0.123	3.428	< LOD
Accuracy with toggle spot	92%	96%	99%	99%	NA	NA	97%	98%	96%	NA

C - British door knob (18th century?)

Element	**Fe**	**Ni**	**Cu**	**Zn**	**As**	**Ag**	**Sn**	**Sb**	**Pb**	**Bi**
Getty standard wt%	<0.17	<0.35	75	22	<0.25	<0.15	<0.27	<0.12	1.9	<0.12
XRF wt%	0.11	0.031	74.852	22.149		< LOD	0.105	0.029	1.967	0.098
Accuracy	65%	9%	99%	99%	NA	NA	39%	24%	97%	82%
XRF wt% with toggle spot	0.109	0.036	75.162	22.216		< LOD	0.094	0.023	2.033	0.097
Accuracy with toggle spot	64%	10%	99%	99%	NA	NA	35%	19%	93%	81%

D - American screwdriver ferrule (19th century)

Element	**Fe**	**Ni**	**Cu**	**Zn**	**As**	**Ag**	**Sn**	**Sb**	**Pb**	**Bi**
Getty standard wt%	<0.17	<0.35	85	3.6	<0.25	<0.15	8.5	0.13	2.3	<0.12
XRF wt%	0.158	0.023	85.084	3.614		< LOD	8.511	0.117	2.345	0.012
Accuracy	93%	7%	99%	99%	NA	NA	99%	90%	98%	10%
XRF wt% with toggle spot	0.164	0.024	84.75	3.536		< LOD	8.687	0.13	2.528	0.015
Accuracy with toggle spot	96.0%	7%	99%	98%	NA	NA	98%	100%	91%	13%

E - British auger cover plate (19th century)

Element	**Fe**	**Ni**	**Cu**	**Zn**	**As**	**Ag**	**Sn**	**Sb**	**Pb**	**Bi**
Getty standard wt%	0.41	<0.35	70	28	0.29	<0.15	0.53	<0.12	<1.22	<0.12
XRF wt%	0.405	0.064	69.833	27.946		< LOD	0.549	0.03	0.972	0.123
Accuracy	99%	18%	99%	99%	NA	NA	97%	25%	80%	98%
XRF wt% with toggle spot	0.404	0.063	69.837	27.954		< LOD	0.548	0.03	0.966	0.133
Accuracy with toggle spot	99%	18%	99%	99%	NA	NA	97%	25%	79%	90%

F - Laboratory-cast ingot

Element	**Fe**	**Ni**	**Cu**	**Zn**	**As**	**Ag**	**Sn**	**Sb**	**Pb**	**Bi**
Getty standard wt%	0.82	0.96	53	34	2.52	<0.15	2.8	3	1.4	0.32
XRF wt%	0.916	1.006	53.58	34.959		< LOD	2.788	2.992	1.153	0.38
Accuracy	90%	95%	99%	97%	NA	NA	99%	99%	82%	84%
XRF wt% with toggle spot	0.914	0.999	53.956	35.074		< LOD	2.87	3.025	1.167	0.384
Accuracy with toggle spot	90%	96%	98%	97%	NA	NA	98%	99%	83%	83%

G - laboratory-cast ingot

Element	**Fe**	**Ni**	**Cu**	**Zn**	**As**	**Ag**	**Sn**	**Sb**	**Pb**	**Bi**
Getty standard wt%	0.41	1.1	72	3	0.93	0.17	16	1.9	3.9	0.18
XRF wt%	0.535	1.122	73.001	3.127		< LOD	15.933	1.819	3.369	0.191
Accuracy	77%	98%	99%	96%	NA	NA	99%	96%	86%	94%
XRF wt% with toggle spot	0.535	1.125	73.038	3.053		< LOD	16.218	1.849	3.387	0.198
Accuracy with toggle spot	77%	98%	99%	98%	NA	NA	99%	97%	87%	91%

H - Dutch East India company coin (1754)

Element	**Fe**	**Ni**	**Cu**	**Zn**	**As**	**Ag**	**Sn**	**Sb**	**Pb**	**Bi**
Getty standard wt%	<0.17	<0.35	98	<0.79	0.25	<0.15	<0.27	0.87	<1.22	<0.12
XRF wt%	0.007	0.132	98.319	< LOD		< LOD	0.009	0.911	0.086	0.017
Accuracy	4%	38%	99%	NA	NA	NA	3%	95%	7%	14%
XRF wt% with toggle spot	< LOD	0.119	98.63	< LOD		< LOD	< LOD	0.932	0.1	0.018
Accuracy with toggle spot	NA	34%	99%	NA	NA	NA	NA	93%	8%	15%

I - Brammer C934 (RM)

Element	Fe	Ni	Cu	Zn	As	Ag	Sn	Sb	Pb	Bi
Getty standard wt%	0.01	0.49	82.64	0.17	-	-	8.1	0.14	8.45	-
XRF wt%	< LOD	0.452	81.847	0.153		< LOD	8.07	0.097	8.366	0.044
Accuracy	NA	92%	99%	90%	NA	NA	99%	69%	99%	NA
XRF wt% with toggle spot	< LOD	0.452	82.128	0.09		< LOD	8.206	0.112	8.478	0.041
Accuracy with toggle spot	NA	92%	99%	53%	NA	NA	99%	80%	99%	NA

J - CTIF B32 (CRM)

Element	Fe	Ni	Cu	Zn	As	Ag	Sn	Sb	Pb	Bi
Getty standard wt%	0.1	1.49	74.85	1.15	0.0056	-	5.9	0.13	16.1	-
XRF wt%	0.124	1.516	74.603	1.06		< LOD	5.298	0.113	15.296	0.039
Accuracy	81%	98%	99%	92%	NA	NA	90%	87%	95%	NA
XRF wt% with toggle spot	0.126	1.503	74.77	1.026		< LOD	5.401	0.119	15.393	0.047
Accuracy with toggle spot	79%	99%	99%	89%	NA	NA	92%	92%	96%	NA

K - MBH 31X B27 A (CRM)

Element	Fe	Ni	Cu	Zn	As	Ag	Sn	Sb	Pb	Bi
Getty standard wt%	0.31	0.042	78.2	19.9	0.03	-	0.92	0.04	0.24	0.055
XRF wt%	0.322	0.043	78.115	19.801		< LOD	0.905	0.034	0.236	0.063
Accuracy	96%	98%	99%	99%	NA	NA	98%	85%	98%	87%
XRF wt% with toggle spot	0.332	0.039	77.95	19.692		< LOD	0.951	0.036	0.273	0.065
Accuracy with toggle spot	93%	93%	99%	99%	NA	NA	97%	90%	88%	85%

L - BNF C71.34-3 (CRM)

Element	Fe	Ni	Cu	Zn	As	Ag	Sn	Sb	Pb	Bi
Getty standard wt%	0.29	-	87.23	1.55	0.18	0.025	8.2	0.071	2.47	0.029
XRF wt%	0.302	< LOD	86.479	1.508		< LOD	8.2	0.072	2.678	0.047
Accuracy	96%	NA	99%	97%	NA	NA	100%	99%	92%	62%
XRF wt% with toggle spot	0.307	< LOD	86.749	1.43		< LOD	8.374	0.079	2.688	0.045
Accuracy with toggle spot	94.0%	NA	99%	92%	NA	NA	98%	90%	92%	64%

Table 4. Iron ore and slag standards in wt% on VPSEM-EDS and pXRF

Slag standard

BCS 382/1	SiO_2	TiO_2	Al_2O_3	Fe	CaO	MgO	Cr_2O_3	MnO	V_2O_5
Standard wt%	13.03	0.42	3.79	19.90	40.10	3.73	0.80	7.96	0.24
pXRF wt%	12.39±0.30	nd	4.58±0.68	19.31	36.34±0.52	nd	0.72±0.13	8.22±0.21	nd
pXRF Accuracy	95%	NA	83%	97%	91%	NA	90%	97%	NA
EDS wt%	11.66	0.88	5.43	20.82	43.79	1.90	0.90	6.69	0.34
EDS Accuracy	90%	48%	70%	96%	92%	51%	89%	84%	71%

Slag standard continued

BCS 382/1	P_2O_5	S	F
Standard wt%	3.06	0.37	0.10
pXRF wt%	2.64±0.11	0.81±0.03	nd
pXRF Accuracy	86%	46%	NA
EDS wt%	2.69	0.65	nd
EDS Accuracy	88%	57%	NA

Ore standard

NIST 692	Fe	SiO_2	Al_2O_3	P	S	TiO_2	MnO	CaO	MgO
Standard wt%	59.58±0.06	10.14±0.05	1.41±0.04	0.039±0.002	0.005±0.001	0.045±0.005	0.46±0.01	0.023±0.003	0.035±0.004
pXRF wt%	62.32±0.76	11.79±0.24	2.78±0.36	nd	nd	nd	0.52±0.15	nd	nd
pXRF Accuracy	96%	86%	51%	NA	NA	NA	88%	NA	NA
EDS wt%	62.34	11.61	3.23	0.06	0.004	0.11	0.55	0.048	0.06
EDS Accuracy	96%	87%	44%	65%	80%	41%	84%	48%	58%

Ore standard continued

NIST 692	Na_2O	K_2O
Standard wt%	0.008±0.002	0.039±0.003
pXRF wt%	nd	nd
pXRF Accuracy	NA	NA
EDS wt%	0.13	0.039
EDS Accuracy	62%	100%

Chapter 4. Experimental Results: Carthaginian Metallurgy at the Precinct of Bir Massouda

Presented here are the results of analysis of one of the largest known Iron Age corpora of metallurgical remains from Carthage, North Africa, and the Near East, in terms of number of tuyères or other metallurgical ceramics with slag attached. This research provides a diachronic perspective of metallurgical technologies at a seat of empire from its mythical foundations to its destruction (814-146 BC). There are hundreds of metallurgical artifacts that were excavated at Bir Massouda, and this study only considers a representative sample that can be observed with medium or high degrees of chronological resolution. Considering both ceramic seriation and stratigraphy, the materials are divided chronologically as follows: one piece of slag dates to the 8th century BC (3348 34318), but the bulk of both household production under the Decumanus Maximus and centralized production at Bir Massouda shows that 15 more pieces of slag, 50 tuyères or metallurgical ceramics with ferrous slag attached, two tuyères with non-ferrous slag attached, a basalt anvil and a hard stone grinder, one ceramic (8091 17466) and one cobalt-rich ore or pigment (1093 10191) used for glass production, and eight copper alloys date from the 7th to 5th centuries BC. The principal investigator, Roald Docter, considers the bulk of metallurgical activity at Bir Massouda to have taken place ca. 650-425 BC. From the 4th to 3rd centuries BC, the metallurgical precinct is reorganized into a residential sector. The only metallurgical production indicator dated to this period was one piece of slag (2504 45012), most certainly residual material remnant from the old precinct. Four more copper alloys and two lead alloys date to the last half of the 4th century BC, with one (7452 40812) broadly dating from ca. 530-300 BC. The final chronological phase, correlating strictly to the cultural historical era of the Late Punic (Table 1), yielded four more copper alloys and one lead alloy (ca. 300-146 BC), one piece of loose slag, and importantly four tuyères with slag attached dating to the final days of Carthage (ca. 200-146 BC). These latter metallurgical ceramics cannot be assigned a typological context such as household or centralized precinct due to the Roman destruction.

All of these results are organized into the Tables and Appendixes. The results of analysis of the tuyères with slag are presented in Appendix I, with metadata presented in Table 5 and Figure 6; results include photography, pXRF, metallurgical optical microscopy, and SEM-EDS. The results of the analysis of loose slag can be found in Appendix II, with metadata presented in Table 6, and a comparison of the slag specimens found in the industrial zone and the residential zone on Figure 7 (quantitatively analyzed), and Figure 8 (qualitatively examined); results include photography, pXRF, metallurgical optical microscopy, and SEM-EDS. Alloy results are found in Appendix III, with metadata in Tables 7 and 8, specimens per alloy type per period in Figure 9, and diachronic changes in the average tin and arsenic contents of the bronzes in Figure 10 (this Figure only includes bronzes of like mechanical properties—further consideration of the leaded bronzes and iron specimens is found below). Appendix IV contains information about the basalt anvil and hard stone grinder; results include photography. Results from analysis of the furnace soil are found in Appendix V; results include pXRF in both ppm and wt%.

A. *Iron Age Ferrous and Non-Ferrous Metallurgy: Iron, Copper, Silver*

It is pertinent to summarize briefly the technical processes behind the smelting, smithing and forging of iron, and the smelting and casting of bronze alloys. It is likely that the earliest smelting was undertaken on copper ores. Natural metal lodes would have contained easily recognizable copper oxide ores such as cuprite, highly prevalent carbonate ores such as malachite and azurite, and copper sulfides such as chalcopyrite or covellite. Native or pure copper nuggets would be interspersed with these deposits of aesthetically brilliant ores, and anatomically modern humans would have readily associated the metal with the ore. In fact, even homo erectus derived value from iron ores as they utilized them for pigments (Schmandt-Besserat 1980). Iron and copper extraction are related, as it is most certain that iron smelting was discovered due to the presence of iron as an impurity produced alongside slag from the smelting of iron-rich copper ores.

i. *Occurrence*

Native, or naturally pure metals, occur as iron, copper, gold, and silver. Telluric iron is native iron that has formed terrestrially with substantial nickel content, defined to be under 5 wt% (Craddock 1995). Meteoric iron finds its origins extraterrestrially. It is distinguished from telluric iron in two principal ways: 1) it has a nickel content of between 5-20 wt %, and 2) this causes it to have a characteristic widmänsttaten structure of overlapping lamellae (which can also occur in human-produced nickel-iron alloys, cf. Hermelin, Tholander, and Blomgren 1979). Ancient humans knew that iron could come from meteors, as is evidenced textually. Egyptians called it “iron from heaven,” and the Hittites—famous for their iron work—called it AN.BAR, or “black metal from the sky” (Waldbaum 1980). However, most iron must be smelted from ores, and iron smelting most certainly was discovered as an accidental byproduct of copper smelting. It should however be noted that iron smelting, occurring at latest by the mid-first millennium BC, may have been an endemic invention in sub-Saharan Africa that may have preceded local copper metallurgy (Killick et al. 1988).

Copper is usually deposited in various levels of sulfides and oxides/carbonates, and also occurs as a native metal. It is relevant to discuss how various mineralization processes of the ores occur, as this directly impacts the chemical and pyrotechnological processes that humans had to develop to extract metal in elemental form. Copper sulfides are at the deeper levels of mines, but are capped at the surface by a gossan of iron oxides, weathered and oxidized copper carbonates, native copper, and at times enriched in other minerals such as arsenic – all easier to work than sulfur rich ores. Oxidation and weathering to produce coppers in native, oxide, and carbonate forms mostly occurs through the uppermost level of minerals interacting with water, but also as the result of bacteria known as *Thiobaccilus ferroxidans* (Charles 1980, 159). Leaching from the surface that trickles down into the rest of the deposit can cause secondary sulfide enrichment which results in the formation of different types of mineral compounds. Arsenic and copper also occur quite frequently together in nature, and this is likely the reason that humans stumbled upon the first copper alloy (Thornton et al. 2002; Heskel and Lamberg-Karlovsky 1980; Lamberg-Karlovsky 1972). Tin oxides, in the form of cassiterite or stannite, are found often in alluvial lodes or veins (Deer, Howie, and Zussman 1992, 534-5).

ii. *Extraction*

In addition to analyzing excavated materials, archaeologists and material scientists have replicated the smelting process for a variety of metals, giving a glimpse into these practices. To name a few, experiments have involved silver ingot casting (Kruse, Smith, and Starling 1988), arsenical copper ingot smelting and casting (Lechtman and Klein 1998), and the production of iron bars (Crew 1991). Smelting of copper, arsenical copper, and tin ores most efficiently requires a furnace environment, although some early, small-scale smelting may have been conducted in an open hearth surrounded by a dug-out fire pit. In the case of copper, the ore would commonly be placed in the furnace with a charge such as charcoal, and brought up to a smelting heat of around 1200°C. The slag and dross would float to the top of the crucible as the molten copper would puddle in the bottom. These former impurities would have to be tapped off of the denser molten metal. Many crucible, tuyère and furnace types evolved over time (detailed discussion of which would exceed the scope of this presentation), showing the growing mastery of smiths and the investment placed in their trade (Bayley and Rehren 2007; Crew and Charlton 2007; Tylecote 1982a, (on Punic and Roman tuyères); 1982b, (on crucibles)).

Silver production required a different set of chemical approaches, mostly focused on cupellation. The lead content of the ore would be partially absorbed by the crucible wall, as well as some of it oxidizing off. A button of molten silver metal is left at the bottom of the crucible. Casting some metals in ingot or elemental form, such as lead and tin, would be relatively easy and could be melted over an open fire (Rhead 1935). The smelting of copper certainly represents one of the great technological achievements of humans—melting of lead and tin are easier to achieve. But the smelting and forging of iron to obtain wrought iron or steel is certainly the most technically challenging metallurgical process developed in the Bronze and Iron Ages.

It is widely held that aside from the two types of native iron, humans discovered how to extract iron from its ore accidentally. There are three scenarios in which iron plays a major role in copper smelting. 1) Reduction of the copper oxides and carbonates, such as malachite and azurite, are aided by the addition of iron ore as a flux in the furnace either from the flux or the iron content of the copper ore (Wertime 1980; Wheeler and Maddin 1980). It would not take long for ancient smiths to see that after slagging, small iron blooms would be left in the furnace. 2) Furthermore, once the oxidized gossan of copper deposits was fully exploited, only the sulfidic ores remained. This could often include substantial iron concentrations, such as in chalcopyrite. Smelting of this ore would likely also leave unmelted iron and matte in the hearth or furnace (Craddock 1995, 149-153). It is important to note that it would also have been clear to the ancient smiths that this iron could not be melted. This limited its usefulness, especially as copper was abundant via burgeoning trade routes throughout the Bronze Age. 3) Recent work has also suggested that iron played a role not only in early copper production, but also in early arsenical copper production (Thornton, Rehren, and Pigott 2009). Iron arsenide ore, or *speiss*, was likely recognized as a special alloying component to be mixed with pure molten copper, or perhaps co-smelted to produce an arsenical bronze. Iron byproducts would have been produced in this way as well, as seen at Tepe Hissar in Iran by the 4th millennium BC (Thornton and Rehren 2009). The interaction with oxygen and various metal and metalloid components proved to be one of the trickier barriers to overcome for the early smiths, as arsenic also sublimes and can make controlling the alloy composition quite difficult (Bray and Pollard 2012; Budd and Ottaway 1991; Eaton and McKerrell 1976; McKerrell and Tylecote 1972; Charles 1967).

Without the formation of slag, iron production from an ore or bloom is impossible. Slag is the byproduct of metallurgical activity resulting from the processing of metallic ores and is usually composed of a glassy mass of ore detritus that contains vitreous gangue, solid dross, and unsmelted metallic components. For iron metallurgical production, an iron ore must be reduced in a furnace environment in order to render wrought iron or steel, which is known as the direct process (Buchwald and Wivel 1998, 73). For ores rich in silicates, a calcareous flux is added in order to combine with the silicon content and flow out in vitreous form, leaving an iron bloom (Appendix III23). The opposite can be true for calcium-rich ores, where a silicon-rich flux would be required. The flux lowers the smelting temperature by forcing the impurities to flow off the iron. The production of slag is one of the most crucial processes of ferrous production, as failure to achieve a slag flow means that the iron cannot be isolated. A partial slag flow means that the iron will stay very impure, and indeed without making slag there can be no iron. Therefore, proper fluxing practices are not only crucial in conserving fuel, but without a developed fluxing system the entire smelt or blooming process would fail. For a complete ternary oxide diagram of the CaO-FeO_x-SiO_2 system, see the *Slag Atlas* (Eisenhüttenleute 1995, 126).

Depending on the composition of the metallurgical charge (which includes the ore, bloom, or ingot compressed together with fuel and flux), a constant source of air or carbon dioxide is required to raise and maintain the heat of the furnace. When humans manually blow through a tuyère, carbon dioxide is directed through ceramic nozzles where the draught interacts with the ore, flux, and charcoal inside of the furnace. Use of animal skins such as goat or cow would provide air and deliver a more intense blast (Niemeyer 2001, figure 3; Donnan 1998, 1973). Evidence from Bir Massouda indicates that sometimes soot would blow back through the tuyère (Appendix I46). In addition to the heat and flux, the other essential component for a successful smelt or reduction of a bloom is carbon monoxide, which can be acquired through the charcoal. This is needed to deoxidize the iron. Smiths would have found ways to produce carbon monoxide through experimentation of various charge components.

As the impurities are tapped off from the slag, an intermediate product called a bloom is formed. The direct process of reducing iron ores into iron metal or alloys via a smelt requires the ore to react with the fuel and furnace environment—sometimes a tuyère or furnace wall—resulting in an iron bloom. Primary smithing is when the bloom is hammered, and secondary smithing is the forging of the metal-rich bar (Blakelock et al. 2009). In secondary smithing, large amounts of metal are lost in the hammering in the form of scales and prills. A pure iron end product is known as wrought iron; a properly carburized iron is steel. The usual bloomery product, having never been molten, consists of mixed areas often of different composition or grain size. For example, some are phosphoric, with a large grain size, and others may have mixed regions with some pearlite and little slag, or more impure areas with higher slag content (Scott 2013; Scott and Eggert 2009). Wrought iron and steel are the two major categories that characterize ferrous technology in the Ancient Near East and North Africa. In contrast, by around 400 BC, cast iron technology was already known in China (Wagner 1996, 2001).

Once iron is produced, it must be forged and smithed into a useable alloy. In a case where the carbon content of the iron is too high to produce a useable metal such as the cast iron produced in China, the oxygen delivered through the tuyères must oxidize some of the carbon in the iron, a process called decarburization. This is more of a problem with cast or pig iron in industrial times, and the major innovation of the Bessemer Process was its ability to solve this (Bessemer 1905/1989). In a case where the iron is poor in carbon, or when a smith needs to steel a wrought iron—both more common in the ancient Near Eastern, African, North African, and European scenarios—a carbon source such as fine charcoal or other organics must enrich the iron in a process known as carburization (Tylecote and Gilmour 1986, 15). “Natural steel” with a pearlitic microstructure could be achieved from the direct process as well (Buchwald and Wivel 1998, 83, 94; Craddock 1995, 236; Tylecote and Gilmour 1986, 15). Steel is formed when the carbon content of the iron alloy is less than 2 wt%, but ideally less than 1 wt% (Davis 1996, 15; Craddock 1995, 236).

It is often hard to distinguish between smelting and smithing slags even with the most advanced analytical techniques (Bachmann 1982, 31), due to the variable success rate of any given smelt. The direct process of reducing iron ores into iron via a smelt requires the ore to react with the fuel and furnace environment—sometimes a tuyère or furnace wall—resulting in an iron bloom. This bloom is then smithed and forged into shapes with desirable properties, necessitating such procedures as carburization, decarburization, and the manipulation of phosphorus-rich areas to provide strength and hardness (Buchwald and Wivel 1998; Tylecote and Gilmour 1986). The sulfur content found in much of the slag presented here indicates that the ore may not have been carefully roasted prior to the smelt (Tylecote 1962, 183).

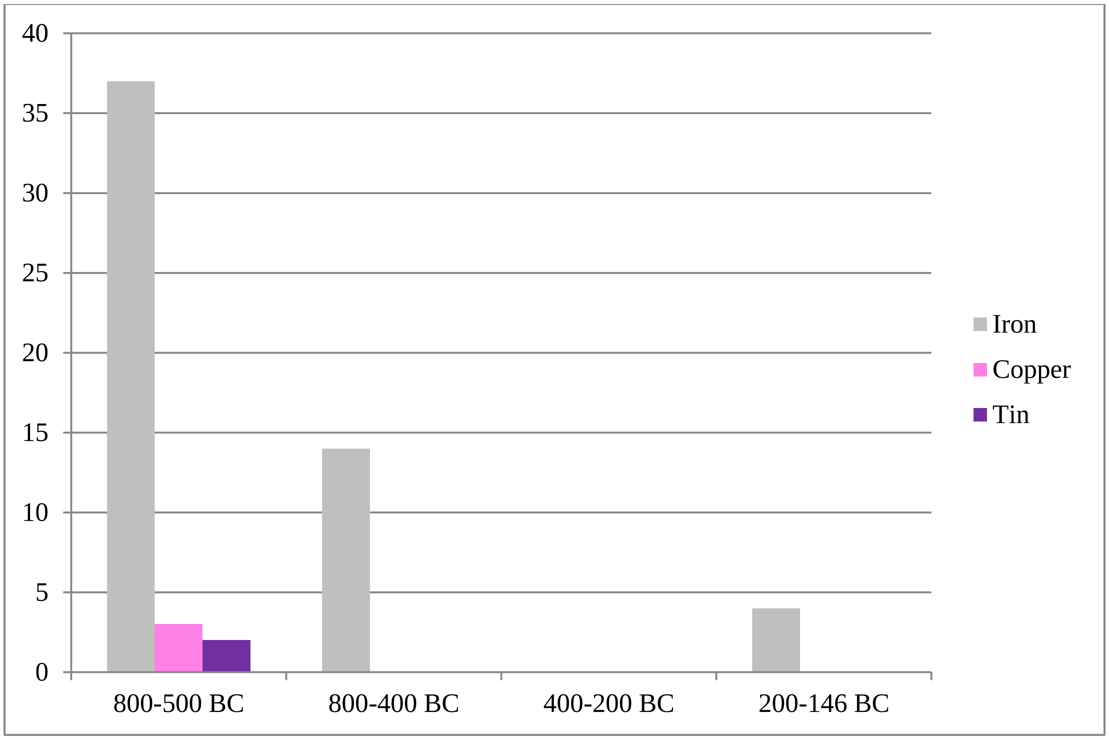

Figure 6. Tuyères with slag per metal produced per period at Bir Massouda (37 tuyères from 800-500 BC, two of them containing Fe, Cu, and Sn and therefore counted twice (Cu-rich 8091 17466 also included even though it seems to be linked to glass production); 14 tuyères from 800-400 BC; four tuyères from 200-146 BC)

B. *Carthaginian Metallurgy*

Despite these hurdles, application of standard reference literature and research to the data from Carthage makes it highly plausible that a full range of activity was taking place, from some smelting to mostly smithing, and from the production of wrought iron to steel. Classic tap and blooming slag is characteristic of the corpus throughout Appendixes I and II, mirroring recent analyses and experimental work demonstrating that tap slags are often rich with secondary wüstite in a fayalitic and glassy matrix (Blakelock et al. 2009, figure 3). Tap slags, associated with smelting (Bachmann 1982, 31) can be found among the slag attached to tuyères in I49, and I53. Among the loose slag, tap slags are represented by I10, II7, II10, parts of II11, II13, II15, and II16. A good example of a bloomery slag resulting in pearlite production is found in II3, according to Bachmann (1982, 32) also II17, and perhaps II1. One object is plausibly a bloom fragment, having phases of slag, ferrite-type grain formation, and (unrelatedly) through luck of preservation deformed wood anatomy probably as part of the fuel source (Appendix III23).

It has been demonstrated that slag inclusions are generally in local equilibria with the surrounding metal, meaning that evidence for production of iron/steel type can be qualitatively determined. The presence of wüstite rich inclusions occurs most frequently with ferrite and wrought iron, whereas the absence of iron oxides but the abundance of the fayalite and glassy, or just glassy phases is associated with pearlite—a key ingredient of "natural steels" (Buchwald and Wivel 1998: 83, 94; Craddock 1995, 236). One of the reasons this occurs is due to the fact that further carburization of wrought iron reduces the iron content of fayalitic slags to more silica rich inclusions (Tylecote 1992, 81). In a clean carburized steel, these inclusions blister and would be closed by forging. Without artifacts possessing good iron metal to test, we cannot conclusively state the kind of steel being produced. But from the nature of the slags it is certain that cast iron was not being produced, a process which leaves almost no iron in the calcium/aluminum/magnesium rich slags (Craddock 1995, 250). But the large amount of slags with only fayalite or glassy phases points to a consistent, intentional production of pearlite.

Examples of this can be found among slag attached to tuyères in I49 which has components of both wüstite rich and fayalitic areas indicating a heterogeneous ferritic and pearlitic product, and perhaps I10. An heterogeneous mixture of fayalite- and wüstite-rich phases is also attested in II2, and slag resultant from the production of pearlite in examples such as II3, II4, and II8.

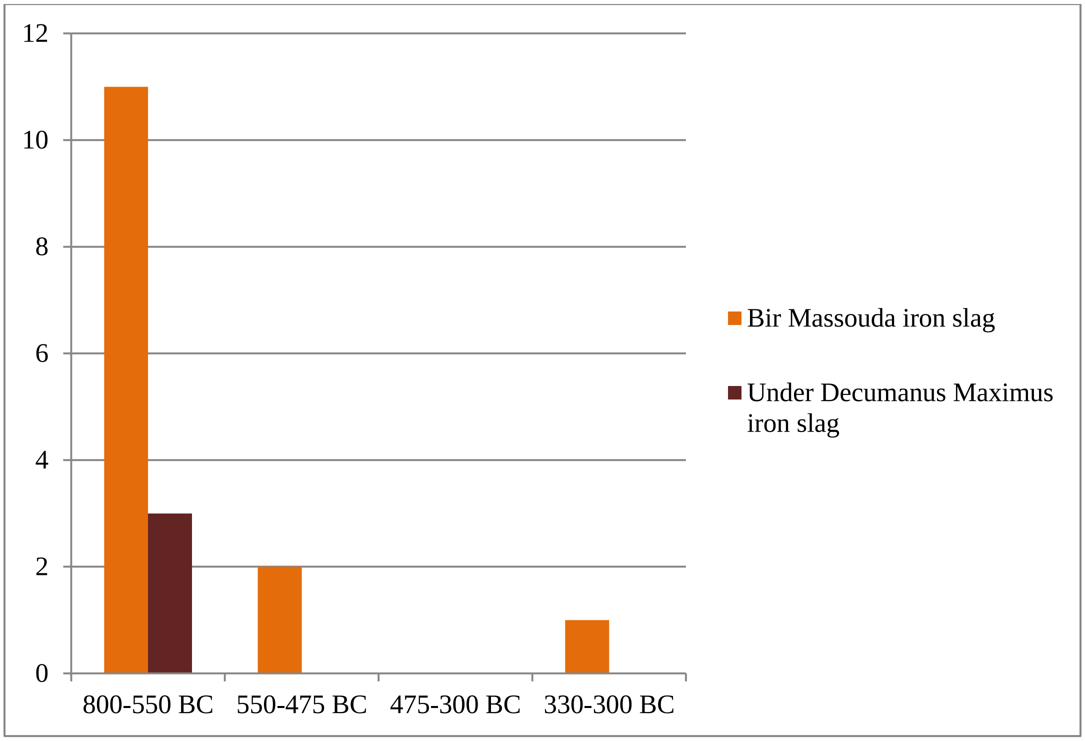

Figure 7. Loose slag specimens in Bir Massouda industrial precinct versus contemporary household contexts, quantitatively determined

Average iron content of slag on the tuyères is 10.14 wt%, whereas the average iron content of loose slag is 30.83 wt%. Of loose slag, about half of the specimens are between 40-60 wt% iron, which is characteristic of bloomery slags wherein the iron content is usually around 50 wt% (Craddock 1995, 250). It is difficult to conclusively assign a given slag to a specific part of the *chaîne opératoire,* so determining why this difference exists would be speculative. However, it is clear from the evidence that smelting and smithing occurred to various degrees from the characteristic tap and bloomery slags and hammerscale deposition (Docter et al. 2003, 44), and that ferritic and pearlitic iron alloys were produced. Smelting operations were likely minimal, as no ore was recovered from the furnace zones, and the tons of slag that would be expected from intensive smelting were not identified. However, it should be mentioned these could have been removed and dumped or used as building material elsewhere.

The data from Bir Massouda has filled an important chronological gap in our understanding of the role of Carthaginian metallurgy. The bulk of metallurgical production at Bir Massouda takes place between 800-500 BC, most intensely between 700 or 625-500 BC, and with the last evidence of tapering production dating to ca. 425-400 BC. Concurrent with this quarter century range—historically concomitant with Magonid control of Sicily, referred to as the *epikrateia*—the metallurgical precinct was transferred to the Byrsa. On the southern slope, the French Mission uncovered metallurgical work of varying intensity that begins when the Bir Massouda metal workshops are dwindling then decommissioned—in the end of the 5th century—and continues down into the end of the 3rd century BC with some evidence at the beginning of the 2nd century (Lancel 1985, 1982, 1981). It is also during the 5th-3rd centuries BC that Carthaginian coins are being minted at a metallurgical site at Tharros in Sardinia, indicating outsourcing practices (Attanasio, Bultrini, and Ingo 2001).

Smaller-scale, localized metallurgical activity is also found throughout pockets of the ancient city. Only three articles have ever been published dealing with any technical analysis of Carthaginian metallurgy (Keesmann 2001, 1994; Tylecote 1982a). There is evidence of a singular later 3rd century workshop just northwest of the Tophet. There is further evidence of occasional iron smelting and smithing on the west side of the channel in the area of the commercial harbor dating to ca. 400-350 BC, with some contemporary material coming from the Ilot de l'Amiraute in the military harbor, as well as slags and tuyères from a 7th century BC dump

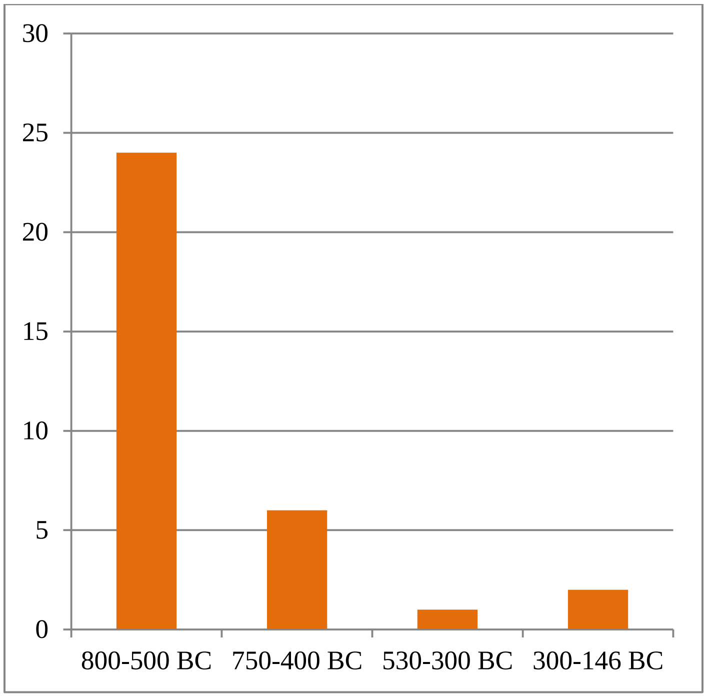

Figure 8. Loose slag from Bir Massouda with temporal overlap, qualitatively determined as slag

at *rue Ibn Chabâat* (Chelbi 2004; Hurst and Stager 1978). However, Tylecote (1982a) dates the channel tuyères to ca. 350-250 BC based on comparisons with the Byrsa examples. Further limited evidence of the metallurgy of the Archaic period from Magon's Quarter, dumped into a Magonid context in antiquity, has been analyzed by Keesmann (2001; Rakob 1989), with some evidence of tin production. Unfortunately, Keesmann (2001) states that the context is "greatly disturbed…, as a result of demolition and leveling work created during the long construction history of the city", whereas Niemeyer (2001) claims the context is broadly dated from ca. 800-300 BC. The well-contextualized slag (three pieces) found by the Hamburg excavations is also part of the current analysis, coming from residential layers under the *Decumanus Maximus*, and dated 700-550 BC. It is at the beginning of the 2nd century BC following the Second Punic War that metallurgical activity may recommence at Bir Massouda, although the material may be residual and if not then it certainly was small-scale.

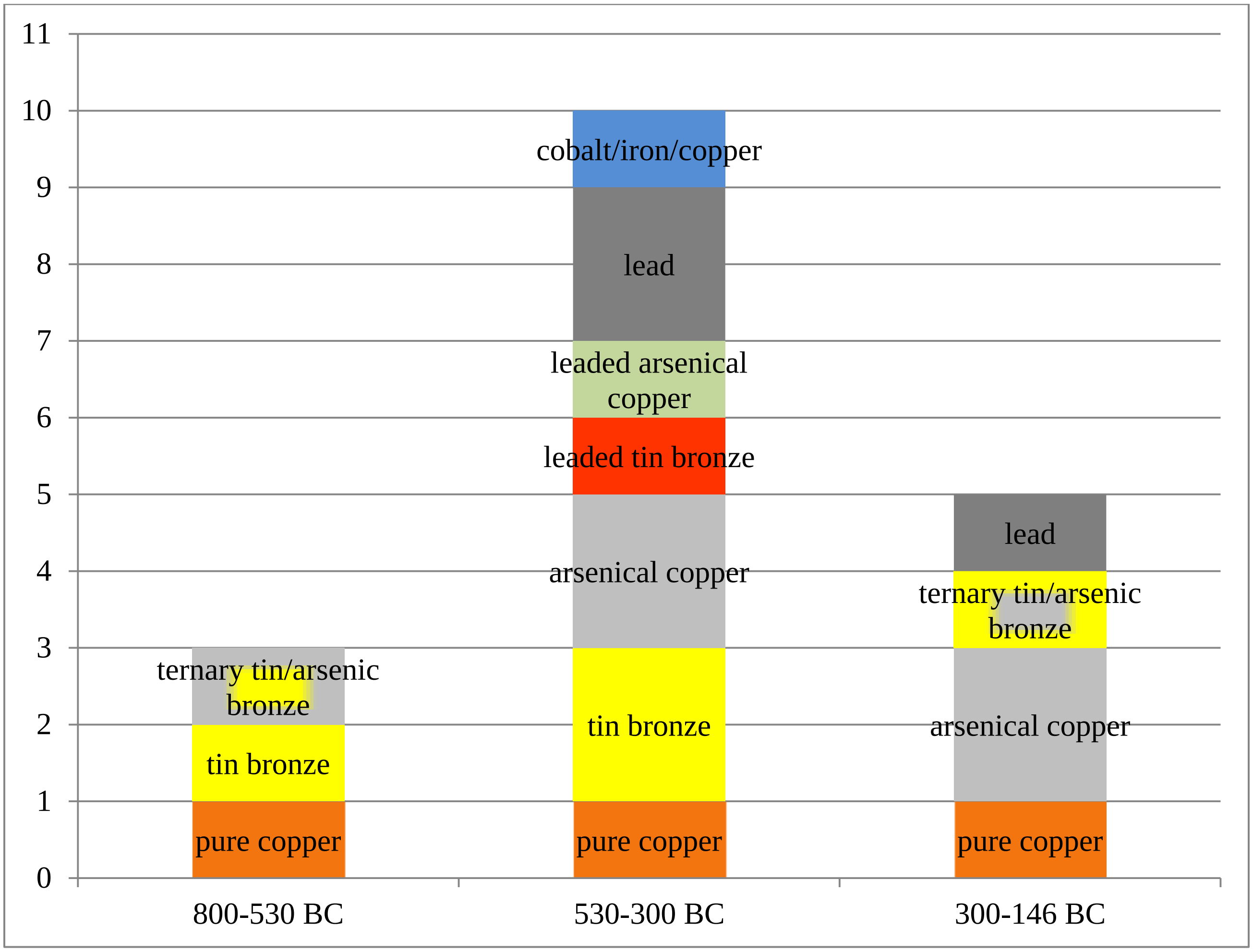

Figure 9. Number of specimens per copper and lead alloy type per period

Two major points can be emphasized:

1) When synthesized together, the data from Bir Massouda and the Byrsa, which represent many centuries of concentrated, dense metalworking, provide a well-stratified view into the decision making process of the Carthaginian state at the intersections of resource production and

consumption, technology, land appropriation in the form of urban planning and precinct commissioning, and outsourcing.

2) The time of the decommissioning of the Bir Massouda metallurgical precinct at the end of the 5th century, and the establishment of the Byrsa metallurgical precinct from the 4th-3rd centuries, is also contemporary with the advent of Carthage as a true imperial power. Intensive agricultural production and settlements across the entire Punic world are expanded and consolidated in the 4th and 3rd centuries, with the evidence clearly attested across Punic sites in Iberia (Castro 2008), Ibiza (Gómez Bellard 2008), across North Africa and on the island of Djerba (Fentress and Docter 2008; Greene 1986), Sicily and Malta (Spanò Giammellaro, Spatafora, and van Dommelen 2008), and Sardinia (van Dommelen and Finocchi 2008). Most of this research was excellently depicted in the volume, *Rural Landscapes of the Punic World* (van Dommelen and Gómez Bellard 2008). The editors conclude with the pertinent point that our knowledge of iron technology is extremely limited across the Punic world in the 4th century expansion.

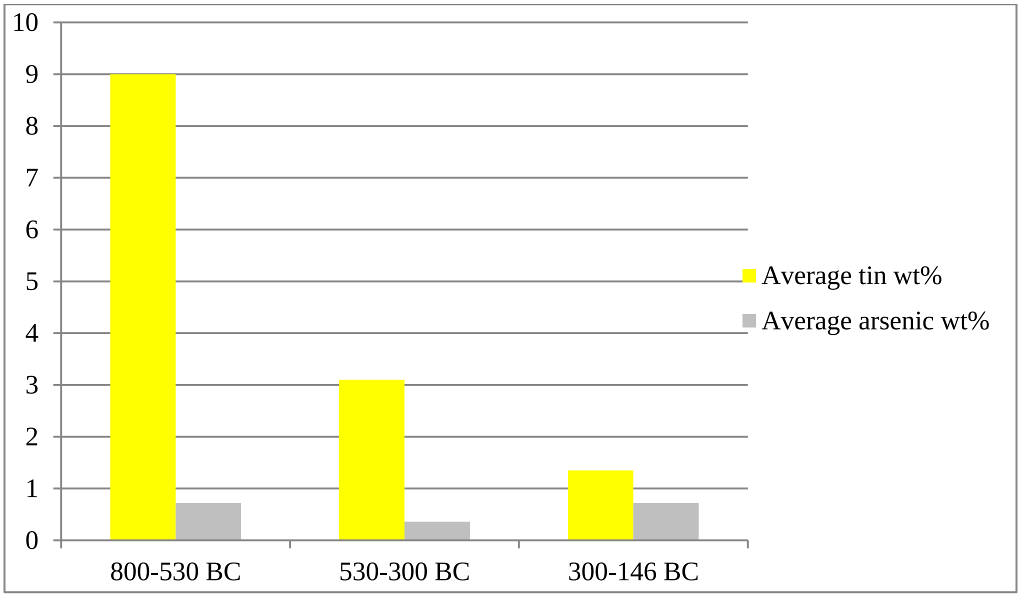

Figure 10. Average tin and arsenic contents in wt% in bronzes per period

C. *Tuyères or Other Ceramics with Slag Attached*

The artifact type of tuyères with slag makes up the basis for this study. Not only is it one of the largest corpora of metallurgical production known from the Near Eastern and North African Iron Ages—with the smoking gun of slag attached to ceramic—but it is also well contextualized from scientific excavations. It is unnecessary to report here all of the data presented in Appendix I, so instead the patterns and trends that emerge are illustrated.

This study utilizes pXRF data generated from all of the tuyères with slag attached (n=54), 15 of which are likely tuyères but are conclusively ceramics with slag attached. Regardless of whether the latter were in fact tuyères, or some other ceramic vessel associated with production, there is no question that the 54 artifacts in question were utilized for metallurgical production. For brevity, they will henceforth all be referred to as tuyères.

There are 54 tuyères with slag attached in the corpus; 37 dating from 800-500 BC – 29 of these date from 700-500 BC – 14 are broadly dated from 800-400, 0 came from 400-200 BC, and 4 date from 200-146 BC. From 800-500 BC, two of 37 of the tuyères exhibit evidence of non-ferrous metallurgy (1112 38082 and 1121 17470). This means that ferrous metallurgy constituted over 90% of production at Carthage in the colonial phase (Figure 6).

The smiths often poked holes through the sometimes toggled nozzles of the tuyères indicating multiple uses (Appendix I). A slag hood would frequently form as well, perhaps indicative of the angles at which the tuyères were propped. Bir Massouda boasts only two-nozzled tuyères, but by the 4th-2nd centuries, a uniform technology was applied across the city in the tapered two-to-one tuyère holes as seen at the Byrsa precinct.

The calcium content indicates a lime-based flux, which based upon excavations is known to be recycled crushed murex shell which is the byproduct of purple dye production (Docter et al.

2006, 63). In the later periods dating to the last phase of the Late Punic era (200-146 BC), fluxing was so precise a science that the range of calcium flux across all samples is 6.263-7.014 wt %. Although these numbers represent semi-quantitative results, the relative proximity is conclusive. In other words, the calcium content was controlled to within 11% accuracy. Tin content occurred conclusively in two instances, L. 1121 17470 (dated 550-450 BC but with a majority of residual material dated 760-600 BC) and L. 1112 38082 (Middle Punic (530-300 BC) leveling layer with residual finds dated 650-580 BC) along with copper (Cu is also attested in L. 8091 17466 with traces of Sn). It is noteworthy that the copper to tin ratio in weight percent is measured as 2.41:0.194 in L. 1121 17470, and as 5.856:0.201 in L. 1112 38082. This would reflect a good tin bronze alloy of around 8 wt% tin, and a low tin bronze of around 3 wt% respectively, indicating that this is recycling dross. Although Keesmann (2001) did find evidence for tin-rich slags from Rakob's excavations, he states that the strata were highly disturbed, and the context apparently cannot be dated definitely even to the Phoenician or Punic era.

Investigations into the tin-rich slag using SEM-EDS allowed further clarification of the metal production. L. 1112 38082 demonstrated evidence of metallic globes, comprised of copper and tin (Appendix I1). The EDS would often report impurities such as Ca, Al, Si, and K that may be remnant from polishing activities (an ultrasonic cleaner was not employed), but more likely from the fact that the electron beam size is one micron so cannot properly measure areas that are smaller than one micron without also analyzing parts of the surrounding matrix.

Appendix I Figures I1b and I2b illustrate different resolutions of the same spectrum, highlighting the overlapping spectral interference of the silver Kβ line and the tin Kα line. Incidentally, this artifact also contains the second highest amounts of both nickel and zinc. Although rare, tin slag has been found in Phoenician contexts such as La Fonteta (Renzi, Montero-Ruiz, and Bode 2009; Renzi and Rovira 2007) and other Iron Age Near Eastern contexts such as at Tayinat (Roames 2011). There does not appear to be any correlation between silicon or manganese content and iron content. The sulfur content indicates that at least some of the iron ores or blooms were sulfidic. The oxidation that is recorded on these spots is not from mineralization in the recycling melt, but likely from surface oxidation following the polish.

Traces of nickel (Ni) were identified in multiple slag phases. This should not be taken as intentional non-ferrous metallurgy but rather impurities from polymetallic ores. Only higher levels of these non-ferrous metals can be taken conclusively as intentional production, such as the tuyères with tin content. Lead values in the slag from 800-400 and 200-146 BC are not presented in Table 5, but are all below 0.05 wt%.

i. *800-500 BC*

By 700 BC, a full-fledged metallurgical industry was in operation that lasted for at least 200 hundred years. The entirety of the evidence at Bir Massouda demonstrates that tuyères were two-holed with toggled, parallel holes running down the entirety of the nozzle from air source to furnace. Before this corpus, metallurgical production at Carthage was only firmly dated to the 5th century BC (Lancel 1982, 1981, 1979), with some possible earlier scattered finds (Keesmann 2001). Now, it is clear that ferrous technology was firmly established in the city from an early date. It is possible that tuyères that began with two holes but joined into one were in operation in the 7th-6th centuries BC in southern Iberia at the Tyrian colony of Morro de Mezquitilla, on the Cerro del Penón (Niemeyer 2001, 88). This indicates a difference in iron technologies during the same period at various colonies. The ironworkers of Carthage were smelting, smithing, and creating both wrought iron and steel (Buchwald and Wivel 1998). Tuyères were used repeatedly as the smiths poked holes through the molten slag in order to keep the airways clear. There is a conspicuous absence of ores at the site. This indicates that no ore smelting activities took place. Nonetheless, the quantity and types of slag almost certainly preclude only forging operations. It is therefore most likely that an intermediate product of refining and then forging fairly dirty blooms that were brought into the city was the major activity, perhaps with some smelting. In the 7th century BC and before, this may be a hallmark of a well-controlled Tyrian policy which designated specific colonies with specialized tasks. In this scenario, smelting of ores was conducted in a different colony and brought to Carthage. In the 6th century BC, when Tyre's influence over the colonies was removed by 573 BC, the same type of scenario of smelting specialization elsewhere may have been employed, but this time by the independent Carthaginian state. In either case, Carthaginian smiths developed centuries of expertise in ferrous metallurgy.

ii. *500-400 BC*

By the 5th century metallurgical production began to taper off, and by 400 BC there was a complete decommissioning of metallurgical production at Bir Massouda. Metallurgical activity was phased out, and a residential sector was constructed (Docter et al. 2006; Docter et al. 2003). Production was eventually transferred to a living cemetery on the slopes of the Byrsa (Lancel 1995). The first evidence of a distinctly Carthaginian metallurgical workshop also appears overseas, at Tharros in Sardinia (Attanasio, Bultrini, and Ingo 2001). The earliest epigraphic evidence begins to make its appearance, broadly dated from 500-200 BC. It becomes clear that there exist guilds, trade groups, and/or state-affiliated individuals who are ironworkers of varying specialties (smiths and forgers), bronze casters or alloy specialists, and goldsmiths and vessel specialists (Chapter 5; Heltzer 1983).

iii. *400-200 BC*

The 4th-3rd centuries BC mark a period wherein Carthage peaked in terms of territorial expansion and military prowess, and it is in the Byrsa where we find the most evidence for internal production at the capital. A handful of tuyère fragments were excavated by the channel of the military port on the Ilôt de l'Amirauté (Tylecote 1982a, 264). These are dated from 350-250 BC, and boast a technology of two holes running parallel but joining to give a single blast at the furnace end. A number of similar tuyères with two holes joining into one were also excavated by the French mission, dating from the 5th to the first years of the 2nd centuries BC (Niemeyer 2001; Lancel 1979; 1982). There was also some evidence of copper base alloy production, but this material has not been analyzed (Tylecote 1982a, 273). By the 4th-2nd centuries, a uniform technology was applied across the city in the tapered two-to-one tuyère holes. Previous interpretations have suggested that at this time, iron was smithed but not smelted like it was at Bir Massouda.

Niemeyer (2001) discusses the number of nozzles and how this impacts technology—two holes throughout may indicate a less effective system than two holes tapering into one hole—or it also may indicate that the tuyère was consumed in the charge to aid in the reduction process and discarded once it receded to where the hole diverges into two. However if this is the case, the holes poked in the Bir Massouda tuyères might instead indicate that they were still being used for further episodes. Organic components of tuyères, such as the hollow cane tuyères used at Chotuna in Peru, may also make tuyères harder to trace in the archaeological record (Donnan 2011).

iv. *200-146 BC*

Metallurgical activity returns to Bir Massouda with the appearance of four tuyères with slag attached dated to the first half of the 2nd century BC. None of them are well-enough preserved to discern how many holes ran throughout, and if they joined together or not. Like the other metal production locations of the 3rd-2nd centuries at the capital, it is a small-scale operation. It appears that instead of the large precincts or industrial zones that characterized the 8th-4th centuries BC, small, decentralized pockets of activity were opted for instead. Although this material may be residual from earlier periods than the destruction layer, it most likely dates to immediately prior to the fall of Carthage. A possible coin mint that may date to the end of the 3rd century BC period has been identified on the basis of a coin striking mould in the destruction layer which would indicate state-level activities conducted at the contemporary Bir Massouda residential zone (Frey-Kupper 2008; Docter 2005).

D. *Loose Slag*

There is an inherent difficulty in the analysis of slag in terms of its heterogeneity. There are multiple instances where this is attested in Appendix II, with classic examples in 8339 34919 (Appendix II9b), as well as 8339 34955B (Appendix II11). Therefore, in order to conduct analysis over as wide a range of slags as possible, an effort was made to take representative samples across all specimens. Among these, 17 individual slag specimens were mounted and polished for analysis, as it was possible to separate these into distinct temporal categories. Another 33 samples were excluded based on their chronological overlap, but are included qualitatively as they are almost certainly slag specimens even though neither pXRF nor optical microscopy was employed (Figure 8). Further evidence for the existence of a dedicated industrial metallurgical precinct is therefore borne out by the data.

Slag recovered from domestic contexts under the *Decumanus Maximus* numbers to three specimens, dating from ca. 700-550 BC, based on the excavation reports. Two of the specimens, KA91/496-17 and KA86/113-61, are ferrous slags likely generated by the production of pearlite due to its exclusively fayalitic and glassy phases (Buchwald and Wivel 1998). One is from a floor covered over with a new floor (Appendix II1), and the other is from the primary destruction layer of a room (Appendix II3).

Slag analyzed quantitatively from Bir Massouda numbers to 11 specimens, dating from 800-600. The oldest slag in the entire corpus of remains of all typologies is 3348 34318, with a *terminus post quem* of 700 BC. This indicates that small-scale metallurgical activity was being conducted in this area before a full-fledged precinct was established by around 700 BC.

From 550-475 BC, two more ferrous slag specimens are recorded. Another slag rich in primary wüstite and with over 50 wt% Fe was analyzed, specimen 1225B dating from 430-380 BC, but this data is not listed in the Tables or Appendixes due to time restrictions.

One final piece of ferrous slag was verified at the end of the 4th century, from 330-300 BC. This locus, 2504, dates to the same period as 2420 and both boast rich metallurgical finds, mostly in its alloys. These small pieces of remnant slags may be due to leveling activity and fill, or from small-scale residential production.

Loose slag qualitatively analyzed—meaning sorted chronologically and labeled slag by ocular inspection alone—yielded 24 specimens from the period 800-500 BC. As seen in Figure 8, there are additional specimens with temporal overlap, but the early group from 800-500 BC is useful for comparison. Taking into account only the slag that has been verified as slag quantitatively, the ratio of household slag (ca. 700-550 BC) to the production facility at Bir Massouda (ca. 800-600 BC) is 3:11. When the qualitative data is included the ratio becomes 3:33.

As mentioned above, the average iron content of slag on tuyères is 10.14 wt%, whereas the average for iron content of loose slag is 30.83 wt%. It is possible that the differences in iron content represent different stages along the smelting and smithing *chaîne opératoire*, with mostly refining of an intermediate bloom product. Many of the slags are in the 50 wt% range of iron content, indicating that these are slags from the bloomery process (Craddock 1995, 250), but it is unclear as to which part of the process they belong. Further evidence of diverse metallurgical capabilities along the *chaîne opératoire* are attested by the basalt anvil and what is likely a grinder (Appendix IV). Ferrous residue can be observed clearly on both of these artifacts.

Fluxing is the process by which the silica is liquefied to melt off of the iron bloom, and is often aided by calcareous materials such as lime or shells (Charlton et al 2010, 363). Ample evidence for the processing of murex shells was also found at Bir Massouda, which was for the purpose of producing purple dye production (Docter et al. 2006, 63). It is apparent that the metalworkers at Carthage utilized the industrial byproduct of crushed murex shells as flux for the iron furnaces. Many lime-like inclusions can be seen throughout the tuyères with slag and loose slag. But fluxing activities are proven most effectively by examination of artifact 8210 A. It is composed of ferrous slag with accompanying detritus from the furnace environment, including a remnant shell (Appendix II5). Further measures to conserve fuel were the creation of a quartz heat-insulating layer around the hearths (Koens in Docter et al. 2003, 64).

8339 38255A provides further evidence of fluxing and forging activities (Appendix II12). Hammerscales form when the iron bloom or metal is continually hot worked. Iron-rich oxides, as well as impurities such as slag, tend to be hammered off. Some of these can be seen in Appendix II12 embedded in a calcium-rich matrix, giving a lens into a non-slag furnace environment with evidence of fluxing and forging.

Some trends in ore source become clear when examining Table 6. Various loci may exhibit the same minor constituents. The slags of 8210, for example, are richer in aluminum, copper, and lead. The three slag specimens share a wide range of average iron content, from ca. 11-45 wt%, indicating that these may represent different stages in the extraction process of the same ore. Batch shipments of different blooms would be brought into the precinct for further smelting and forging. A closer examination of 8210 A (Appendix II5) verified copper, zinc, nickel, and possible arsenic components (but arsenic could not be verified by EDS and was more likely magnesium content). So many impurities in a ferrous slag with no iron oxide phases, and only fayalitic and glassy phases, indicates that this is an early phase of the smelt and not from a later smithing or forging activity. Hedges and Salter (1979) discuss how free energy considerations show that copper, nickel, arsenic, and cobalt are reduced from their oxides more readily than iron in the smelt. This shows that Carthaginian smiths were likely able to produce good low-carbon steels early on in the direct process.

Traces of copper, nickel, and zinc were detected in the loose slag, such as in 8210A. Like with the slag attached to tuyères, this should not be taken as intentional non-ferrous metallurgy but rather impurities from polymetallic ores. pXRF also showed 3348 34318 to contain nickel traces, and both metallography and SEM-EDS verified nickel-rich globes in a fayalitic and glassy matrix—a result of the production of steel.

Since epigraphic evidence show there are actual title-holding metallurgists, this is clearly an endeavor that is executed beyond just the household scale. Some small scale metallurgy would be carried out in the home. The important takeaways from examination of the loose slag are that although there are scattered finds throughout the MP and LP, 1) the bulk of production occurred before the end of the 6th century BC, 2) there is a clear distinction between industrial and residential zones of Carthage, with four to eleven times more production in the metallurgical precinct, and 3) the wide range of iron content in loose slag, from ca. 4 to 61 wt%, is evidence of both a wide range in the *chaîne opératoire* in terms of the stages of extraction, as well as a likely variability in iron sources.

E. *Alloys and Corrosion*

The metadata from analysis of the copper and lead alloys at Carthage (Tables 7 and 8; Figures 9 and 10) correlate with the archaeological data. During the earlier stages of the Early Punic period, at the height of metallurgical activity, there are just three copper alloys. They are the standard copper alloys that can be expected at most archaeological sites of the Iron Age—pure or leaded copper, with some tin and arsenic. Most of the metal being produced in the first few centuries was destined to be sent elsewhere, likely for export, tribute to Tyre and the Assyrians, trade with the Numidians for food, and some domestic consumption at the colony. By the time that the metallurgical precinct was being phased out of Bir Massouda in the 5th century until right through the end of the Middle Punic, the diversity of alloys in the 15 artifacts recovered is striking (Figure 9). Of ten artifacts, seven are distinctly different alloy types. This corresponds archaeologically with the residential levels of the site, and historically from the imperial peak of Carthage abroad. There is evidence in this period of what is likely production of cobalt—the high cobalt, iron, and copper contents are unlikely to occur naturally meaning that this unidentified object was intentionally made. Whatever it may have been, there is no doubt that it is a luxury item. Of the 17 artifacts, four of them (nearly a quarter of all alloy specimens), date to the well-bracketed thirty-year period at the end of the 4th century BC (330-300 BC). These include two finely produced coppers with low arsenic contents (Appendix III7, 8), a leaded tin bronze (Appendix III15), and the lead weight (Appendix III17). This period immediately follows the final fall of Tyre to Alexander the Great (332 BC), placing Carthage as the undisputed leader of the Phoenician and Punic World (Figure 1). It is also the final period where it can be said that Carthage was one of the uncontested empires of the Mediterranean. The military contests officially began with Rome in 264 BC. The richness of metal finds converges well with the imperial peak of the Carthaginian Empire.

It cannot be determined if the alloys were made in the capital, such as at Bir Massouda where there is evidence of polymetallic copper alloy production (Appendix I1, 2), on the slopes of Byrsa with metal production including some copper base alloys (Tylecote 1982a), at Carthaginian outsourcing metal production sites such as at Tharros or Lixus (González-Ruibal 2006; Attanasio, Bultrini, and Ingo 2001), or elsewhere.

Carthaginian copper alloy specialists and casters are attested epigraphically. The level of control that these metallurgists employed in their trade is of a high quality, as attested in the bimetallic artifact 2420 38597, with the intentional pure copper core placed in the low arsenical copper cast (Appendix III17). Many of the artifacts show evidence of tightly controlled, repeated annealing and hammering episodes in such a way that has resulted in minimal intergranular corrosion attacking over the millennia. Many of the artifacts, such as 4440 38431 and 4438 38439 (the latter having zinc traces although this was not in levels high enough to be detected by the EDS average), were heavily worked and are rife with twins and strain lines (Appendix III6, 19). Artifact 4490 38458 demonstrates classic Liesegang corrosion phenomena (Appendix III1;

Scott 1985). Coupled selenium and sulfur impurities in 4440 38441 are common in Ancient Near Eastern bronzes (Appendix III6; Rehren 1991).

Another convergence of historical and archaeometallurgical remains is evident from the average tin and arsenic contents of the copper alloys (Figure 10). Tin, a tactical metal used for bronze and essential for the creation of naval fittings, bridles for cavalry, and weapons for infantry, was in great shortage at Carthage during the period of its greatest need during the three Punic Wars. Due to its castability over iron, copper alloys continued to be employed in this period for armor and helmets alongside steel weapons (Blyth 1993, 25). Considering only alloys of similar material properties—arsenical and tin bronzes, there was an 85% drop in average tin content from the Early Punic to Late Punic (the Late Punic must be considered in light of the fact that their context may have been disturbed during the Roman destruction). Considering this same group again, there was a reduction in average tin content of 56% from the Middle to Late Punic. If the tin content of the softer leaded bronzes is also included, the average tin content from the Middle to Late Punic (3.18 wt%) stays about the same as it is reduced by 58%. This shows that a tin shortage existed in the capital during the Punic Wars[2]. Lancel (1998, 182) surmised correctly that following the Second Punic War, "Carthage had lost the exploitation of Spanish mines, and very probably control of the tin route, as well."

Only four iron artifacts were recovered from Bir Massouda, 7439 40770 (530-300 BC), 1281 33569 (300-146 BC, although context not conclusive), and 4460 49172 (800-530 BC), and 1246 (550-500 BC; Appendices III19, III20, III21, and III22). Three of these fall within the

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[2] Application of a thermodynamic model in order to quantify the exact fuel efficiency loss in this period due to decrease in tin content must wait, as the model developed by the author is currently under review (Kaufman and Scott).

period of metallurgical activity at Bir Massouda. L. 1246 a (550-500 BC), Appendix III23, could even be a bloom itself. The inverse correlation of iron slag to iron artifacts is another persuasive line of evidence for export or trade practices being the reason for the intensified metallurgical production at early Carthage.

F. *Furnace Soil*

The soil sampled from the furnace was analyzed and found to have no remains that can be related to metallurgy. Photographs taken at the site indicate that some minimal carburized soil was excavated. The average iron content on the earth's crust is around 5%, which was roughly the average iron content in both furnace soils sampled (Charles 1980). There is a high calcium content which could indicate a fill rich with fluxing agents, but other soil samples were not taken meaning there is no constant against which to test this hypothesis. This lack of metal in the soil, with just some carburized remains visible in Figure 4, is indicative of a filling activity. Based on this analysis, it is therefore likely that the soil that was sampled from the furnaces represents the final act of decommissioning of the metallurgical precinct at Bir Massouda in 400 BC, the *terminus ante quem* of both furnaces sampled. The hearths were put out of use and filled with soil in order to begin the leveling activities for construction of the residential zone.

Table 5. Slag attached to tuyères or ceramics in wt% on pXRF

800-500 BC

Artifact	Dates BC	Appx I	Spots	Fe	Ca	Si	K	P	S	Al
L.1112 38082	650-580	I1	2	4.504±0.094	1.491±0.097	16.549±0.289	0.928±0.041	0.128±0.066	0.116±0.018	1.301±0.299
L.1121 17470	760-600	I2	1	9.89±0.086	5.075±0.113	25.965±0.226	2.526±0.056	0.708±0.038	0.237±0.015	4.045±0.221
L.8066 17267	700-500	I3	1	8.291±0.07	4.69±0.1	23.577±0.219	2.116±0.049	0.889±0.036	0.067±0.011	3.954±0.186
L.8069 16621	700-500	I4	1	10.974±0.085	3.521±0.091	14.049±0.161	1.399±0.044	0.463±0.027	0.051±0.01	1.853±0.131
L.8069 16622	700-500	I5	2	5.568±0.054	3.89±0.084	18.886±0.191	2.005±0.045	0.854±0.033	0.333±0.014	2.935±0.149
L.8069 16624	700-500	I6	1	11.615±0.096	6.872±0.131	18.132±0.197	1.223±0.044	1.094±0.039	0.095±0.013	2.605±0.184
L.8069 16627	700-500	I7	3	11.594±0.096	4.386±0.1	16.841±0.183	1.909±0.049	0.63±0.032	0.21±0.014	3.272±0.178
L.8069 16628	700-500	I8	1	9.208±0.071	5.464±0.11	18.03±0.187	1.555±0.045	1.132±0.036	0.201±0.013	3.519±0.177
L.8085 17471	750-650	I9	3	7.21±0.064	5.628±0.104	21.633±0.202	1.412±0.039	1.155±0.038	0.082±0.012	3.293±0.173
L.8091 12679	700-500	I10	1	9.088±0.076	7.867±0.133	10.854±0.146	1.098±0.040	1.075±0.036	0.063±0.012	1.110±0.133
L.8091 17464	700-500	I11	3	14.383±0.119	6.186±0.127	15.985±0.185	1.578±0.049	1.079±0.039	0.035±0.013	3.344±0.208
L.8091 17466	700-500	I12	1	1.401±0.037	4.685±0.077	26.783±0.216	2.987±0.043	0.298±0.032	0.038±0.011	2.988±0.146
L.8091 17468	700-500	I13	2	13.995±0.105	5.287±0.112	18.515±0.189	1.427±0.046	1.029±0.036	0.054±0.011	4.145±0.206
L.8091 17469	700-500	I14	1	5.260±0.052	3.133±0.065	12.770±0.144	1.231±0.032	0.425±0.024	—	1.175±0.093
L.8091 17481	700-500	I15	3	14.765±0.111	5.907±0.124	16.716±0.186	1.227±0.046	1.3±0.038	0.062±0.011	2.998±0.185
L.8091 17482	700-500	I16	2	7.575±0.064	7.195±0.12	21.534±0.202	1.958±0.045	0.606±0.035	0.07±0.012	4.404±0.211
L.8091 18719	700-500	I17	3	12.224±0.093	6.512±0.126	18.092±0.19	1.244±0.044	0.882±0.035	0.098±0.012	3.279±0.19
L.8091 30191	700-500	I18	2	12.316±0.093	4.629±0.107	20.622±0.199	1.931±0.05	1.339±0.039	0.047±0.01	4.052±0.198
L.8091 37992	700-500	I19	1	14.578±0.111	7.597±0.136	16.21±0.176	1.112±0.041	1.055±0.037	0.063±0.011	3.715±0.212
L.8091 38018	700-500	I20	3	20.008±0.163	4.945±0.114	11.435±0.143	1.225±0.043	0.317±0.026	0.041±0.011	2.611±0.175
L.8091 38027	700-500	I21	2	7.21±0.064	8.426±0.126	18.313±0.18	1.272±0.036	1.448±0.041	0.106±0.012	3.695±0.191
L.8091 38034	700-500	I22	1	4.714±0.103	1.543±0.109	17.359±0.316	1.244±0.049	0.403±0.048	0.147±0.018	0.525±0.186
L.8091 38038	700-500	I23	1	5.177±0.098	1.097±0.092	18.643±0.302	1.225±0.044	0.122±0.041	0.105±0.014	—
L.8091 38039	700-500	I24	3	6.483±0.064	6.552±0.116	22.834±0.213	2.6±0.051	1.129±0.041	0.046±0.012	4.014±0.205
L.8091 38042	700-500	I25	3	5.274±0.053	4.956±0.09	23.471±0.208	1.468±0.037	0.914±0.035	0.044±0.01	3.962±0.168
L.8091 38096	700-500	I26	1	4.969±0.050	2.346±0.054	11.460±0.130	0.783±0.026	0.321±0.021	—	0.938±0.080
L.8091 38111	700-500	I27	2	7.038±0.059	4.801±0.094	21.787±0.195	1.647±0.041	0.515±0.03	0.025±0.009	4.182±0.172
L.8091 38118	700-500	I28	3	12.762±0.102	6.381±0.122	19.279±0.195	1.429±0.044	0.345±0.031	0.024±0.011	4.583±0.216
L.8091 38212	700-500	I29	1	21.564±0.161	4.992±0.116	8.201±0.116	0.728±0.039	0.309±0.022	—	1.385±0.130
L.8091 38214	700-500	I30	2	6.542±0.062	5.205±0.095	23.699±0.214	1.498±0.038	0.259±0.031	0.092±0.012	4.427±0.194
L.8091 38215	700-500	I31	1	20.496±0.153	3.196±0.107	21.716±0.223	2.571±0.067	0.538±0.034	0.323±0.015	5.431±0.256
L.8210 49138	750-600	I32	3	8.657±0.074	9.173±0.138	17.39±0.183	1.178±0.039	1.261±0.04	0.054±0.012	3.046±0.19
L.8210 49141	750-600	I33	2	10.846±0.092	11.059±0.16	16.406±0.184	1.433±0.042	1.364±0.044	0.084±0.014	3.383±0.226
L.8217 32232	800-530	I34	1	9.348±0.076	5.56±0.109	19.371±0.195	1.523±0.043	0.945±0.036	0.041±0.011	3.94±0.194

L.8217 32233	800-530	I35	3	10.023±0.08	5.133±0.104	21.635±0.201	1.907±0.047	1.339±0.04	0.171±0.013	2.629±0.164
L.8217 49145	800-530	I36	1	8.008±0.067	6.115±0.117	23.431±0.215	2.09±0.049	1.837±0.045	0.047±0.011	3.762±0.194
L.8217 49154	800-530	I37	1	5.022±0.051	4.622±0.08	22.817±0.2	1.333±0.033	0.276±0.029	—	5.53±0.198

800-500 BC continued

Artifact	Dates BC	Appx I	Spots	Mn	Zr	Cu	Sn	Zn	Pb	Ni	As
L.1112 38082	650-580	I1	2	0.183±0.155	0.014±0.001	5.856±0.097	0.201±0.011	—	0.034±0.004	—	0.004±0.003
L.1121 17470	760-600	I2	1	1.006±0.111	0.023±0.001	2.412±0.027	0.194±0.005	0.011±0.003	0.02±0.001	0.022±0.005	0.002±0.001
L.8066 17267	700-500	I3	1	—	0.018±0.001	0.006±0.002	—	0.007±0.001	—	—	0.006±0.001
L.8069 16621	700-500	I4	1	0.806±0.101	0.021±0.001	±	—	0.002±0.001	—	0.012±0.004	0.003±0.001
L.8069 16622	700-500	I5	2	0.291±0.104	0.021±0.001	0.01±0.002	—	0.006±0.001	—	—	0.004±0.001
L.8069 16624	700-500	I6	1	0.78±0.11	0.021±0.001	0.013±0.002	—	0.004±0.001	—	0.008±0.004	0.008±0.001
L.8069 16627	700-500	I7	3	0.346±0.108	0.018±0.001	0.017±0.002	—	0.005±0.001	—	—	0.007±0.001
L.8069 16628	700-500	I8	1	0.739±0.095	0.022±0.001	0.018±0.002	—	0.009±0.001	—	—	0.008±0.001
L.8085 17471	750-650	I9	3	0.369±0.104	0.019±0.001	0.058±0.003	—	0.013±0.001	0.003±0.001	0.019±0.004	0.003±0.001
L.8091 12679	700-500	I10	1	0.661±0.102	0.026±0.001	0.022±0.002	—	0.003±0.001	—	0.009±0.004	0.005±0.001
L.8091 17464	700-500	I11	3	0.38±0.115	0.019±0.001	0.012±0.002	—	0.005±0.001	0.004±0.001	0.009±0.004	0.008±0.001
L.8091 17466	700-500	I12	1	0.589±0.12	0.049±0.001	0.321±0.006	0.006±0.002	0.013±0.001	0.056±0.002	—	—
L.8091 17468	700-500	I13	2	0.656±0.1	0.024±0.001	0.01±0.002	—	0.005±0.001	—	0.008±0.004	0.003±0.001
L.8091 17469	700-500	I14	1	0.399±0.100	0.022±0.001	0.016±0.002	—	0.005±0.001	—	—	0.002±0.001
L.8091 17481	700-500	I15	3	0.647±0.102	0.019±0.001	0.015±0.002	—	0.005±0.001	0.003±0.001	0.01±0.004	0.008±0.001
L.8091 17482	700-500	I16	2	0.561±0.097	0.02±0.001	0.008±0.002	—	0.003±0.001	—	—	0.004±0.001
L.8091 18719	700-500	I17	3	0.868±0.1	0.022±0.001	0.014±0.002	—	0.004±0.001	—	0.011±0.004	0.004±0.001
L.8091 30191	700-500	I18	2	0.741±0.099	0.017±0.001	0.024±0.002	—	0.003±0.001	—	0.011±0.004	0.003±0.001
L.8091 37992	700-500	I19	1	1.643±0.103	0.015±0.001	0.034±0.003	—	0.008±0.001	0.005±0.001	0.017±0.004	0.005±0.001
L.8091 38018	700-500	I20	3	0.64±0.104	0.017±0.001	0.025±0.003	—	0.005±0.001	—	0.013±0.005	0.007±0.001
L.8091 38027	700-500	I21	2	0.398±0.103	0.021±0.001	0.007±0.002	—	0.006±0.001	0.026±0.001	—	0.01±0.001
L.8091 38034	700-500	I22	1	—	0.022±0.001	—	—	0.007±0.002	—	—	—
L.8091 38038	700-500	I23	1	—	0.032±0.001	—	—	0.006±0.002	—	—	—
L.8091 38039	700-500	I24	3	0.253±0.11	0.023±0.001	0.007±0.002	—	0.004±0.001	—	—	0.004±0.001
L.8091 38042	700-500	I25	3	0.242±0.106	0.024±0.001	0.022±0.002	—	0.006±0.001	0.002±0.001	—	0.006±0.001
L.8091 38096	700-500	I26	1	—	0.018±0.001	—	—	0.005±0.001	—	—	—
L.8091 38111	700-500	I27	2	0.358±0.097	0.019±0.001	0.008±0.002	—	0.011±0.001	0.005±0.001	—	0.006±0.001
L.8091 38118	700-500	I28	3	0.246±0.108	0.02±0.001	0.04±0.003	—	0.006±0.001	±	0.011±0.004	0.003±0.001
L.8091 38212	700-500	I29	1	0.363±0.096	0.016±0.001	0.004±.002	—	0.004±0.001	—	0.015±0.004	0.006±0.001
L.8091 38214	700-500	I30	2	—	0.018±0.001	0.005±0.002	—	0.006±0.001	—	—	0.003±0.001
L.8091 38215	700-500	I31	1	0.54±0.096	0.016±0.001	0.035±0.003	—	0.003±0.001	—	0.009±0.004	0.003±0.001
L.8210 49138	750-600	I32	3	0.571±0.107	0.026±0.001	0.005±0.002	—	0.004±0.001	—	—	0.007±0.001
L.8210 49141	750-600	I33	2	0.391±0.112	0.027±0.001	0.018±0.002	—	0.006±0.001	0.012±0.001	—	0.01±0.001
L.8217 32232	800-530	I34	1	—	0.021±0.001	0.01±0.002	—	0.003±0.001	—	—	0.009±0.001

L.8217 32233	800-530	I35	3	0.712±0.102	0.024±0.001	0.011±0.002	—	0.004±0.001	—	—	0.011±0.001
L.8217 49145	800-530	I36	1	0.67±0.103	0.023±0.001	0.009±0.002	—	0.003±0.001	0.006±0.001	—	0.009±0.001
L.8217 49154	800-530	I37	1	—	0.018±0.001	—	—	0.005±0.001	—	—	—

800-400 BC

Artifact	Dates	Appx I	Spots	Fe	Ca	Si	K	P	S	Al
L.1093 38011	450-425	I38	2	4.066±0.045	5.738±0.095	26.878±0.217	1.739±0.038	0.662±0.036	0.101±0.012	2.817±0.158
L.8020 17459	750-400	I39	2	15.957±0.121	5.149±0.119	15.520±0.179	1.369±0.049	0.663±0.031	0.185±0.012	2.589±0.170
L.8020 17475	750-400	I40	2	8.364±0.072	6.682±0.121	19.292±0.195	1.890±0.046	0.467±0.032	0.245±0.014	3.363±0.185
L.8068 37993	800-450	I41	1	4.45±0.047	3.143±0.066	25.583±0.217	1.405±0.034	0.131±0.027	0.041±0.009	6.992±0.209
L.8089 16903	750-400	I42	2	11.195±0.090	6.323±0.120	22.435±0.206	1.852±0.047	0.842±0.036	0.034±0.011	4.544±0.216
L.8089 17486	750-400	I43	1	17.128±0.132	6.423±0.141	20.741±0.222	1.580±0.054	1.492±0.046	0.049±0.012	3.574±0.233
L.8089 38106	750-400	I44	1	7.465±0.069	3.840±0.083	16.833±0.179	1.022±0.035	0.349±0.027	—	1.323±0.113
L.8092	750-400	I45	1	10.463±0.083	5.787±0.118	16.802±0.183	1.256±0.043	0.434±0.031	0.028±0.011	1.894±0.15
L.8092 17472	750-400	I46	2	14.208±0.115	5.013±0.114	21.004±0.203	2.094±0.052	0.339±0.032	0.124±0.012	4.223±0.215
L.8092 17473	750-400	I47	2	12.05±0.093	5.907±0.116	15.696±0.166	1.354±0.042	0.426±0.028	0.063±0.01	3.118±0.168
L.8092 17479	750-400	I48	1	4.992±0.052	2.852±0.072	23.047±0.215	2.266±0.047	0.627±0.031	—	5.779±0.2
L.8092 17480	750-400	I49	2	10.858±0.094	7.347±0.132	27.262±0.241	1.608±0.046	0.221±0.036	—	5.471±0.256
L.8092 38015	750-400	I50	2	24.653±0.201	7.303±0.141	14.652±0.17	1.048±0.043	0.387±0.03	0.094±0.012	3.986±0.243
L.8099 38086	750-400	I51	1	4.516±0.048	3.229±0.070	19.733±.192	0.912±0.031	0.329±0.026	—	1.561±0.104

800-400 BC continued

Artifact	Dates	Appx I	Spots	Mn	Zr	Cu	Sn	Zn	Ni	As
L.1093 38011	450-425	I38	2	0.909±0.099	0.023±0.001	0.003±0.001	—	0.004±0.001	—	0.002±0.001
L.8020 17459	750-400	I39	2	1.197±0.107	0.034±0.001	0.012±0.002	—	0.009±0.001	0.015±0.004	0.007±0.001
L.8020 17475	750-400	I40	2	1.241±0.105	0.023±0.001	0.010±0.002	—	0.007±0.001	0.009±0.004	0.005±0.001
L.8068 37993	800-450	I41	1	—	0.029±0.001	—	—	0.008±0.001	—	—
L.8089 16903	750-400	I42	2	0.542±0.106	0.020±0.001	0.035±0.003	—	0.006±0.001	0.008±0.004	0.004±0.001
L.8089 17486	750-400	I43	1	0.771±0.105	0.016±0.001	0.027±0.003	—	0.007±0.001	0.017±0.004	0.006±0.001
L.8089 38106	750-400	I44	1	—	0.022±0.001	0.008±0.002	—	0.005±0.001	—	—
L.8092	750-400	I45	1	0.995±0.1	0.018±0.001	0.006±0.002	—	—	0.015±0.004	0.004±0.001
L.8092 17472	750-400	I46	2	0.447±0.108	0.02±0.001	0.021±0.002	—	0.01±0.001	0.014±0.004	0.004±0.001
L.8092 17473	750-400	I47	2	0.729±0.102	0.016±0.001	0.012±0.002	—	0.005±0.001	—	0.006±0.001
L.8092 17479	750-400	I48	1	0.412±0.108	0.021±0.001	0.004±0.001	—	0.007±0.001	—	—
L.8092 17480	750-400	I49	2	—	0.019±0.001	0.004±0.002	—	0.006±0.001	—	0.004±0.001
L.8092 38015	750-400	I50	2	0.406±0.106	0.012±0.001	0.026±0.003	—	0.005±0.001	—	0.011±0.001
L.8099 38086	750-400	I51	1	—	0.021±0.001	0.005±0.001	—	0.006±0.001	—	—

200-146 BC

Artifact	Dates	Appx I	Spots	Fe	Ca	Si	K	P	S	Al
L.1060 17477	200-146	I52	3	9.535±0.082	6.263±0.115	18.072±0.183	1.591±0.043	1.1±0.037	0.163±0.013	3.579±0.184
L.1060 17478	200-146	I53	1	21.84±0.171	7.09±0.146	20.126±0.208	1.021±0.045	0.535±0.036	0.127±0.015	4.728±0.284
L.1078 38051	200-146	I54	2	7.363±0.072	6.813±0.109	23.567±0.216	1.069±0.034	0.428±0.037	0.061±0.014	3.322±0.198
L.1096 38001	200-146	I55	2	9.978±0.079	7.014±0.12	14.541±0.162	1.299±0.04	0.618±0.031	0.102±0.012	3.175±0.178

200-146 BC continued

Artifact	Dates	Appx I	Spots	Mn	Zr	Cu	Sn	Zn	Ni	As
L.1060 17477	200-146	I52	3	0.289±0.103	0.019±0.001	0.006±0.002	—	0.005±0.001	—	0.004±0.001
L.1060 17478	200-146	I53	1	1.163±0.104	0.016±0.001	0.057±0.004	—	0.006±0.001	0.035±0.005	0.004±0.001
L.1078 38051	200-146	I54	2	0.907±0.116	0.019±0.001	0.007±0.002	—	0.007±0.001	—	0.01±0.001
L.1096 38001	200-146	I55	2	0.967±0.099	0.019±0.001	0.007±0.002	—	0.005±0.001	.01±0.004	0.01±0.001

Table 6. Loose slag in wt% on pXRF from non-overlapping contexts

Under *Decumanus Maximus*
700-550 BC

Artifact	Dates BC	Appx II	Spots	Fe	Ca	Si	K	P	S	Al	Mn
KA86/113-61	700-675	II1	2	8.561±0.077	4.272±0.093	24.872±0.22	2.012±0.047	2.435±0.05	—	3.197±0.176	—
KA88/41-1	600-550	II2	2	33.825±0.305	7.482±0.166	7.154±0.126	0.791±0.047	2.664±0.053	0.142±0.015	1.278±0.216	—
KA91/496-17	~675	II3	1	23.031±0.207	6.795±0.148	8.022±0.134	1.035±0.047	1.855±0.045	0.057±0.014	0.355±0.16	—

Under *Decumanus Maximus*
700-550 BC continued

Artifact	Dates BC	Appx II	Spots	Cu	Sn	Zn	Pb	Ni	As	Zr
KA86/113-61	700-675	II1	2	0.005±0.002	—	0.01±0.002	—	—	0.011±0.001	0.021±0.001
KA88/41-1	600-550	II2	2	0.056±0.004	—	0.007±0.002	—	0.013±0.006	0.014±0.001	0.011±0.001
KA91/496-17	~675	II3	1	0.013±0.003	—	0.005±0.002	—	0.017±0.006	0.007±0.001	0.011±0.001

Bir Massouda
800-600 BC

Artifact	Dates BC	Appx II	Spots	Fe	Ca	Si	K	P	S	Al	Mn
3348 34318	800-700	II4	1	7.122±0.127	2.285±0.113	11.905±0.234	1.872±0.056	0.619±0.046	0.199±0.019	—	0.707±0.174
8210 A	750-600	II5	1	10.877±0.09	10.981±0.162	15.396±0.176	1.379±0.043	2.171±0.05	0.092±0.014	2.995±0.211	0.772±0.107
8210 C	750-600	II6	2	44.75±0.449	4.867±0.132	10.622±0.157	0.85±0.051	0.538±0.03	0.731±0.021	3.887±0.28	—
8210 D	750-600	II7	2	24.526±0.198	10.043±0.183	13.616±0.18	0.978±0.049	1.852±0.047	0.088±0.013	3.556±0.254	—
8339 34910	800-600	II8	2	4.232±0.047	7.084±0.102	27.897±0.212	1.242±0.031	0.338±0.034	0.075±0.011	2.391±0.145	—
8339 34919	800-600	II9	2	19.486±0.414	6.023±0.219	11.06±0.283	0.955±0.055	0.756±0.064	0.22±0.024	—	1.344±0.291
8339 34955A	800-600	II10	1	48.658±0.83	1.009±0.119	5.717±0.158	0.52±0.043	0.2±0.032	0.302±0.021	—	—
8339 34955B	800-600	II11	1	61.236±1.164	1.455±0.14	3.914±0.133	0.199±0.04	0.242±0.032	0.237±0.02	—	—
8339 38255A	800-600	II12	1	47.781±1.149	4.752±0.208	6.452±0.225	0.432±0.047	—	0.245±0.027	—	—
8339 38255B	800-600	II13	1	13.986±0.35	2.785±0.161	8.353±0.278	0.541±0.047	0.23±0.059	0.193±0.021	—	—
8360 34930	700-600	II14	1	40.103±0.587	4.117±0.145	6.234±0.146	0.218±0.031	—	0.131±0.017	—	—

Bir Massouda
800-600 BC continued

Artifact	Dates BC	Appx II	Spots	Cu	Sn	Zn	Pb	Ni	As	Zr
3348 34318	800-700	II4	1	—	—	0.007±0.002	—	0.017±0.009	0.01±0.001	0.017±0.001
8210 A	750-600	II5	1	0.01±0.002	—	0.007±0.001	0.008±0.001	—	0.017±0.001	0.038±0.001

8210 C	750-600	II6	2	0.044±0.005	—	0.006±0.002	0.007±0.002	—	0.01±0.001	0.01±0.001
8210 D	750-600	II7	2	0.015±0.003	—	0.024±0.002	0.003±0.001	—	0.027±0.001	0.021±0.001
8339 34910	800-600	II8	2	—	—	0.004±0.001	—	—	—	0.027±0.001
8339 34919	800-600	II9	2	—	—	—	—	—	0.013±0.003	—
8339 34955A	800-600	II10	1	—	—	0.014±0.004	—	—		0.007±0.001
8339 34955B	800-600	II11	1	—	—	0.021±0.005	—	—	0.054±0.006	0.003±0.001
8339 38255A	800-600	II12	1	—	—	—	—	—	0.007±0.003	0.008±0.002
8339 38255B	800-600	II13	1	—	—	—	—	—	—	0.013±0.002
8360 34930	700-600	II14	1	—	—	0.009±0.003	—	—	—	0.008±0.001

Bir Massaouda
550-475 BC

Artifact	Dates BC	Appx II	Spots	Fe	Ca	Si	K	P	S	Al	Mn
1113 38057	525-475	II15	2	39.71±0.398	3.909±0.132	3.814±0.097	0.367±0.057	0.907±0.032	0.279±0.015	0.453±0.167	—
1249	525-500	I16	1	47.511±0.486	10.986±0.202	1.645±0.066	0.083±0.033	0.386±0.026	0.07±0.012	—	—

Bir Massouda
550-475 BC continued

Artifact	Dates BC	Appx II	Spots	Cu	Sn	Zn	Pb	Ni	As	Zr
1113 38057	525-475	II15	2	0.017±0.004	0.006±0.003	0.017±0.002	0.012±0.002	—	0.052±0.002	0.008±0.001
1249	525-500	I16	1	0.01±0.004	—	—	0.009±0.002	—	0.003±0.001	—

Bir Massouda
330-300 BC

Artifact	Dates BC	Appx II	Spots	Fe	Ca	Si	K	P	S	Al	Mn
2504 45012	330-300	I17	1	48.79±1.008	2.184±0.153	5.047±0.178	0.286±0.042	0.499±0.048	0.262±0.024	—	—

Bir Massouda
330-300 BC continued

Artifact	Dates BC	Appx II	Spots	Cu	Sn	Zn	Pb	Ni	As	Zr
2504 45012	330-300	I17	1	—	—	0.011±0.004	—	—	0.009±0.003	0.011±0.002

Table 7. Copper alloys, cobalt, and leaded bronzes in wt% on VPSEM-EDS

Early Punic

Artifact	Dates	Appx III	Spots	Cu	Sn	As	Fe	Pb	S	Ag	Ni
4490 38458	800-530	III1	4	88.90	10.63	—	—	—	0.48	—	—
7466 40820	800-530	III2	5	76.69	16.37	1.82	—	5.01	—	0.10	—
4460 38465	800-530	III3	5	96.12	—	0.33	0.28	—	3.27	—	—
Average					9.00	0.72					

Middle Punic

Artifact	Dates	Appx III	Spots	Cu	Sn	As	Fe	Pb	S	Ag	Ni
7452 40812	530-300	III4	5	84.40	13.62	0.34	0.31	—	1.34	—	—
1104 30007	500-400	III5	5	97.11	1.90	0.25	0.34	0.28	0.13	—	—
4440 38441	360-340	III6	5	99.87	—	—	—	0.13	—	—	—
2420 38597	330-300	III7	5	97.89	—	0.65	0.06	—	1.40	—	—
2420 38599	330-300	III8	5	98.75	—	0.55	0.62	—	0.09	—	
Average					3.10	0.36					

Late Punic

Artifact	Dates	Appx III	Spots	Cu	Sn	As	Fe	Pb	S	Ag	Ni
4438 38439†	300-146	III9	5	90.77	5.39	0.68	0.63	1.50	1.04	—	—
1295 33573	300-146	III10	5	99.42	—	0.09	0.37	0.01	0.11	—	—
7271 33531	300-146	III11	5	98.93	—	0.77	—	—	0.29	—	—
7288 33539	300-146	III12	5	97.30	—	1.34	0.44	—	0.92	—	—
Average					1.35	0.72					

Cobalt

Artifact	Dates	Appx III	Spots	Co	Cu	Fe	Zn	Zr	Si	Ca	Al	P	K
1093 10191	450-425	III13	5	16.55	6.40	42.03	0.11	0.02	3.28	1.18	0.55	0.02	0.15

Cobalt continued

Artifact	Dates	Appx III	Spots	Cl	O	C
1093 10191	450-425	III13	5	0.99	26.50	2.24

Leaded bronzes

Artifact	Dates	Appx III	Spots	Pb	Sn	As	Fe	Cu	S
4444 38448	430-400	III14	5	33.42	—	23.87	—	41.84	0.77
2504 45010	330-300	III15	5	20.29	6.71	0.32	—	72.68	—

Leaded bronzes continued

Artifact	Dates	Appx III	Spots	Ni	Mo	Zr	Bi	Sb
4444 38448	430-400	III14	5	0.10		—	—	—
2504 45010	330-300	III15	5	—	—	—	—	—

†verified traces of zinc in some of the spots

Table 8. Lead in wt% on pXRF

425-300 BC

Artifact	Dates	Appx III	Spots	Pb	Sn	As	Fe	Cu	S
1107 38237	425-400	III16	2	99.594±0.147	—	—	0.075±0.025	0.055±0.009	—
2420 42777	330-300	III17	6	96.123±0.15	0.049±0.008	—	0.576±0.019	0.023±0.005	—

425-300 BC continued

Artifact	Dates	Appx III	Spots	Ni	Mo	Zr	Bi	Sb
1107 38237	425-400	III16	2	—	0.011±0.003	—	0.105±0.046	0.03±0.014
2420 42777	330-300	III17	6	—	0.082±0.003	0.039±0.004	0.119±0.022	—

300-146 BC

Artifact	Dates	Appx III	Spots	Pb	Sn	As	Fe	Cu	S
1068	300-146	III18	4	98.845±0.132	0.354±0.018	—	0.425±0.03	—	—

300-146 BC

Artifact	Dates	Appx III	Spots	Ni	Mo	Zr	Bi	Sb
1068	300-146	III18	4	—	0.182±0.007	0.017±0.011	0.123±0.042	—

Chapter 5. Epigraphic Results: Punic Metalworkers and the Carthaginian State

The epigraphic evidence for metalworkers at Carthage points to a connection between metallurgical production and state affiliation. There are 16 Phoenician and Punic inscriptions that mention metalworkers. Four were excavated outside of Carthage, and 12 were found at the capital. Nearly all of the ancient textual accounts that we possess today dealing with Carthage were written by their enemies or erstwhile allies—the Greeks, Romans, and Judeans, and preserved in the Classics and Hebrew Bible—a common trope of the current study. But the Carthaginians did in fact produce thousands of funerary votive stelae for the Tophet, or child sacrifice precinct, the inscribed ones mostly from the 5th-2nd centuries BC (cf. Kaufman 2009; Brown 1991). Although these inscriptions are devoid of historical or literary accounts, they actually do contain a great deal of anthropological data regarding worship, kinship, and employment that is by and large overlooked. Metalworkers' titles suggest a ranked hierarchy between specialists of the various metal types attested, limited to iron, copper, and gold (also see Mosca 1975). Brown (1991) broadly dates the inscribed stelae from the 5th-2nd centuries BC, and Lancel dates the Urbanistic Inscription to the 3rd century BC (Lancel 1995, 144).

A. *A Metallurgical Glossary of the Punic Language*

In Ugaritic tradition, guilds of metalworkers were officially "royal dependents" and were obliged to serve the state in a number of ways, including militarily (Heltzer 1983). It is of course possible that the Levantine Late Bronze and Early Iron Age antecedents to the Phoenicians and Carthage differed from what we find in the Iron IIA-C in the Phoenician homeland and North Africa. But most evidence that we have from this latter period suffices to show that metallurgical production was tied to the State—be it Judean, Tyrian, or Carthaginian. Historically, King Solomon employs an official חרש נחשת (*ḥr*š *nḥšt*), “copper smith” (1 Kings 7:14), who acts as his master smith. There are a number of inscriptions to consider: some that are not from Carthage (Figures 11-14), some from Carthage that do not mention a particular metal (Figures 15-18), and finally inscriptions from Carthage that mention a particular metal (Figures 19-26).

All line drawings were redrawn by the author from CIS I except for the Akhziv Inscription (traced from Dayagi-Mendels 2002), the Punic-Numidian bilingual inscription from Dougga, traced from Février (1959), and the Urbanistic Inscription, traced from a photograph. The available inscriptions from Carthage were traced (all but RES 6; Clermont-Ganneau and Chabot 1900) by the author, as well as the one from Larnaca due to the linguistic interest it provides in an additional ironworking specialty. For photographs of the bilingual Punic-Libyan inscription from Dougga, see Février (1959). Much of this inscription is damaged and difficult to read, but fortunately the relevant last line (line 7 of 7) is fairly clear and is rendered below (Figure 14). Transliterations are provided only for key terms throughout the manuscript.

Before presenting the data, it is necessary to provide translations of some of the key terms. Understandably, there has been a considerable amount of confusion among epigraphers when attempting to translate metallurgical terminology. Presented here is the metallurgical glossary derived from the translations provided below, with explanations and justifications presented when they occur in the translations of individual inscriptions:

נסך (*nsk*) –1) metalworker; 2) ironsmith; 3) smelter(?)
חרש (*ḥrš*) – 1) artisan; 2) metalworker
ארך (*ark*) – 1) forger, literally “lengthener (of metal)”
מסך (*msk*) – 1) caster; 2) alloy specialist
מסף (*msp*) – 1) vessel specialist; 2) ritual vessel or bowl specialist
נסך הנסכת (*nsk hnḥšt*) – 1) master smith; 2) smelter(?)
מיופחת (*mywpḥt*) – describing the person or process delivering the blast of air or carbon dioxide in a smelting or smithing furnace

שפט (*šp*ṭ) – 1) the title of judge; 2) a personal name adopted by a holder of the title judge; 3) a personal name meaning judge popularized by the importance of the title
בן (*bn*) – 1) son of, regarding familial lineage; 2) member of a guild; 3) citizen or member of a national or governmental entity (cf. Kaufman 2009; Bordreuil and Ferjaoui 1988)

i. *Master Smiths and Metalworkers*

There are four Phoenician inscriptions that originate outside of Carthage dealing with metalwork. The first is a silver bowl from a tomb dated to the end of the 8th-beginning of the 7th century BC near Salerno in Italy, listing a personal name with the title "metalworker," בלשא בן נסך, "Balsha of the guild of metalworkers," or "Balsha son of the metalworker" (Heltzer 1983; d'Agostino 1977).

The second is from a tomb at Akhziv, again with a personal name and the title "metalworker," לעמא הנסך, "Belonging to 'Ama the metalworker" (Dayagi-Mendels 2002, 171; Heltzer 1983; Friedrich and Röllig 1970). The Akhziv inscription can also be dated on paleographic grounds to the first half of the 7th century BC. Although the tomb was looted, the ceramic assemblage still provides a date in the 10th-9th centuries BC (Dayagi-Mendels 2002, 64). Three rings—two bronze and one silver fragment—accompany the burial. An Egyptianizing Ankh is in place where the symbol of Tanit in later Carthaginian stela would appear:

Figure 11. Akhziv Inscription – Belonging to 'Ama the smith

לעמא הנסך
"Belonging to 'Ama the smith"

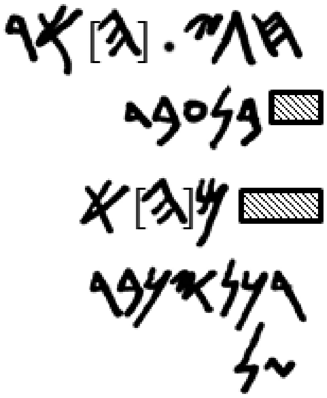
Figure 12. ‘Akko Inscription – By order to the guild of (metal?) artisans

1. בדת לבנ חרש אש יתנ אגנ כ
2. בד לשלת אש על אשרת גלנמ
3. ... וממלאמ...ופכש
4. תאדרת...ולפמ
5. ... ולגממ...ו
6. מיופחת...
7. ודקרת צערת...

This inscription from Tell ‘Akko (Acre) also in the Phoenician homeland provides evidence for a guild of artisans, in this case likely smiths. Dothan (1985) interprets the inscription as an order to the guild to give or donate metal vessels to the temple. The ostracon ceramic dates to the late Iron Age II, and the find context is that of the Persian and Hellenistic periods, meaning that it was probably written after 530 BC. The inscription is fragmented but it is seems likely based on the presence of חרש along with מיופחת (indicating a blowing action or operation of tuyères or bellows from root נפח) that the guild discussed here are indeed metalworkers, although חרש can indicate any artisan or craftsman. The word מיופחת is the most crucial element of the inscription regarding technological processes, but owing to the lack additional context not much more can be said about it except that it quite plausibly describes the person or process delivering the blast of air or carbon dioxide in a smelting or smithing furnace. There are also many unpublished metal finds from the tell that once published should offer another foundational corpus to Phoenician metallurgy.

The fourth inscription is CIS I 67 from Larnaca, Cyprus:

Figure 13. CIS I 67 - iron forger and smith



חגי. [ה]אר... \ בן עבד \ ...מ [ה]ארך נסך בר\זל
“Haggai [t]he spou[se] of…son of ‘Abd…m [t]he iron forger and smith”

It is proposed here that CIS I incorrectly states that ארך is either the name of a dignitary, or from the Greek term for architect. It should rather be taken from the Semitic “to lengthen,” indicating in this context a forger—literally “lengthener”—or smith.

The following inscription is from Dougga in Carthaginian territory. It is a bilingual Punic-Numidian inscription:

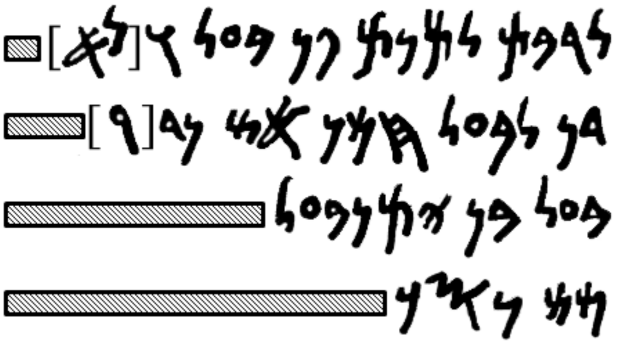
Figure 14. Bilingual Punic-Numidian inscription – ironsmiths Judge and Papi

הנסכם ש ברזל שפט ב[ן] בלל ופפי בן [ב]בי
“The ironworkers: Judge, so[n] of Balal, and Papi, son of [B]abi”

Donner and Röllig (1968, KAI I 100) translate הנסכם ש ברזל into “Eisengießer,” or “iron founder/moulder,” which is roughly correct as long as moulder is not taken to mean “one who casts into a mould.” Février (1959, 53) also correctly describes them as “fondeurs de fer.” Iron was only smelted or smithed in this period, known as the direct process. Heltzer (1983), whose article is an excellent compendium, translates this as “iron caster” which is a mistake from a metallurgical standpoint. Cast iron, or iron produced by the indirect process, was developed contemporaneously in China by 400 BC (Wagner 2001, 1996; Rostoker 1986; Tylecote 1962; Coghlan 1956). The evidence from Carthage is either for smelted or smithed ferritic and/or pearlitic iron, or cast copper alloys (Appendixes I, II, III). No cast iron has been excavated at Carthage, and crucially, none of the slag analyzed could be from a cast iron (cf. Craddock 1995, 250). Heltzer’s (1983) is a useful compilation of inscriptions, but the terminology is metallurgically incorrect. It should be entertained that this title of נסך may also mean smelter, due the occurrence of the two iron specialties we know of: ארך and נסך . It is possible that “forger” and “smith” is a redundant reading, which would instead be “forger” and “smelter.”

There are furthermore a number of inscriptions from Carthage that do not mention a particular metal, but all mention the title נסך or a derivative thereof. The rest of the inscriptions presented are from Carthage.

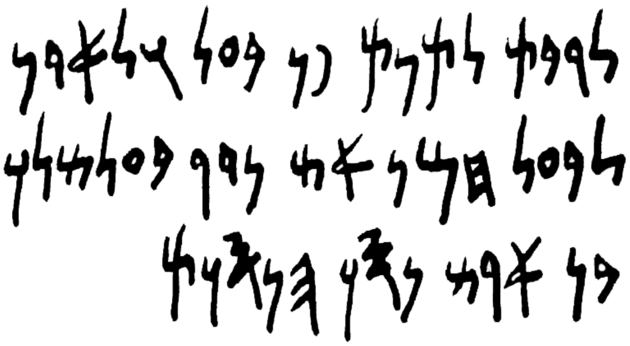
Figure 15. CIS I 1293 – metalworker



לרבת לתנת פן בעל ו[לא]דן לבעל חמן אש נד[ר]...בעל בן יתנבעל...מש נסך

“To the Lady Tanit, Face of Ba’al, and [to the L]ord Ba’al Hammon to whom …ba’al, son of Yatonba’al…mash (the) metalworker, made a vo[w]”

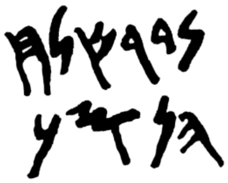
Figure 16. CIS I 3275 – son of the spouse of the master smith



לרבת לתנת פן בעל ולאדן לבעל חמן אש נדר בעלשלך בן ארש נסך הנסכת
“To the Lady Tanit, Face of Ba’al, and to the Lord Ba’al Hammon to whom Ba’alshilkh, son of the spouse of the master smith, made a vow”

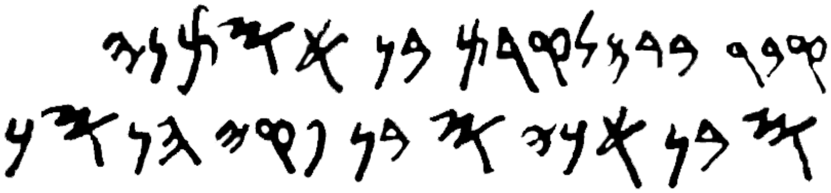
The repetition of the root in נסך הנסכת is likely to place additional emphasis on the function of the smith. This would translate literally as something like “forger of the forged (metal),” meaning “excellent smith,” “smith of the smithing (guild),” “master smith.” It is also possible that the emphasis is placed because of a rarer specialized function, such as “smelter.” This latter option, however, is more speculative and “master smith” is the reading proposed here. It is rather noteworthy that here the בן does indeed indicate familial lineage but membership to a build of metalworkers. This can be stated with certainty due to the fact that the title is interrupted by “spouse.” It is unlikely that there is a “guild of the master smiths’ spouses,” demonstrating that at times an individual can be called only by his title or guild membership on a stelae. This has import for the other inscriptions that cannot necessarily only be read as belonging to a guild.

Figure 17. CIS I 4880 – Tzalach the metalworker



נדר צלח הנסך
“Tzalach the metalworker made a vow”

Figure 18. CIS I 5984 – Paqi the metalworker

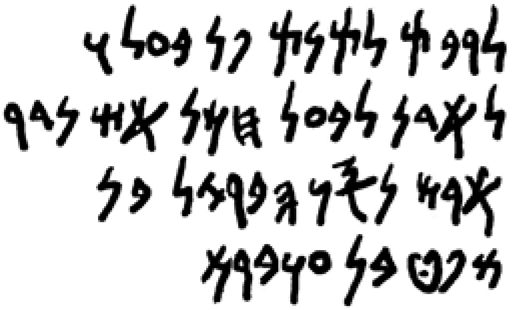


קבר בדמלקרת בן אסתניס בן אכיס בן פקי הנסך
“The grave of Bodmelqart, son of Estanis, son of Akhis, son of Paqi the metalworker”

Bodmelqart’s father, grandfather, and metalworking great-grandfather do not have Punic names, but he received a Phoenician name. Although these last four inscriptions (Figures 15-18) do not mention a specific metal, the usage of the term נסך indicates a general metallurgical capability or profession, including iron. If the casting specific term מסך was used, then it would preclude the working of iron and instead refer to copper working. This further indicates that the term “metalworker” is the broadest definition possible for נסך, unless a specific metal is named. However, it is certainly plausible that the stand alone נסך denotes an ironsmith. Finally, the bulk of inscriptions that deal with metallurgy and the state come from Carthage itself. This is not surprising at all, as metallurgy was, and still is to this day, a strategic industry wherein the most cutting edge technologies are proprietary to the State.

ii. *Ironsmiths*

Figure 19. CIS I 3014 –spouse of the ironsmith, son of Judge



לרבת לתנת פן בעל ו\לאדן לבעל חמן אש נדר \ ארש נסך הברזל בן \ שפט בן עכברם
“To the Lady Tanit, Face of Ba’al, and to the Lord Ba’al Hammon to whom the spouse of the ironsmith, son of Judge, son of ‘Akhbaram, made a vow”

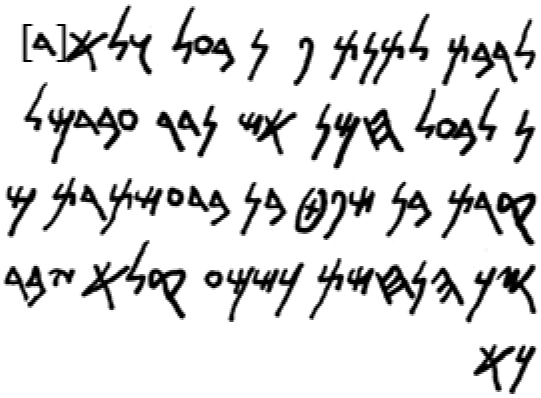
In this inscription, an individual ironsmith is mentioned, whose spouse is the dedicant. Furthermore, this ironsmith is the son of a Judge, himself belongs to the guild of Judges, or is the son of a man named “Judge.”

Figure 20. RES 6 – grave of ‘Akhbaram the ironsmith

קבר עכברם נסך\ הברזל בן בעלשלך
“The grave of ‘Akhbaram the ironsmith, son of Ba’alshilkh”

iii. *Bronze casters*

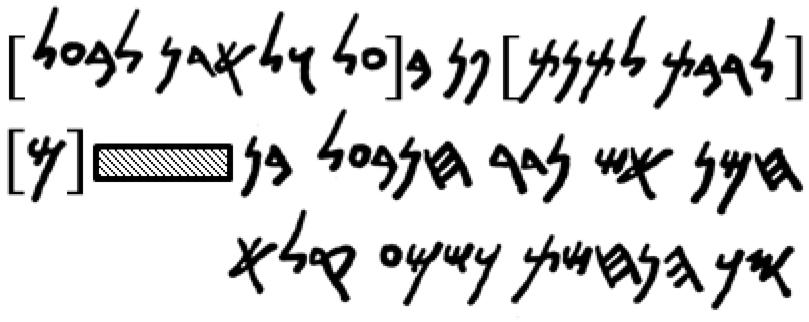
Figure 21. CIS I 330 – Bod’ashtarte the bronze caster, father of Judge



לרבת לתנת פן בעל ולא[ד]\ן לבעל חמן אש נדר עבדמל\קרת בן שפט בן בדעשתרת מ\סך הנחשת כשמע קלא יבר\כא
“To the Lady Tanit, Face of Ba’al, and to Ba’al Hammon, to whom ‘Abdmelqart, son of Judge, son of Bod’ashtarte the bronze caster, made a vow because he heard His blessed voice”

Here is the only fully preserved instance of מסך, or “caster,” associated with copper. This is markedly different than נסך, which is grouped with iron. It likely denotes a specialist in copper alloying practices—literally a caster as opposed to a forger. Furthermore, Bod’astharte the bronze caster is the father of a Judge, the father of someone in the guild of Judges, or the father of a man named “Judge.”

Figure 22. CIS I 331 – Hannibal, son of…the bronze caster

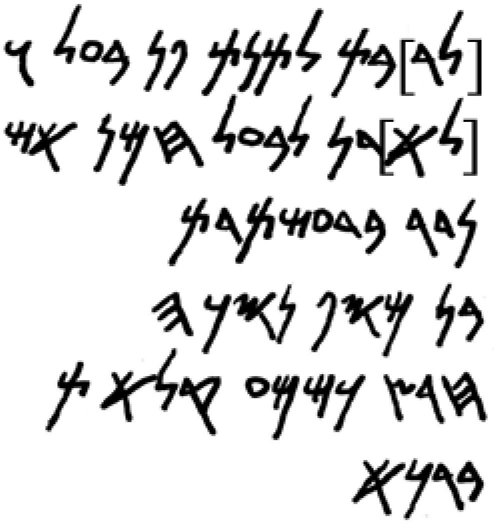


[לרבת לתנת] פן ב[על ולאדן לבעל] \ חמן אש נדר חנבעל בן ...[מ]\סך הנחשת כשמע קלא
"[To the Lady Tanit], Face of B[a'al, and to the Lord Ba'al] Hammon, to whom Hannibal, son of…the bronze [c]aster, made a vow because he heard His voice"

This Hannibal is either in the guild of bronze casters, or is himself son of a bronze caster. It is unfortunate that this only other opportunity to provide the מ of מסך is unclear, but it is likely correct to distinguish between an iron "smith" and a copper alloy "caster." Based on the clear evidence from CIS I 330, and the completely different metallurgical technology inherent in copper alloy smelting and melting as opposed to iron and steel smelting and smithing, it is reasonable to extrapolate this reconstruction. In this reconstruction, it appears that the editors of CIS are correct.

iv. *Goldsmiths and Vessel Specialists*

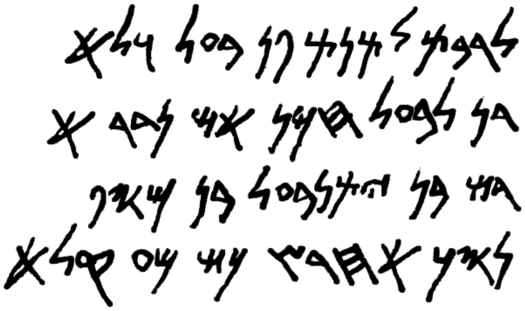
Figure 23. CIS I 327 – Bod’astharte, son of the gold vessel specialist and goldsmith



[לר]בת לתנת פן בעל ו \ [לא]דן לבעל חמן אש \ נדר בדעשתרת \ בן מסף נסך ה\חרץ כשמע קלא ת\ברכא
“]To the L]ady Tanit, Face of Ba’al, and [to the L]ord Ba’al Hammon to whom Bod’ashtarte, son of the gold vessel specialist and goldsmith made a vow because he heard His blessed voice”

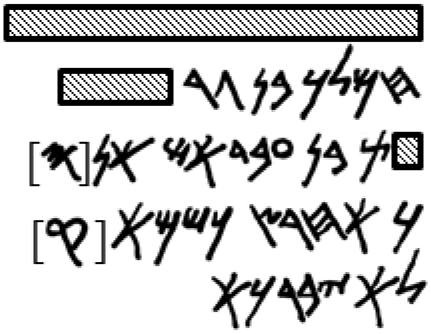
The editors of CIS translate מסף as a personal name, perhaps derived from יוסף, and Heltzer (1983) adopts this and further claims the unlikely scenario that this man may be the father of both dedicants in CIS I 327 and 328. A much more plausible situation is that this is the title of an advanced metallurgical specialty. The term is certainly related to the Hebrew סף, which in Exodus 12:22 denotes a metal bowl used for the cult, and in Akkadian is a metal vessel (Koehler and Baumgartner 2001, 762). Therefore we see here a worker of gold, or a smith, with the advanced specialty of being able and entrusted to craft vessels, perhaps for ritual functions.

Figure 24. CIS I 328 – spouse of Yaton’baal, son of the gold vessel specialist and goldsmith



לרבת לתנת פן בעל ולא\דן לבעל חמן אש נדר א\רש בן יתנבעל בן מסף \ נסך אחרץ [כש]מע קלא
“To the Lady Tanit, Face of Ba’al, and to the Lord Ba’al Hammon to whom the spouse of Yatonba’al, son of the gold vessel specialist and goldsmith made a vow because he heard His voice”

Figure 25. CIS I 329 – ‘Abd who is the goldsmith

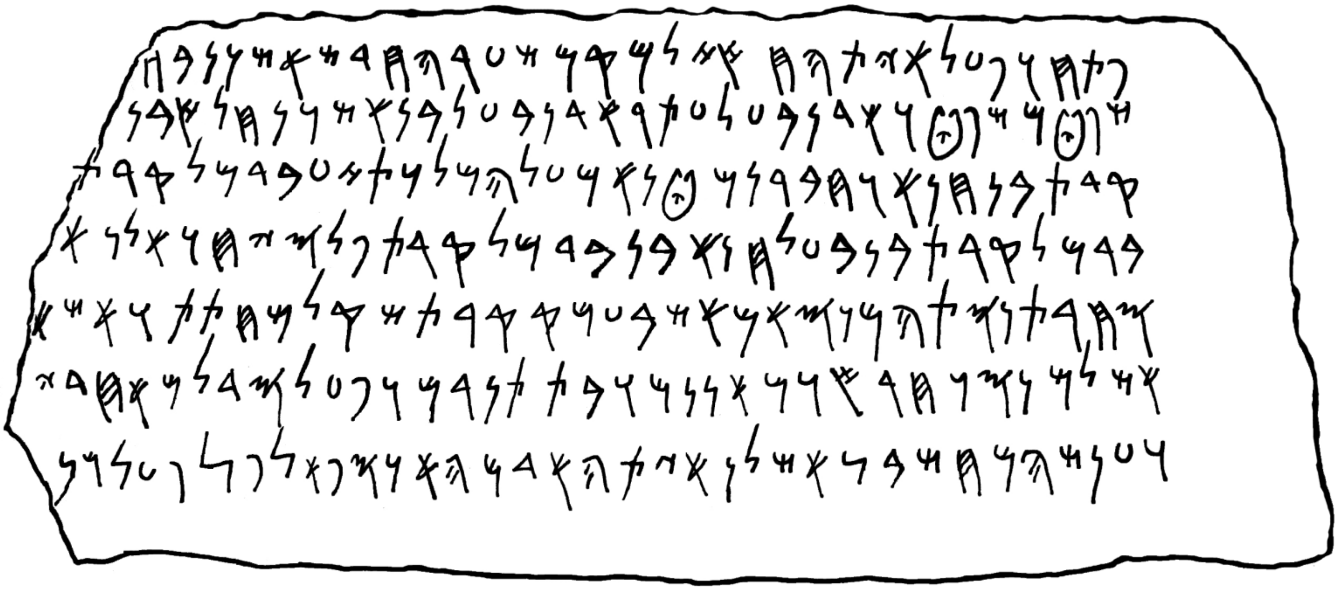


חמלך בן גר\...ת בן עבד אש אנ[ס]\ך אחרץ כשמא [ק]\לא יברכא
“Himilco, son of Gar…t, son of ‘Abd who is the golds[m]ith because he heard His blessed voice”

Here is an example of a regular goldsmith. Although the word “smith” is partially reconstructed, it is correct beyond a reasonable doubt. This serves as a good example, like in the Urbanistic Inscription below, that there are at least two ranks of goldsmith: the regular smith, and the one who is also a vessel specialist. כשמא [sic] is a mistake on the editors of CIS, and should read כשמע.

v. *Urbanistic Inscription*

Figure 26. Urbanistic Inscription – judges, the government, goldsmiths, and workers in the furnaces



1. פתח ופעל אית החץ ז למקם שער החדש אש ננב---------
2. שפטם שפט ואדנבעל עת ר אדנבעל בן אשמנחלץ בן-------
3. קרת בן חנא וחבר נמטנא מעל המלכת ז עבדמלקר[ת]-----
4. בדמלקרת בן בעלחנא בן בדמלקרת פלס יחכא לנא----
5. סחרת נסת המכסא כאש בעמק קרת שקלם חתת כאש א---
6. אש לם נסך חרץ ומאננם ובת תנרם ופעל סדל מאחדי--
7. ועל ש המחשבם אש לנאית האדם ה אכסף אלף לפעלם נ-

This is the only monumental inscription that remains from the Carthaginians. It is both quite damaged, and written in a high, cryptic-type language. It has mostly defied translation. Therefore, instead of providing a speculative translation, only clear phrases are presented:

1. The opening and construction…of this in the place of the New Gate that
2. The Judges are: Judge and Adonba’al, in the time of…Adonba’al, son of Eshmunhilletz, son of…
3. [Mel]qart, son of Hanno and the company…heading this government are Abdmelqart…
4. Bodmelqart, son of Ba’alhanno, son of Bodmelqart…those dealing in statue making…

5. trading…roofing/tiling, such as those living in the valley of the city (lower town), those dealing with weights…
6. (For those who have), goldsmiths, (and from those who do not have), workers in the furnaces, and workers of ? from one...
7. And about (this) the accountants…one thousand silver (pieces) to the workers…

This inscription provides both another instance of a goldsmith, but most significantly, he is in the employ of the state. A few issues clearly stand out: the New Gate is completed; judges and heads of state are named; gold smiths and “workers in the furnaces” are in the employ of this project. The furnaces mentioned here are not necessarily iron furnaces, and could plausibly be potters or other skilled pyrotechnological laborers. But the nature of the relationship between the metal laborers and the state is contractual at the least, and at best represents permanent state employment. It is also useful here to state that the name and title of “Judge” occur side by side, indicating that this word can be used for both the personal name and the titular function. It is possible that individuals changed their name to Judge after winning the title. Their personal identity was equivalent to their service to the state. Names like Shofetba’al may be theophoric in nature, referring to God as a judge, meaning the attribute name “judge” could be implying a theophoric element as well. Clearly, the prevalence of this specific name on so many occasions means that it evoked a reminder of the coveted state office, even if the person named Judge did not hold the actual title. Similar theophoric elements may be implied by the name Magon (cf. CIS I 5526, 6051, Kaufman 2009). Magon, “shield” or “warrior” is the same type of name. It may be speculated that either the holder of the name Magon was a warrior, or else the use of the name is characteristic of a country at war whose citizenry incorporated a martial viewpoint into the names of their children.

From the capital itself, there are four inscriptions that mention a “metalworker” or “master smith,” literally “smith of smiths,” but do not label which metal was being produced.

Specific references to silver smiths are conspicuously absent, and it may be posited that the inscriptions without reference to a specific metal could be working iron, silver, or were perhaps generalists that could work a number of different alloys. There are a further two inscriptions that mention an ironworker, two that mention a bronze caster, and four that reference gold specialists. The ratio of iron:copper:gold production based on epigraphy of verified metal produced would then be 2:2:4. Although the נסך from the silver bowl from Salerno was likely a silversmith, it is most likely that at Carthage this term usually refers to an ironsmith. The proliferation of ironworking from the 8th-3rd centuries BC at Bir Massouda and the Byrsa—with very little evidence of other metals being produced—supports the idea that if no metal was listed the default assumption would be that of an ironworker. If we extend this line of reasoning, then the ratio of iron:copper:gold becomes 6:2:4. At Bir Massouda, the ratio of iron:copper production is more along the lines of 9:1. This indicates that goldsmiths, although certainly fewer in number than ironsmiths or bronze casters, were more likely to be able to afford an inscribed stele for the Tophet, and this is logical. However, the proliferation of iron and copper workers who were able to commission stele is substantial. Further ratios using the metal assemblages from the Tophet urns would be a worthwhile endeavor.

Some of the metalworkers above do not have their names mentioned, but are just referred to by their title (CIS I 327, 328). It is possible that in many cases, such as Figure 23, alternate translations would be “Bod’ashtarte of the gold vessel specialist and goldsmith guild” rather than Bod’ashtarte being the son of such a smith. This argument would be challenged by Figure 25, in which ‘Abd himself is named as the goldsmith, either deviating from the formula employed in all other known cases, or else holding a different meaning in that the rest of the cases are indeed sons of smiths and only ‘Abd is named by title. In any case, if metalworkers were immortalized or identified by their profession alone, it stands to reason that judges would be as well. It is highly likely that some of these people named “Judge” held the title as well, so an alternate translation to “son of a judge” or “son of Judge” is “belonging to the guild of judges.”

Rather than being laborers in what is sometimes considered a “dirty industry,” Carthaginian smiths occupied privileged positions as engineers of one of the state’s most strategic technologies. Further substance is given to the fact that many metalworkers were affiliated with the family of individuals named “Judge” or had family members in the guild or caste of judges, and from the case at Dougga, the ironsmith himself is named “Judge.” There is not enough evidence to conclude that all of these individuals actually held the title of judge (although it is more than reasonable to postulate this), but it is clear enough from epigraphic evidence alone that ironsmiths and other metalworkers occupied a prominent place in Carthaginian society, often paralleling judge-level status, and were employed directly at times by the government as evidenced in the Urbanistic Inscription.

Chapter 6. Cultural Evolution of the Carthaginian Empire and its Oriental Legacy

A. *A Techno-Cultural History of Carthage*

The discussions presented in this Chapter maintain a close proximity to the history of scholarship from which anthropological archaeological thought has been borne, with an effort to provide explanations of empire formation at Carthage. These are mainly 1) post-colonial approaches to the data and a recognition of the ingrained bias inherent in studying Carthage, 2) cultural evolutionary trends that can be extrapolated from the historical, archaeological, and metallurgical data, and 3) cultural or historical ecological data that provide an insight into Carthaginian practices of mineral and timber resource management, crucial for sustainability of empire in both individual lifespans and the *longue durée*.

Archaeologists have generally not succeeded in writing "narrative political histories" that fuse various schools of cultural history while simultaneously incorporating "geographical time, social time, and individual time" (Morris 2000, 4-6, and see citations therein; specifically Snodgrass 1987, 36-66; Braudel 1972, 21). Combining historical texts with the archaeological record in an attempt to extract interpretive power often relies on a high frequency of similarities between the two bodies of data—a phenomenon that has been called "relational" (Hodder 1982) or "convergent" (Dever 2001). For the Phoenicians and Carthage, it is fruitful not to be tempted into distinguishing between the two groups based upon historical trends alone; that is, although scholarship has inherited such arbitrary ethnic affiliations as Phoenicians (from Greek "Φοινίκη," *phoinike*), and Punic (from Latin "Poenus," ultimately derived from the Greek), greater explanatory power will be possible only if the history of scholarship based in ethnonyms from antiquity is traded in for a history of Carthage rooted in evolutionary approaches of cultural continuity or adaptation (Binford 1962).

The last portion of this Chapter is an attempt to write a “narrative evolutionary history” of Carthage. Cultural historical periods and cultural evolutionary phases are considered in tandem. Geographical time is considered in the cultural ecological approaches that Carthaginian smiths encountered while finding ways to save fuel, the natural and anthropogenic activities witnessed in the shaping of the paleogeography of the Mediterranean coast for the construction of harbors (Gifford, Rapp, and Vitali 1992), and in the mining operations for the extraction of metal resources. Social time is measured in the cultural and political adaptations that the Carthaginian state enacted in order to maneuver itself into a position of imperial power. Individual time is seen in the lineages, hierarchies, and specialties that metalworkers memorialized in their worship to Tanit and Ba’al Hammon.

Consultation of evolutionary trends does not mean the discarding of the particular historical context into which Carthage wrote its own adaptation. In fact, it is essential to incorporate Carthaginian histories, both from the perspective of the classical and biblical authors, and the scribes or stonecutters of Carthage whose work is mostly preserved in the funerary stelae. The extent to which a state-level entity exercises political control through its colonial establishments has become considered an effective path by which archaeology can offer a contribution (cf. Stanish 2003, 2002). Whereas much of the discussion surrounding Carthage has been derived from classical history, the current study benefits greatly from the fact that results are generated from data coming from the space of the capital or primate center itself, and from the period spanning the entire history of the polity known as Carthage.

In cultural historical terms, it is paramount not to buy into the recent popular trend of a "deliberate distancing from the texts" (Papadopoulos 2003). Perhaps scholars have misused data in the past, but there is no guilty data (cf. 18th century AD uses of the Bible for explaining history in Wagner 1996, 51). The transformation of "Phoenician" to "Carthaginian" is not primarily one of a shift in cultural, religious, or ethnic identity, but rather a shift from a mercantile cooperative empire to a mercantile coercive empire (cf. Earle 1997, 68-9, who describes these processes as "voluntarist, adaptionist" versus "coercive, political"). The Phoenicians mostly relied on trade, effected by exploiting nascent commercial networks specializing in argentiferous metallurgy, and crystallized by offering symbolic and functional goodwill by the establishment of temples, provision of luxury commodities, and the transfer of architectural technologies (Aubet Semmler 2002b, 230; Ruiz Mata 2002, 267-9). Trade in iron represents a "sustaining technology" for the Phoenicians in Iberia and the hinterlands of Carthage in that it made the Punic settlers valuable to the local population that desired their ferrous commodities (Gordon and Killick 1993).

The change to a coercive system of extraction based on naval and military superiority was a cultural adaptation to Carthaginian independence from Tyre, a reaction to the Tyrian capitulation to Babylon, a vacuum left by the latter in the Punic world and their indigenous neighbors, and competition with Greeks and Romans who also employed force as they themselves expanded and colonized the Mediterranean. The "crisis of the 6th century BC" may likely be interpreted as a restructuring of alliances with subsequent conflict between the Iberian polities. In this explanation, internecine warfare between Iberians occurred in tandem with Carthaginian protection afforded to the Punic Iberian colonies—much as Carthage provided military assistance to the Punic Sicilian colonies at just the same time. This is not to suggest that all Punic colonies submitted to or requested aid from Carthage—there were undoubtedly rivalries among the Punic city states themselves—but rather that a mix of both Iberian and Punic cities sided with Carthage during the reorientation of power and subsequently show an influx of Carthaginian material culture and mortuary practices once the economic and military allegiances were redrawn. The historical evidence for military intervention in Sicily and the archaeological evidence for a realignment of city states to Carthage are contemporary with the peak of metallurgical activity in Bir Massouda.

The switch from a trade-based focus to one of "highly structured control hierarchies" can be found in universal analogies between the Phoenicians, Tiwanaku, and Sumerians on the one hand, and to the Carthaginians, Inka, and Akkadians on the other (Stanish 2003, 284). Further attempts to draw broad comparisons between the Phoenicians and Carthage, and Tiwanaku and the Inka are found to be useful in reconstructing the political and socioeconomic underpinnings of these cultures. The legacy of bias toward Carthage that began in antiquity also found a home in the imperialist ideologies of the Spanish in the New World, as the Chroniclers attempted to frame the Inka and others in an essentially Orientalist way with Carthage as their ideal. An exercise is undertaken to extricate the racial biases that the Spanish drew between the perceived common inferiorities of these two groups, and substitute instead an examination of common imperialist approaches to resource extraction that they shared, divorced of ethnic considerations. The foundational scholarship undertaken over the past 150 years in the spheres of Phoenician and Punic studies has been essential in reconstructing relatively synchronic trends in the cultural history of this Northwest Semitic linguistic group. The commercial aspirations of the Phoenicians were born from their rapid recovery following the Late Bronze Age collapse, and eventually became rooted in a desire for political autonomy from the Neo-Assyrian Empire. The maritime exodus from the Levantine mainland to the farthest reaches of the Mediterranean and Afro-European Atlantic seaboard was codified in politico-cultural realities. However, definitions of “Phoenician” and “Punic” insofar as they relate to the real identities of these groups has been largely relegated to the history of scholarship between Biblical/Near Eastern studies or Classical studies. This distinction is legitimate as it relates to political change—there was certainly a shift in the seat of Phoenician political power from Tyre to Carthage in the 6th century BC. But the distinction falls short when considering cultural continuity, which in this case mandates encompassing political realities. The Phoenicians and Carthaginians forged what can be called a maritime imperial culture that can trace its roots at least to the Middle Bronze Age (cf. Kuhrt 1995, for a broad synthesis of Bronze and Iron Age Levantine history and cultural continuity). Where Tyre opted for the establishment of mutualistic, if not equal, commercial relationships with indigenous communities across Iberia, North Africa, and Sardinia, Carthage emerged from the “crisis of the 6th century BC” with military and territorial aspirations much more in line with the Greco-Roman model of *polis-chora* (i.e. city-hinterland; Dietler 2010; Neville 2007).

B. *Carthage and its Legacy of Bias: Hannibal and Atahualpa (and Vikings)*

The perspectives that the allies or erstwhile enemies of Carthage have written about the state, with Hannibal as its convenient, anthropomorphized face, share one thing—their persistence over millennia. Many 19th century colonial administrators and scholars were well-versed in the classical texts (Dietler 2010, 22; de Onis 1960, xxxii), and were born into a world where Carthage could be romantically popularized as the Orientalized epitome of evil and otherness such as in Flaubert’s *Salammbô* (Said 1978, 185). The list of the biases that may inform an archaeologist in Carthaginian studies is long, and a comprehensive treatment unnecessary. These issues are clearly received today into American popular culture, Tunisian national identity, and Lebanese Phoenicianism (Altekamp and Khechen 2013; Salameh 2010).

What is most crucial for this discussion is to provide insight into the reality that Phoenician studies were split from Carthaginian studies due to the two original goals of antiquarianism and early archaeology: 1) to provide evidence for the biblical narrative through archaeology (Silberman 1995), and 2) to test the veracity of the classical authors in order to construct a modern European identity based on cultural affiliation with Greece and Rome (Dietler 2009, 13). This long process of extrication of Phoenician from Carthaginian became codified into university scholarship over the past centuries. The division into what appears to be two distinct cultural histories has artificially separated Phoenicia from Carthage. The fact that the “two” groups are known historically largely from two separate bodies of literature—namely the Bible on one hand, and the “Classics” on the other, has provided a convenient reassurance to the separateness of the groups (cf. Ortega 2013). There has not yet been a monograph that bridges the phenomena of Phoenician and Carthaginian commercial, colonial, and imperial aspirations as one overriding cultural historical group viewed from an evolutionary perspective. This is a task that will require the critical work of many scholars in the various fields of archaeology, but a first attempt is made in this research.

There is a distinction that must be made between the scholarship that has been generated since the European Renaissance, and the classical scholars. For the latter, a more proper term than “bias” may be “ambivalence,” ranging from a quiet respect of Herodotus stating that Phoenicians introduced writing to the Greeks (Herodotus *The Histories* V.58), to Livy, recounting the consul Varro’s voice, accusing the Carthaginians of having “no knowledge of human law and civilization…bloodthirsty and brutish in their nature and customs, and their leader has further brutalized them by building bridges and dykes from piles of human bodies and—one shudders even at the mention—by teaching them to feed on human flesh" (Livy XXIII.5). "Punic perfidy" was a constant trope (Lancel 1998), as in the *Poenulus* (*The Little Pune*); "he also knows all languages, but he knowingly pretends not to know: he's an out-and-out Carthaginian" (Plautus Act I 112-13; De Melo 2012). Roman writers were quick to condemn those military leaders of whom they disapproved as having brutal traits comparable to Hannibal (Lancel 1998, 219).

Both biblical and classical authors were fond to accuse—and in this case their accusations have now largely been demonstrated to be accurate[3]—the Carthaginian practice of child sacrifice (cf., Diodorus Siculus XX 14; Kleitarchos, *Scholia on Plato's Republic* 337A; Plutarch, *On Superstition* 13; Pseudo-Plato, *Minos* 315E; Quintus Curtius, *History of Alexander* IV 3.23). These accusations were common and showed a Greco-Roman obsession with the practice that has continued to occupy the attention of scholars until today. The accusations also reflect a biblical warning against those who may be influenced by the Ba'al worshipping Canaanites (cf., 2 Kings 3:26-27; 2 Kings 17: 16-17; 2 Kings 23:10; Jeremiah 7:31-32). Let it also be said that the Judean biblical authors of the 8th and 7th centuries BC (Schniedewind 2004) remember the Tyrians and Sidonians fondly during the alliance between Kings David and Solomon and King Hiram, in the 11th and 10th centuries BC. But by the time of the Divided Monarchy in the 9th century BC, the Judean relationship with Tyre soured. The Kingdom of Israel was prosperous, and the relationship between the northern kings of Samaria and Tyre grew with such notable examples as the marriage between the Tyrian Princess Jezebel and King Ahab

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[3] (Smith et al. 2013; Xella et al. 2013; Smith et al. 2011; with contra Schwartz et al. 2012, for just the most recent manifestations of this debate; see also Garnand 2006; Tatlock 2006; Bénichou-Safar 2004; Brown 1991; Gras, Rouillard, and Teixidor 1991; Day 1989; Stager and Wolff 1984)

of Israel (1 Kings 16:30-31). From this point onward, the Judean authors of the Bible tended to demonize the Ba'al worshipping Phoenicians. It is important to emphasize that this new relationship between Israel and Tyre was not fabricated by the perplexed Judeans, but is attested archaeologically as well at Samaria with Phoenician ashlar masonry, ivories, (Barkay 1992, 320), and through multiple theophoric names on ostraca with Ba'al elements (Mazar 1990, 410).

As previously mentioned, it is unacceptable and unscientific to discard historical data. Marcus and Flannery (1994) utilize ethnographic and ethnohistoric data in tandem with archaeological data in order to draw interpretations about pre-Columbian Zapotec populations, in a methodology referred to as the Direct Historical Approach. This is distinct but parallel to the explanatory power derived from the convergent intersections between text and archaeology (Dever 2001), whilst maintaining a critical view in an as objective way as possible (cf. Wagner 1996). Combining two approaches with considerations of bias and recently developed post-colonial theory, this research can at least begin to propose evolutionary adaptations that the Carthaginian state undertook.

> Resolving the contradictions between our ethnohistoric expectations and our archaeological observations will be one challenge of the method; another will be to decide whether those cases in which our observations and expectations fit are genuine continuities, or only superficial similarities (Marcus and Flannery 1994, 57).

In order to be able to fully examine the processes of empire formation at Carthage, it will first be essential to deconstruct briefly many of the preconceived notions that modern classical scholarship has imbued upon classical antiquity regarding the supposed universal belief of ancient peoples that ethnicity was the driving force in kinship affiliation and state formation.

At its core, post-colonial studies seek to divorce from established discourse integrated notions of cultural or biological superiority of a colonizing group over indigenous peoples.

Assumptions of inherently superior material culture, religious practices, or economic models are exchanged for discussions of complex and amorphous personal and group identity of both colonizer and colonized, varying trends of landscape formation (i.e., *polis* (city) and *chora* (hinterland) as the natural state of civilization), and different degrees of social structure and hierarchy at the familial, village, and/or state levels (van Dommelen 2006, 2002, 1998, 1997; Tronchetti and van Dommelen 2005; Said 1978). Recent attempts at explaining colonial integrations have inspired approaches dealing with entangled or hybrid interactions (Dietler 2010, 2009; van Dommelen 2006). Research into the interactions between Phoenicians and Carthaginians, and indigenous groups of Iberia and Sardinia have become more common (Dietler and López-Ruiz 2009; Vives-Ferrándiz 2008; González-Ruibal 2006). This is due to a number of reasons; scarce historical evidence, a wealth of archaeological material, and the symbolic nature of Phoenicians and ancient Orientalizing forces to contemporary post-colonial studies. A lack of research into early contact with indigenous North African communities is largely due to a paucity of archaeological evidence.[4]

This is not to say that ethnicity is never relevant—in the case of Egyptian history, being an “ethnic” Egyptian was so important as to be codified in the prohibition of female royalty to be betrothed to foreign kings, a practice that had the negative potential to impact political alliances (Schulman 1979). But even to the Romans in the Republican era and later, citizenship and nationality was based not on ethnicity but on loyalty to Rome, a legal practice that invited territorial and demographic expansion in their imperial strategy (Walbank 1972; Smith 1954). Conversely, the Athenian Empire may have limited itself in a fashion similar to Carthage by making the achievement of citizenship essentially impossible (Davies 1977-1978). Seeking

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[4] I am interested to address this problem through renewed excavations in Carthaginian territories under the auspices of the Zita Project in the Archaeology, Anthropology, and Ethnography of Southern Tunisia.

cultural and political systems based inherently upon ethnic affiliation is one that may lack explanatory significance, and is perhaps more rooted in the history of scholarship than in an ancient reality. As Gonzalez-Ruibal (2006) suggests, the indigenous peoples with whom the Phoenicians interacted, such as the Iberians, should theoretically have as much agency as their colonial counterparts. The same is true among the Nuraghic Sardinians (van Dommelen 2002, 122). It is crucial at this stage of the pendulum swing that we consider indigenous agencies equally as important as the colonizers. Despite nearly constant warfare between the Carthaginians and Sicilian Greeks, Carthage adopted worship of Sicilian goddesses Demeter and Kore at the beginning of the 4th century BC (Lancel 1995, 114). This implies that even where states were at odds, their citizenry's identity was somewhat fluid.

The theoretical issues surrounding Carthage are distinct however from the usual anthropological corrections; modern scholars correctly may incorporate the worldviews of indigenous peoples as a didactic tool (Gosden 2004), and it is useful to analyze the power relations of victor over vanquished when this situation applies to foreign groups coming into contact with previously unknown indigenes (Simmons 1981). But the situation of Carthage and Rome is more akin to two powerful equals, with entangled and entrenched notions of the other spanning centuries. This is further compounded by a legacy and symbolism that Carthage has possessed throughout the millennia in forming what has become a modern Western consciousness of the other.

This consciousness has been so ingrained in Western thought that there have been both unintentional and intentional nods to Carthage. The myth of the foundation of Carthage by the Tyrian Princess Elissa was widespread enough to be adopted by the Vikings. In Virgil's *Aeneid*, Elissa (Dido) is reputed, with typical "Punic perfidy," to have tricked the local chieftain into a land grant for the future capital. Leading the Phoenician exiles who "bought as much land as they could encircle with the skin of a bull," she proceeded to have the hide cut into strips in order to encompass a massive area (*Aeneid* I, 367-368; Lancel 1995, 24-25). This bit of trickery was apparently thought to be ingenious by Icelanders of the 13th century AD, and was adopted as a trope. In *The Saga of Ragnar Lodbrok and his Sons* (written in around 1230 AD, Waggoner 2009, xxiv), it is related that Ivar, son of legendary Viking Ragnar Lodbrok, convinced King Ælle of England to agree to give him a land grant. Seeking revenge for his father, Ivar was allowed to "own as much of England as could be spanned by the largest ox-hide he could get" (*The Saga of Ragnar Lodbrok and his Sons*, chapter XVII). Ivar repeated the Phoenician ruse and went on to found London. In other versions, it is York that is founded; in Geoffrey of Monmouth's *History of the Kings of Britain*, Hengist acquires the land of the fort at Vortigern in this way as well (Waggoner 2009, 103)

It is likely no coincidence that the editors of *Corpus Inscriptionum Semiticarum* rendered their primary translations and explanations of the entire known corpus of Punic inscriptions into Latin. This work was of course commissioned by the Académie des Inscriptions et Belles-Lettres, and it is no surprise that Latin would be the scholarly language of choice. The interpretation that a symbolic victory over Carthage was felt by the French editors—the self-obliged inheritors of *romanitas*—cannot be discarded. The trope of Carthaginian as the original Oriental other was consumed and received across Europe. The Moors surrendered at Grenada in 1492 (Hemming 1970), granting a sense of justification to the perceived Roman heritage of Spain by the defeat of a contemporary North African enemy. Charles V conquered Tunis in 1535 and was portrayed as Scipio reborn (Brotton 2000). Not a few decades after Jacopo Ripanda painted the famous early 16th century AD image of the turban-clad Hannibal riding the last elephant of his army, Atahualpa found himself face to face with Francisco Pizarro. The Spanish had ready access to Latin texts, and the values and histories of Roman writers were adopted by the conquerors of the Andes. They "formulated specific analogies between the history of antiquity, especially of Rome, and the history of Peru" (MacCormack 2008, 23, 9). Pedro Cieza de León draws analogies between the Inka and many groups throughout his 121 chapters. But he does not shy away from establishing an immediate connection to the first—and most terrifying to his audience—of his analogous groups with the quintessential Roman enemy:

> Proceeding from Ipiales, one comes to a small province called Huaca, and before reaching it, one sees the famous highway of the Incas, as famous in these parts as that which Hannibal built across the Alps when he marched into Italy. And it is worthy of higher esteem, both because of the lodgings and depots to be found all along it as well as by reason of the difficulty of its construction over such rough and barren sierras, which make it an astounding thing to see (Pedro de Cieza de León 1552, XXXVII.20; de Onis 1960).

By claiming that the Inka were indeed "worthy of higher esteem" than Hannibal, Cieza is simultaneously 1) elevating his own military prowess over that of Scipio Africanus, and 2) finding justification for the destruction of the Inka Empire. In effect, the acquisition of Peru and its inhabitants was legitimized through a constructed connection to Rome and invocation of a Roman *casus belli*: Carthage must be destroyed, hence Peru. Moreover, Bernabé Cobo relays that many Spaniards believed that the Indians of the New World were descendants of wayward Phoenicians and Carthaginians (Cobo 1653/1964, Capitulo XI). This claim has continued to spawn forged Phoenician inscriptions until recent times (Cross 1968).

Finally, the focus on Phoenicians and Carthage at the state level has excluded two other topics that contain a high degree of anthropological interest. The first is the contact period between the Phoenicians and indigenous North Africans, often referred to by their classical name of Numidians. This group, lacking iron technology like the Iberians, became incorporated into both empires to varying degrees. The early centuries of this interaction is essentially unknown.

Another group that has fallen outside of the interests of the Great Tradition (Renfrew 1980) are the Neo-Punic populations. They are the defeated Carthaginians and Punic peoples across North Africa. Writing Punic in Latin script (Kerr 2010; Jongeling 2008), they were apparently allowed to continue their Tanit worship to varying degrees (McCarty 2013; Quinn 2011; Hurst 1999). The cultural history of this group, far from being fused into an evolutionary framework of the Biblical and Classical cultural histories, has not yet even been written. Both of these contact components are integral to the research design in the author's ongoing excavations in Tunisia.

C. *Cultural Evolution of the Carthaginian State*

The evolution of social complexity is characterized by oft-debated phases such as the classic "band-tribe-chiefdom-state" model (Marcus 2008), with further inferred social hierarchies such as "ranked" or "egalitarian" (Renfrew 1982). This type of linear progression may or may not be suitable to every nuanced occurrence of complexity, but that argument is largely irrelevant to the current work which deals with an advanced complex state. What is clear is that social organization is removed from the sphere of biological evolution, and can be genetically explained by phenotypic variations of organic community manifestations (Wilson and Sober 1994). Varying types of social behavior can be observed within the same primate species in diverging geographic regions (Read 2012). Early complexity and the advent of so-called archaic or pristine states has been studied most prevalently in the Near East under an overarching theory of World Systems (Algaze 2008, 1993; Stein 1999), with environmental determinism considered to be profoundly significant to the formation of empire in the early historical periods such as under the Akkadians (Weiss 2000; Dalfes, Kukla, and Weiss 1997; Weiss et al. 1993). So-called peripheral areas in the Old World have received treatments mostly focused on Secondary State

Formation (Esse 1989). New World archaeology also tends to center more heavily on environmental deterministic approaches but with a more powerful lens focused on resource catchment zones and the ideology of statecraft as an exploitative mechanism (Stanish 2003). Further useful models of territorial hegemony and imperial strategy can be consulted (D'Altroy 1992; Santley and Alexander 1992) for studying the spread of empire, which is defined as when “developing state networks are periodically centralized into a single political unit incorporating most previously existing polities” (Wright 1977, 385).

Carthage is an ideal case study to examine not only its unique strategies of empire formation, but also to provide a theoretical approach to the connection of empire formation and state-sponsored metallurgy within a cultural evolutionary framework (Lechtman 2007; Wagner 2001). Processual parallels can be drawn from our understanding of the rise and fall of the Inka Empire (Stanish 2003), seated within the Northwest Semitic/Mediterranean cultural history particularly appropriate for Phoenicians and Carthage. It has been demonstrated through epigraphic and textual sources that service to the state was paramount at Carthage, for instance with the proliferation of names like “Judge” or “Shield.” The Inka incorporated “metals of empire,” gold, silver, and copper, along with tin bronze, in order to project political power (Lechtman 2007). Although there are parallels between Carthage and the Inka in the incorporation of disparate cultural entities over a wide geographical area into their imperial network, and in their legacies of historical bias, their metallurgical traditions are distinct. A much closer parallel in an actual metallurgical regard to Carthage is found in the Han Dynasty, for which there is ample historical and archaeological evidence for a state monopoly of the iron industry beginning in 117 BC (Wagner 2001).

Although comparative approaches bridging the Atlantic are rare in either of the hemispheres (but see Trigger 2003), the similarities of both state formation processes and the history of scholarship between the Inka and Carthage provide an opportunity to apply processual approaches to human behavior while refining explanation by framing each culture within its own particular context. Ethnographies dealing with the Inka Empire are vividly focused on the collapse of the state, with the periods of empire formation mostly relegated to apocryphal tales. Greco-Roman histories of Carthage are a mirror image of this situation, with the victor much more concerned with the victory, and much less with the long-term processes that brought their enemy to an original position of power. The Spanish Conquistadors, self-proclaimed inheritors of the Roman worldview, were well-trained to identify what they perceived as Carthaginian type barbarians in their enemies. The further parallel of the paucity of surviving texts written by both Inka and Carthaginian historians, combined with the external ethnographies compiled about each of these groups a posteriori to their political extinction, increases the chances for valid explanatory power.

The waters are murky when it comes to constructing clear comparisons between Phoenicians, Carthaginians, Tiwanaku, and the Inka. A half-Inka, half-Spanish writer named Garcilaso preferred to portray the Inka in terms of Rome (MacCormack 2008, 33). But a few broad traits of state-structured hierarchies and imperial control can be universally applied. Ideologies are developed in order to justify resource acquisition and management. The ideological differences between groups are in how these resources are acquired and distributed, each culture having its own morals that guide its interactions with its own populace as well as with potential opponents. As Stanish (2003, 236) writes, “like virtually every other imperial state in history, the motive for Inca expansion was territorial gain, appropriation of other peoples’ resources, and neutralization of potential enemies." In the case of the Phoenicians, they fit this model insofar as the neutralization of their opponents was in the form of appeasement to the Neo-Assyrians by acquiring other peoples' land and mineral wealth. Carthage differs in this regard and can be considered a true imperial state in line with this model, as their enemies were political equals, not overlords. In the sense that Tiwanaku was the first polity to achieve state-level political control in the Lake Titicaca Basin, so Tyre was the first to catalyze a regional export economy in Iberia. Neither the Titicaca Basin nor Iberia was economically or politically unified under a military authority until the emergence of the Inka and Carthaginian states, respectively.

The Phoenician engagement with Iberian sites, and likely others in North Africa and the Central Mediterranean, was characterized by growing economic sway based in the exchange of silver and iron. The withdrawal or collapse of many of the Phoenician and Iberian sites in the mid-6th century can be explained partially by the certain political changes that are known historically, such as the removal of Tyrian autonomy following the Neo-Babylonian siege ending in 573 BC. It is also likely that economic factors contributed to the weakness of Tyre, stemming from changes in market value of commodities provided by their colonies. Clearly, Carthage began to develop its own independent strategy, and it stands to reason that other Punic and indigenous sites were acting similarly. Following the "crisis of the 6th century BC," Carthage gradually moved into the territory formerly unified, roughly speaking, in a commercial sense. The "crisis" can be readily compared to the Altiplano period in the Andes. After the collapse of Tiwanaku, the Inkas initiated a "reimposition of political control in the region after the hiatus of the Altiplano period," ushering in a period of military control that had been previously unknown

(Stanish 2003, 294). The Carthaginian state also attempted to coopt Phoenician strategies of "nonmarket imperialism":

> …expansionist states such as the Inka had to rely on systems of labor control that dramatically altered local political and economic organization in territories where they sought to create economically productive province…The absence of regional market systems promotes imperial systems based on labor control. The Inka occupation of the Titicaca Basin stands as a classic example of such a labor-based system (Stanish 1997, 211-2).

In the case of the Phoenicians, Iberian elites were encouraged to harness their own labor in order to increase silver production. There is almost no evidence to support that the Phoenicians themselves worked the silver mines or participated in the smelting of large amounts of silver. Carthage instigated a more market-driven type of imperialism, accompanied with more military force than the Tyrians had used. Carthage coopted preexisting foundations, the Inka manipulated and transformed them. Both the Tiwanaku and Carthage incorporated a "pan-ethnic" and "pan-regional" ideology to maximize surplus and profit to Carthaginian traders (Stanish 2003, 282-3). The desire for extraction of wealth from abroad led to two competing strategies at Carthage: the merchant elite, inherited from centuries of Phoenician colonial expansion, and the burgeoning new class of the military elite, crystallizing in the 6th century BC. This latter elite included Malchus, the Magonids, and ending with the Barcids. These two poles of the Carthaginian political system were hard pressed to reconcile, as evidenced ultimately by the plotted betrayal of Hannibal to Rome (Lancel 1998, 191-2).

However, whereas there is no question as to the prominence of the Carthaginian military machine from the 4th century BC onward from historical accounts, the evidence for military domination over the Iberian, Sardinian, and Sicilian Punic and indigenous colonies is unclear before this time. It is antiquated to consider Carthaginian military ascendance as aiming to unify an ethnic group, or emulate the Greeks. There was certainly a sense of national identity based in the city state, as is known from inscriptions such as CIS I 270 that mentions the “Nation of Carthage,” “עם קרתחדש[ת]" (‘*am qarṭḥdšṭ*). But ethnicity in the context of Punic people was more a linguistic reality that created a common ground for commerce than a racial bond, and national identity was rooted in affiliation with a city state (Kaufman 2009). It is valid to question the narrative that Carthage began as a military juggernaut, but there is no doubt that by the 4th century it was fully militarized. It is more likely that Carthage began to militarize locally, expanding across North Africa (Warmington 1969), incorporating indigenous communities of the Central Mediterranean already accustomed to a Phoenician presence into its economic sphere through processes that can be called “hybridity” or “entanglement,” with some threat or acts of military coercion (Dietler 2010; Bernardini 2008; van Dommelen 2006, 2002, 1998, 1997; Tronchetti and van Dommelen 2005). The Carthaginians eventually exploited internecine strife between the decentralized entities of the Iberian coasts of the Mediterranean and Atlantic, manipulating them into dependence on the Carthaginian state (Burke 2008; González-Ruibal 2006). These processes all converged for Carthage with the military and agricultural expansion of the 4th century BC across the Central and Western Mediterranean (van Dommelen and Gómez Bellard 2008; Greene 1986). After two centuries of development from around 600-400 BC, Carthage was able to leverage the massive aforementioned territories and local populations to its benefit in ways ranging from a loose cultural or economic affiliation, to formalized military alliance.

Carthage was certainly spurred into a defensive posture by the realities of its time, and its expansion across North Africa, the Central Mediterranean, and Iberia can be seen as the manifestations of their strategies. Iron metallurgy at Carthage is considered an industrial, strategic technology, with state-sponsored intensified production indicative of colonial expansion, in light of the other available archaeological, historical, and epigraphic data. Following these lines of reasoning, metallurgical production at Carthage was a state-controlled affair. In the 8th-7th centuries BC, the Carthaginian colonial leadership may have been tasked with iron production by the Tyrian monarchy. But by the end of the 7th century BC, it is likely that production was firmly entrenched in the hands of the independent Carthaginian state. Effective control over the metal production is evinced by the ratio of ferrous to non-ferrous metallurgy—a nearly complete focus on iron production indicates that this material was not reserved for domestic consumption alone. State control is also demonstrated by the commissioning and decommissioning of industrial, residential, and funerary precincts, such as at Bir Massouda and the Byrsa, as well as the outsourcing of metal production to sites such as the Carthaginian mint at Tharros in Sardinia, and perhaps as far as the Punic mint at Lixus. Furthermore, iron was produced at both residential and industrial scales. Iron production in the residential zone under the *Decumanus Maximus* (ca. 700-550 BC) yielded slag specimens to the order of between four and eleven times fewer than the contemporary industrial zone at Bir Massouda (800-500 BC; Figure 7). Carthaginian smiths were smithing and forging iron, resulting in both wrought iron and steel in both residential and industrial contexts. Fuel-saving measures were enacted by insulating furnaces, as well as the recycling of murex shells from purple dye production as a flux in the smelting process. Epigraphic evidence makes some type of affiliation between the state and metalworkers abundantly clear. By the time Carthage began to poise as leaders of the Phoenician world following the reduction of Tyrian importance by the Neo-Babylonians, its smiths had already gained considerable experience in steel production and were able to produce weaponry to rival Greco-Roman encroachments and challenges to its territorial aspirations.

Relevant questions that have been, and can continue to be posed based upon this data include: why did Carthage set out to defend its own interests, and generally pan-Punic interests starting in the 6th century BC? To what extent did the Carthaginian military play a role in this strategy? The current results presented here cannot necessarily provide a great deal of resolution for these questions, but it does suggest that of all the other candidate cities across the Punic world, Carthage was in the best position to take the place of Tyre.

Indications of the ability of Carthage to achieve this prominence are found in the industrial-scale production of ferrous metallurgy. Carthage was able to capitalize on its early specialty in iron and steel technology and attain the competitive advantage over other cities. Even though it may be enough to define Carthaginian production as “industrial” based on the sole fact that this corpus of metallurgical debris is the one of the largest known in the North African and Near Eastern Iron Ages, the level of production can also be ascertained by comparison. Ranked hierarchies of production organization are known to range from the household to “large-scale industry,” the latter being characterized by a full-time, specialized, sedentary labor force that exports its product (van der Leeuw 1984, 723). The data from Carthage represent a level of industrialization that exceeds the constraints of van der Leeuw’s model, as metallurgy there was not only sedentary but was located in a precinct specifically established by the state for dedicated iron production. Contrast of this precinct with nearby contemporaneous household strata makes this a distinctly non-household archaeological feature (Figure 7; Hendon 2004). The Inka elite employed what has been called a “retainer workshop,” defined as full-time specialists working on a large-scale “for an elite patron or government institution within a segregated, highly specialized setting or facility” (Costin 1996, 211, 20-21). The combination of metallurgical and epigraphic evidence at Carthage, when considered alongside these models, suggests that a more appropriate term for the data here would be "state industry" with imperial connotations of a military-industrial complex. The epigraphic depictions of metalworkers in the votive and monumental inscriptions indicate that the labor force at Carthage was highly specialized, ranked, affiliated with the state, and associated into guilds. Historical evidence, combined with iron artifacts known from Carthage and Phoenicia that are by and large weapons and tools (Mazar 2004, 2001; Dayagi-Mendels 2002; Gal and Alexandre 2000; Delattre 1899, 1898), support the designation of state industry for the Carthaginian precinct. Other limited excavations yielding metallurgical production in Phoenician colonial contexts have been found from the 8th-6th centuries BC (Aubet Semmler 2002d; Niemeyer 2002, 2001), and it is not likely due to chance alone that the number of metallurgical production specimens from Carthage dwarfs those of other sites.

D. *Cultural Ecology: Timber and Mineral Resource Extraction and Management*

The relationship between humans and their surroundings is imbued with both social and physical value. Social values of a landscape are often manifested in ritual connection to a certain place—evidenced by temples, rock art, etc.—which has bearing on the principles of group and individual ownership (Anschuetz, Wilshusen, and Scheick 2001; Tilley 1994). These social values are often derived from an actual necessity or dependence on the physical resources, meaning that embedded social constructs can serve either consciously or subconsciously to manipulate a population and legitimize an attachment or ownership to land that is fundamentally only worthwhile due to the resources offered. Cultural adaptation to available resources is an essential characteristic of cultural evolution, but one that is not always readily seen due to conservative cultural taboos against innovative technologies (Rosen 1995).

Cultural or historical ecology or environmental archaeology, at the core, is about defining "characteristics and processes of the biophysical environment that provide a matrix for and interact with socioeconomic systems, as reflected…in subsistence activities and settlement patterns" (Butzer 1982, 6). Butzer presents five central themes that can be used as a model to understand Carthaginian ecological adaptations within their contextualized environment, namely space (metallurgical precinct at Bir Massouda; households under the *Decumanus Maximus*), scale (state industry; household), complexity (overseas resource extraction), interaction (fuel and tin scarcity; flux abundance), and equilibrium state (ca. 600 years of metallurgical activity executed in various ways and at shifting locations). These guidelines can serve to qualify—and sometimes also quantify—the human-environment interactions all within the framework of societal interconnectivity, meaning peer-polity, hegemony, etc. (Butzer 2012).

The pertinent natural resources for this study involve 1) metal ores and ingots for production, 2) timber for charcoal fuel and shipbuilding (Treumann 2009, 1997), and 3) land or territory for agricultural, mineral, and timber exploitation. Approaches to the human/natural resource relationship can take many different forms, such as supply and demand (availability), extraction, and ownership (which is a tripartite relationship between human group x, human group y, and the environment), to name a few. All of these issues concern human strategies, and are directly related to political and social decision-making, and also relate specifically to metallurgical concerns. Arguments over the reasons for the diffusion of iron technology across the Mediterranean are diverse. Traditional and recent theories suggest that ubiquitous iron ore was preferred following the Late Bronze Age collapse and the subsequent copper and tin shortages (Waldbaum 1980; Childe 1951), that iron ore was more fuel efficient to smelt following Iron Age I timber shortages (King and Stager 2001), that steeled iron tools were more effective at hammering other metals into shape (Snodgrass 1980; Childe 1951), or that iron was ideal for specific weaponry and military applications (Kassianidou 2012; Muhly 2006; Childe 1951, 1944). The British Iron Age is concomitant with a “more highly ranked society” and the proliferation of hill-forts, around 800-700 BC (Renfrew 1982).

These questions can be examined using the vast amount of the iron metallurgy excavated at Carthage. Iron became the metal of choice by the 10th century BC and onward in the Levant (Gottlieb 2010; Waldbaum 1980), and there is a temporal connection between the fragmentation of the Northwest Semitic linguistic groups into states (i.e. Aramaeans, Tyrians, Carthaginians, Judeans, Israelites, Moabites, etc.) and iron adoption. Although it is likely that much of the iron at Carthage came from Sardinia, Iberia, or Tunisia itself, sourcing the iron and copper alloys is not part of this research project, as this does not inform on whether or not these resources were extracted against the will of the indigenous Iberians, Sardinians, etc., or whether they were traded (Giardino 1995, 1992; Massoli-Novelli 1986; Wolff 1986). Instead, the plethora of metallurgical production at the capital itself is taken as a testament to production of weapons, tools, and ship-fittings for tribute, and eventually military purposes. The population was not agrarian and was, therefore, likely not mass producing tools—they did however depend on iron to trade for food— thereby increasing the marginal importance of iron.

But what type of iron implements were actually being produced at Carthage? The excavations at Bir Massouda yielded very few iron artifacts, mostly lumps of corrosion beyond typological recognition or nails. Previous excavations have, however, produced iron artifacts. Delattre (1899, 1898) encountered mostly knives and a spear point in the Byrsa necropolis, with many nails. Rare examples of finished metal products are often weapons, such as the Punic sword found in Magon’s Quarter and on display in that museum (Niemeyer, Docter, and Schmidt

2007a, 2007b). Traditional approaches to the spread of iron metallurgy acknowledge that the Assyrians began to apply iron metallurgy to novel military endeavors by the mid-9th century BC (Childe 1944). Only beginning in the 6th century BC, and attested heavily by the 4th century BC, is iron metallurgy fully developed for agricultural and construction implements in the Greek world. State commissioning of metallurgical zones also implies strategic rather than purely economic roles. Of iron artifacts from Bir Massouda, all were corroded beyond recognition except for the two nails (Appendix III19, 20). The slag indicates Carthaginian smiths' consistent ability to produce steel. This was most likely delivered at first to Tyre, but later incorporated as a fundamental element of the military-industrial complex of the burgeoning Carthaginian Empire. Carthage was a city that originally thrived mostly on maritime trade, but in later periods we read of the bitter feud between the Phoenician old guard that had an eye on profit, and those who sought wealth via military expansion such as the Barcids— distinctly Carthaginian. These two types of groups likely reflected the major poles of interest since the 6th century BC. On one hand, a group that required metallurgy and timber to fashion ships for trade, and on the other, a group that required metallurgy and timber to fashion weapons for its citizen officers in addition to ships.

There is evidence that Carthaginian smiths intentionally manipulated the furnace environment in order to save fuel. The furnaces were lined with quartz of fine-medium coarseness, ideal to insulate furnace heat (Docter et al. 2003, 64). Recycling of murex shells from purple dye production provided a flux by which to lower the melting point of the silicates and conserve fuel. Purple dye production is known from many sites, such as at Sarepta in the homeland, and was achieved by the processing of murex harvested from the Mediterranean (McGovern and Michel 1985). Tyrian purple was the royal color of choice in the ancient

Mediterranean, and it has been demonstrated experimentally that the dyeing of one robe would take around 10,000 murex snail shells to produce (Koren 2005, 146). The industrial byproduct of ground up shells was therefore enormous, and the Carthaginian smiths utilized the calcium-rich shells as a flux. This is likely one of the major reasons why Carthage was able to produce iron and steel on an industry level—namely through the synergistic recycling of industrial byproducts and the subsequent mass fluxing activities of the iron silicates. This flux allowed for mass production while also increasing iron oxide output into the bloom, and saving fuel (Charlton et al. 2010, 363). North Africa is not known for being rich in iron ore (Niemeyer 2001), and only in Roman times is there evidence for iron ore extraction at Djerissa, near Althiburos (Sanmartí et al. 2012; Wolff 1986, 182). It is possible that the Carthaginians exploited local iron ores and the evidence has not been found, but it is more likely that sailors brought in the supplies to be worked by the metallurgical specialists at the urban center as in the colonial centuries Carthage did not dominate its own hinterland.

These fuel saving measures were crucial for production at Carthage, as the scant palynological evidence that is available indicates a relatively deforested landscape. Metallurgical trends are always at least partially dictated by fuel considerations (Kaufman 2013; Ben-Yosef 2012). Palynological data for North Africa is relatively limited, but the data that are available show that Carthage did not only lack mineral resources relative to Iberia and Sardinia, but also lacked forests as well. It is possible that olive pulp was used as fuel at Carthage (van Zeist, Bottema, and van der Veen 2001, 59), although it is unclear to what extent this could have been harnessed enough calorific potential for ancient metallurgical production (Arvanitoyannis, Kassaveti, and Stefanatos 2007). The high herbaceous pollen evidence also indicates that tree growth, outside of orchards, was rare at Phoenician and Punic Carthage, but there must have been enough in the 7th-5th centuries for smithing activities. Other evidence of large scale anthropogenic deforestation is contemporaneous with the Punic Wars—occurring during the third century BC in the Moroccan Atlas range—with a reduction of hardwood oak and cedar trees, among others (Lamb, Eicher, and Switsur 1989, 72). Further fuel conservation in the colonial and transitional phases of the city, from 800-530 BC, was executed in the production of tin bronzes. The only evidence at Bir Massouda of bronze production, in the form of recycling, occurred between ca. 760-580 BC. This is also the period wherein the bronzes recovered from excavations contain the highest average tin content compared to later periods. The 3rd century BC shows the greatest decrease of tin content in any period. This is due to the cessation of trade routes into Carthage by Rome, removing the tactical component of the bronze alloy. Tin bronze allows both good mechanical properties and fuel efficiency, and is the most preferable bronze alloy for cultures that have fuel shortages (Kaufman 2013), but the tin routes were restricted by Rome during the collapse of the empire. It would be appropriate to further investigate fuel availability trends in the colonial phase to see what impact this may have had for choosing Carthage as a smithing center.

E. *An evolutionary history of Carthage*

i. *Colonial Phase*: *800-700 BC*

For the Tyrians, maintaining autonomy required resource acquisition in the form of precious metals, closely guarded techniques in the extraction of purple dye from murex shells, and other exotica for the Neo-Assyrians. Carthage was strategically located to be a geographically well-placed port of call for Tyrian ships heading east from Iberia. It was also possibly founded as a refuge for Tyrian royalty. But if there is any veracity to this story, it is more likely that exiled

Tyrian royalty joined a previously established, nascent colony. Iron production, although perhaps not the original raison d'être for the establishment of a colony at Carthage, made Carthage a key component of the Phoenician metal procurement assembly line starting around 700 BC. By the 7th century BC there was also the erection at Bir Massouda of what may be casemate walls, part of a defensive structure (Docter et al. 2003). Iron was used for tribute and/or export to Tyre, trade with local populations for food, as well as domestic consumption. The contemporary ironworking complex at Morro de Mezquitilla boasted different metallurgical technology than Carthage—perhaps a more efficient one in terms of extraction. This attests to the agency of smiths in choosing production technique, or perhaps a difference in smelting versus smithing tuyères. Adopting Charlton et al.'s (2010) model of various production lineages even at one smelting site, this may reflect a situation in which most of the final product was owned by the state, and the smiths were encouraged to be efficient with an incentive of owning part of the production output. Therefore, different Phoenician smiths found various ways to produce that would maximize their profit. It is possible that the Carthaginian smiths adopted the tapering-to-one-hole nozzle system by the end of this period at the Byrsa, but in any case it is noteworthy that a difference existed between Phoenician smiths providing to Tyre from different regions. This indicates a free enterprise system operating within a state framework. During the 8th century BC, the earliest known necropolis at the city was also decommissioned, perhaps to make way for the metallurgical precinct.

ii. *Formative Phase: 700-500 BC*

Why did Gadir or Morro de Mezquitilla not become the primary Punic settlement, or more reasonably, Nora, Sulcis, or Tharros? These are all environmentally similar locations to

Carthage, with agricultural potential, richer than Carthage in metal (and perhaps fuel) resources, and with similar potential threats from surrounding indigenous and Greek populations. The answer may lie partially in political structure—that Carthage was effective at negotiating with various groups, while certainly not incorporating them into its citizenry. But a more concrete answer is to be found in the scale of industrial production of iron and steel.

By 700-650 BC, a full-fledged state industry developed at Carthage, centralized at Bir Massouda. In the 7th century BC, it cannot be said which state was behind the production— Tyre or Carthage—although it is likely that a combination of private and state enterprise existed at both the imperial and colonial scales. By the traditional band, autonomous village, rank-society models, social adaptation is often envisioned to be a slow phenomenon, and one that makes all societies look artificially similar. By incorporating action theory and social evolution, transition periods are viewed as a way to distinguish between cultures and their evolutionary adaptations. These are the rapid phases where new societal paradigms are sparked, and tend to look different among various "first generation" cultures (Marcus and Flannery 1996, 244-5). Phoenicians and Carthaginians do not represent a pristine example of state or empire formation, but the colonial inhabitants of Carthage did undergo rapid transitions in their formation of empire. This two-century period witnessed one of the largest and earliest known industrial production of iron and steel known to scholars from North Africa or the Near East. Smiths, operating in an ecological framework with relatively low timber resources, recycled purple dye industrial byproducts in the form of murex shell as a fuel-efficient calcium-rich metallurgical flux that must be employed with a high degree of skill to generate a slag flow and purify the iron. They also used quartz-rich heat trapping layers in their furnaces to conserve fuel. Historical attestations indicate that Carthage achieved independence from Tyre in 654 BC. Babylon hegemony over Tyre by 573 BC certainly created a realpolitik which removed any real Tyrian influence over Carthage, although a ceremonial link of national kinship was maintained. Therefore, historically between 654 and 573 BC, the primate center of the Phoenician and Punic world was transferred from Tyre to Carthage (Johnson 1980). As Greeks and Carthaginians were battling in Sicily ca. 580 BC, the state metal industry at Carthage was at its height archaeologically. Docter (2007, 42) also suggests that indications of garbage collection in the last half of the 6th century BC is evidence for centralized planning. Much more data has been preserved for this formative 200 year period than for the last century and a half of Carthaginian existence, although there is no doubt that intensive ferrous technology in weaponry and tools was being practiced *somewhere* in the Carthaginian empire, if not at the capital. It also cannot be ruled out that other pockets of state industry have not yet been excavated at the capital. Private Carthaginian residents were also producing iron and steel in their homes, but by an order of at least four times less than the industrial zone, and perhaps as much as eleven times less (Figure 7).

iii. *Imperial Phase: ca. 500-200 BC*

The fifth century witnessed a sharp reduction in metallurgical activity at Bir Massouda. By ca. 425-400 BC, metallurgical production was completely halted, the precinct decommissioned, and a residential zone built. During this century, the only other evidence of large-scale Carthaginian metallurgy at the capital is to be found on the slopes of the Byrsa. The state transferred the metallurgical precinct to a living cemetery on the Byrsa, thereby temporarily splitting production over multiple zones. It may be possible to link metallurgical precincts with funerary zones: the Archaic necropolis and metallurgical zones were commissioned in succession to each other in Bir Massouda; the imperial necropolis and metallurgical zone were in simultaneous operation on the Byrsa. Production at the Byrsa continued until the end of the 3rd century BC. There is also the evidence for Carthaginian outsourcing practices at Tharros in Sardinia, with a metallurgical zone that also likely included a Carthaginian mint. The bronzes excavated from Tharros indicate that Carthage was receiving metal down the line mostly from Cyprus, and some from Sardinia. The lands and mines that the Tyrians controlled were now coopted into the holdings of the Carthaginian state. This Sardinian precinct and mint was coterminous with that of the Byrsa, and likely contemporaneous with the mint at Bir Massouda (Frey-Kupper 2008; Docter 2005). Recycling metal was common practice. A gated sea defense wall was erected in the 5th-4th centuries BC (Lancel 1995: 137-141). The rectangular harbor was constructed in the 4th century BC, and a fluorescence in agricultural expansion occurred during the imperial 4th century BC as well. A rare type of inscription dealing with military history has Carthaginian generals conducting military campaigns in Sicily around 405 BC {Schmitz, 1994 #8583`; CIS I 5510}. Metalworkers were entrenched in the state hierarchy in such a way that their occupations were immortalized over the burnt offerings of what were likely their children. Carthaginians' personal and communal identities were intertwined with the state. The exclusive nature of Carthaginian citizenship managed to continuously unify or convince its people to buy-in and jointly leverage natural and human resources across the Mediterranean for centuries.

iv. *Collapse: 200-146*

It should be mentioned that this study does not endeavor to outline the reasons for collapse, per se, but there are multiple patterns that emerge from studying the mechanisms of empire formation that can then be applied relevantly to the problems surrounding collapse. It could however be argued on solid historical ground that the period of collapse was from 264-146 BC, during which the imperial future of Carthage was tested during the Punic Wars with Rome. At its military height in the 3rd century BC, Carthage exerted real military might over Iberia and much of the Italian peninsula down to Capua. Reasons for the collapse of Carthage will not be dealt with here comprehensively, as the archaeological evidence is largely nonexistent due to Roman destruction and rebuilding efforts.

However, a few points do emerge from the data presented herein. What is known is that no large-scale metallurgical precinct has been excavated dating to the last half-century before the destruction of Carthage. Instead, small pockets of activity are found throughout the capital, sometimes associated with industrial or military state-level activities such as at the circular harbor. After a hiatus of at least two centuries, it may be that localized ferrous metallurgy returned to Bir Massouda, but in vastly lower numbers due to the loss of territorial holdings and outsourcing facilities. It is possible that the tuyères and slag dating to the Late Punic at Bir Massouda are residuals from earlier periods, but if they do date to the Late Punic period they most certainly do not represent an organized precinct and can only be argued as a localized, decentralized phenomenon.

Regarding the metal alloys, the tin supply was severely curtailed by the Romans in the 3rd century BC, despite historical evidence of vast commercial prosperity at Carthage with huge quantities of silver attested in the 2nd century BC following the Second Punic War. This strongly indicates that certain commodities were restricted by the terms of the armistice, including tin. Despite the strict terms by which Carthage had to abide, a luxurious residential sector referred to as Hannibal’s Quarter (Lancel 1995: 156) was built ca. 200 BC. Despite military defeat and territorial loss, the city-state of Carthage thrived commercially in its last half century, its merchant elite thriving so much that they were able to offer the full 50 year war indemnity it owed to Rome—10,000 Euboic talents=260,000 kilograms of silver—after a mere 10 years (Lancel 1998: 182). Rome refused. Reputedly, Carthage supplied 400,000 bushels of wheat to Rome in 200 BC, and again offered 500,000 bushels for free in 191 BC, surpluses that alarmed Cato the Elder sufficiently to eventually call for the destruction of the city (Livy XXXI, 19, 2; XXXVI, 4, 9; Lancel 1998, 183). Even if we are to reduce Livy's numbers considerably, such an enormous potential to acquire silver and supply grain when under embargo provides a window into the capacities of the state before the loss to Rome in the Second Punic War.

Insofar as the reasons for collapse are rooted in the formation of the Carthaginian system, it could be proposed that a systemic reliance on mercenary forces in lieu of granting citizenship rights is partially to blame for a Carthaginian inability to muster its own forces or allies. A Roman ability to transform both communal and individual allies into its citizenry and army was certainly a political adaptation to a nuanced military situation (Lancel 1998). With large amounts of both natural resources and manpower at their respective disposals, both Roman and Carthaginian commanders had their decisions influenced by political systems that were largely beyond their control. Although we have large parts of the Roman constitution preserved, we do not have a comparative sample from Carthage.

The levels of organized industrial activity that we find in both the formative and imperial phases at Bir Massouda and on the Byrsa have not yet been attested for the Late Punic period. It may also be that the state forges dating to the Punic Wars have not been excavated or preserved. Historically, the military power of Carthage was overwhelmingly strongest in Iberia and the Italian peninsula in the 3rd century BC, and it may be at locations like Cartagena that we would expect to find the Late Punic metallurgical zones such as those at Bir Massouda and the Byrsa.

The betrayal of Hannibal by the Carthaginian Senate as recorded by classical authors can be seen also as a symbolic culmination of the broader economic and political tension in Carthage between the old Phoenician-type merchant class and the Carthaginian generals that had minted their military tradition in the 6th century BC. The victims of this tension were ultimately the Carthaginian people, the constitutional freedoms they enjoyed in the People's Assembly fated with widespread destruction in 146 BC.

v. *Political extinction: 146 BC – …*

Once Scipio Aemilianus actually destroyed the capital at Carthage in 146 BC, the empire was shattered. The date for the extinction of the Carthaginian state as an entity is undisputed. However, Punic religious rites, and the Punic language, continued on for centuries. Cultural extinction was not necessarily achieved, and an indirect Carthaginian influence on the cultural perception of the "other" continued to thrive under Roman society, as well as under societies that perceived themselves as the cultural inheritors of Rome.

Chapter 7. Conclusions

The Chapters presented above display that through the application of archaeological, historical, and metallurgical trends, diachronic evidence of imperial expansion and industrial technologies can clarify the behaviors of an expansionist state. The results from this study provide a model of how states may utilize strategic technologies from their establishment to their fluorescence and finally to their decline and fall. Material correlates to centrally organized behaviors can most effectively be viewed at the urban center where state-level decisions are executed. In other words, the "archaeology of capitals" may be considered a method through which the social and political activities of the state can be witnessed materially at the primate center in a way that is impossible at any other site that the polity controls. Whereas the idea of network systems that are distilled into core and peripheral sites based on size can be somewhat arbitrary and coarse, the material remains of a capital must be distinct from all other sites.

Carthage has few inscriptions that explicitly inform scholarship on the machinations of the state, however, there are just enough endemically generated texts to provide some crucial information on the connection between state and industry. There are many sites throughout both the Old and New Worlds that have a similarly limited number of texts, and in some cases none. The excavation of mass-production zones that fluctuate in intensity, size, and distribution can aid in the identification of these sites as the core centers of emerging or secondary states. It may not be enough to characterize synchronic production zones as a hallmark of burgeoning or established states. It is rather through evidence of long-term manufacture and the oscillations therein that state strategies and centrally controlled technological traditions can be discerned.

One hypothesis throughout this manuscript is that Carthage is an ideal case study to observe these behaviors.

Chapter 1 outlined the fundamental connection between Phoenician colonial foundations and metal prospecting. The establishment of far-flung warehousing centers could only be commercially viable for the Tyrian state if high returns on their investment into colonial and mercantile infrastructure could be obtained, the likes of which could only be derived from precious metals. Phoenician traders were the agents of this mercantile cooperative network that enfranchised local elites through the provision of otherwise unobtainable luxury commodities, mostly in exchange for rights to silver mines, silver, and establishment of warehousing colonies. Each of these including Carthage operated with a specific function in the greater scheme of tribute provision back to Tyre and ultimately to Assyria.

Chapter 2 focused the lens of Phoenician experience onto the flagship Tyrian colony of Carthage, exploring the archaeological evidence of Carthaginian influence across the Mediterranean as well as offering a reconstruction of its constitution based on texts and epigraphy. It is while discussing the ascendance of Carthage that the arbitrary division of the terms “Phoenician” and “Punic” break down when trying to assign some sort of ethnic or temporal shift in identity. The Phoenicians themselves are essentially seagoing Canaanites, distinct from other Northwest Semitic language groups such as the Israelites, Judeans, Moabites, and Aramaeans mostly because of the gods they worshipped and their maritime expertise. The colony of Carthage, historically founded in 814 BC and with the first archaeological evidence dating roughly to this period, was to surpass all other colonies due to a combination of strategic location in the Central Mediterranean and an incipient role producing industrial levels of iron and steel. The lapse of Tyre in the 6th century BC and the vacuum that it created after its fall to

Babylon was the spark that allowed Carthage to emerge as the most powerful Phoenician city-state. The removal of Tyre meant that the enormously profitable trade network that it had built up over centuries was now precariously placed. Tyrian colonies, local elites in Sardinia, Sicily, North Africa, and especially Iberia were forced to restructure their alliances and reorient their hierarchies that had been based in the silver trade. The destructions and abandonments witnessed during the "crisis of the 6th century BC" can be seen as a combination of internecine conflict and external jockeying for power. Although the exact processes of reorientation cannot be reconstructed exactly, what is clear from the subsequent material culture is that Carthage emerged as the new power broker in lieu of Tyre.

Chapter 3 presented the methods by which the archaeometallurgical results of Chapter 4 are derived. Representative samples of hundreds of whole and fragmented tuyères, slag, alloys and corrosion products, and other infrastructure such as an anvil and bloom or ore grinder were analyzed in light of their archaeological, historical, and epigraphic contexts. From the 8th century BC, when Carthage was still a colony of Tyre, small-scale metallurgy began and continued into the early 7th century BC in domestic contexts under the *Decumanus Maximus* as well as at Bir Massouda. By the middle of the 7th century BC, at around the time that Diodorus Siculus places Carthaginian independence (654 BC), the site of Bir Massouda was home to an industrial operation of smithing and forging. It may be that the colony at this time was still part of the Tyrian metal procurement system, providing tribute iron to Tyre. The other option is that Carthage commissioned this precinct around the time of independence, choosing to invest resources in the mass production of iron and steel. The data here cannot resolve this issue, but what is certain is that by time Carthage was independent of Tyre, certainly by the end of the

Neo-Babylonian siege of Tyre in 573 BC, Carthaginian smiths had at least a century of expertise in ferrous technology upon which to draw.

Furnaces were set in compacted layers comprised of materials from the 8th-7th centuries BC, and lined with heat-insulating layers of appropriately-sized quartz grains. Murex shells leftover from purple dye production were transferred into the metallurgical precinct to be used as flux, further conserve fuel, and generate a slag flow to succeed in purifying the iron. Carthage was an iron and steel producing hub of the Phoenician metal procurement network; iron-rich blooms that had been smelted from their ores at a location other than Bir Massouda were brought here to be further refined and forged into final form. Rectangular double-barreled tuyères, different in typology from contemporary ones at Tyrian colonies in Spain, were employed in the hundreds to operate the furnaces. Likely coupled with animal skin bellows, these were reused multiple times, as the smiths would poke holes in the viscous slag. Tuyères were held at an angle, directing an oxygen or carbon dioxide blast into the furnace charge. The slag would smelt out of the bloom, forming a slag hood over the tuyère terminus as the blast was directed to the furnace charge beneath. The smiths produced steel, wrought iron, and recycled the odd bronze object that needed to be melted down. Despite an almost exclusive focus on iron production, only four iron artifacts were recovered from the excavations at Bir Massouda over all periods. Iron was surely consumed locally at Carthage, but the inverse proportion of iron slag to iron products is a clear indicator of export activities.

The 6th century BC was the time where the Phoenician world transformed from what can be characterized as a Tyrian mercantile cooperative empire to a Carthaginian mercantile coercive empire. Beginning ca. 530 BC, the diversity of bronze alloys flourished. It is during the period from around 580-300 BC that Carthaginian expansion fluoresced across Africa, Sicily, Sardinia, and the Iberian Peninsula. The furnaces at Bir Massouda continued to operate throughout the archaeologically attested “crisis of the 6th century BC” and the blossoming of Carthaginian material culture in Spain, the wars of Malchus on Sicily ca. 580 BC, the wars on Corsica, the first treaty with Rome, much of the Magonid period and this dynasty’s territorial expansion, and many other events that represent imperial strategy based in militaristic rather than agrarian or commercial policies. The old Phoenician naval prowess was now complemented by Punic land operations. The longevity of a zone that was dedicated to iron and steel production at the capital is explained by central organization of the state with a strategic interest in ferrous technologies. At around the time that Carthage reached its peak control of Sicily at the end of the 5th century BC, the precinct of Bir Massouda was decommissioned into a residential zone and another precinct that had been operational on the Byrsa was tasked with the continuation of fostering ferrous technologies. This Byrsa precinct continued from ca. 500-200 BC, contemporary with the erection of a Carthaginian state mint in Sardinia. These behaviors indicate that the state pared down industrial activity in the capital while simultaneously outsourcing metallurgical production to the territories, all pointing to the existence of rigidly controlled centralized planning. There is little doubt that despite the Byrsa production, along with smaller-scale activities at the Harbor and Tophet, the state was organizing massive levels of iron production in its acquired territories during the 3rd century BC, the period during which the First and Second Punic Wars with Rome occurred and the demand for iron hardware may never have been higher. By the first half of the 2nd century BC once Hannibal had lost the dynastic Barcid bid to expand empire at Rome’s expense, industrial production at the capital ceased completely.

Chapter 5 offered epigraphic insights into the agents of the state industry at Carthage, the smiths. Smiths at Carthage occupied a prominent place in their state. They were responsible for the working of gold objects and ceremonial vessels, but curiously there is no archaeological or epigraphic evidence for the production of silver. Smiths were, however, stratified into specialties and ranks. Master smiths, metalworkers, ironsmiths, and bronze casters were proud enough of their professions, and wealthy enough because of them, to commission inscribed stelae for their sacrificial offerings in the Tophet. The sons, fathers, and sometimes the metalworkers themselves were called "Judge," at least exhibiting a pride in their ancient state office through naming practices, and at most indicating that they themselves also held the judicial title. Upon erecting a monumental structure probably sometime in the 3rd century BC—the "New Gate"—the state celebrated through inscription its goldsmiths and furnace workers, paying out at least 1000 silver pieces.

Chapter 6 traces the legacy of Carthage through time, showing that it can be considered the original "Oriental" other. A jointly romanticized and vilified state, anthropomorphized through the terrifying and awe-inspiring figure of Hannibal, particularly fashioned knowledges of Carthage have persisted since its destruction in 146 BC. The Romans saw in Carthage the ever-present specter of their demise. The Vikings respected the cleverness of Dido's land grab. The Spanish justified the disenfranchisement of New World inhabitants by painting themselves as Rome resurrected and the Indians as the descendants of wayward Carthaginian sailors, which morally mandated territorial seizure. Modern populations in Lebanon and Tunisia draw their national aspirations from the Phoenicians and Carthage. It is through these lenses—that may tend to skew the reality of 1st millennium BC Phoenicia and Carthage—that scholars view the data, meaning that recognizing these biases is of paramount importance. For this reason universal analogies were proposed and juxtaposed between the mercantile cooperative economic systems of Phoenicia, Tiwanaku, and Sumerians on the one hand, and the mercantile coercive economic systems of Carthage, Inka, and Akkadians on the other. Attempts to reconstruct an evolutionary history of Carthage reveal that state planners had a deep tradition of tension over these two fundamentally different approaches to resource extraction. The old Phoenician merchant elite at Carthage were the latter-day vestiges of an uninterrupted maritime commercial culture that can find its roots on the Levantine coast as far as back as the Early Bronze Age. This group, influential until 146 BC, faced displacement by the nouveau warrior judges of the 6th century BC, a class of generals and dynasts that attempted to adapt the Phoenician world to the new Mediterranean realities of Greek and Roman expansion.

Appendix I. Tuyères with Slag

A. *800-500 BC*

I1. Locus 1112, Artifact 38082

Context: 650-580 BC – "= 1093, (below) 1111, (next to) 1115, (above) 1116: Compact levelling layer." Further comments by Roald Docter – "1112 was a compact levelling layer with many metal (working?) finds and faeces, suggesting also an outdoor surface, with residual finds dated to c. 650-580 BC; the context itself is Middle Punic."

Overview: This polymetallic slag contains copper, tin, and iron – the lead and arsenic contents recorded on the pXRF could not be verified by EDS. The slag is characterized by a host of unique microstructures including prilly tin-rich silicates, leafy bronze shoots, bimetallic iron-copper silicates, and metallic bronze globules. The bronze globules confirm recycling activities. Tin is never found without copper or iron, making a tin smelting scenario unlikely. There is not enough of the ceramic remaining to determine whether it is a tuyère, crucible, or another metallurgical ceramic.

Figure I1a. L. 1112 38082. Mounted and polished cross section

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P	S	Al	Mn	Zr	Cu	Sn	Zn	Pb	Ni	As
L.1112 38082	650-580	2	4.504±0.094	1.491±0.097	16.549±0.289	0.928±0.041	0.128±0.066	0.116±0.018	1.301±0.299	0.183±0.155	0.014±0.001	5.856±0.097	0.201±0.011	—	0.034±0.004	—	0.004±0.003

Table I1. pXRF slag composition

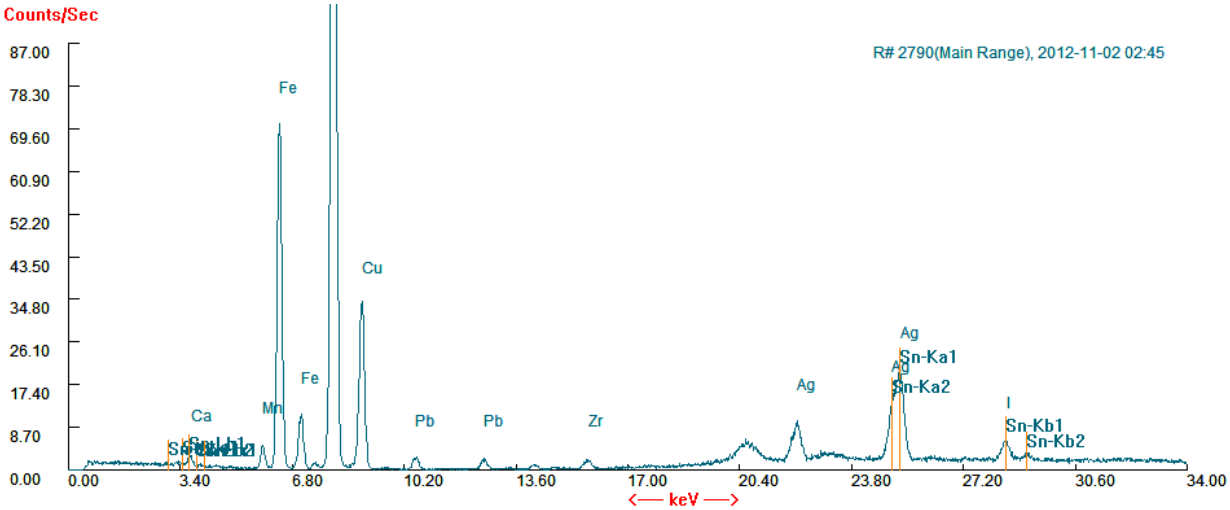

Figure I1b. pXRF - Overlapping spectral interference of the silver Kβ line and the tin Kα line

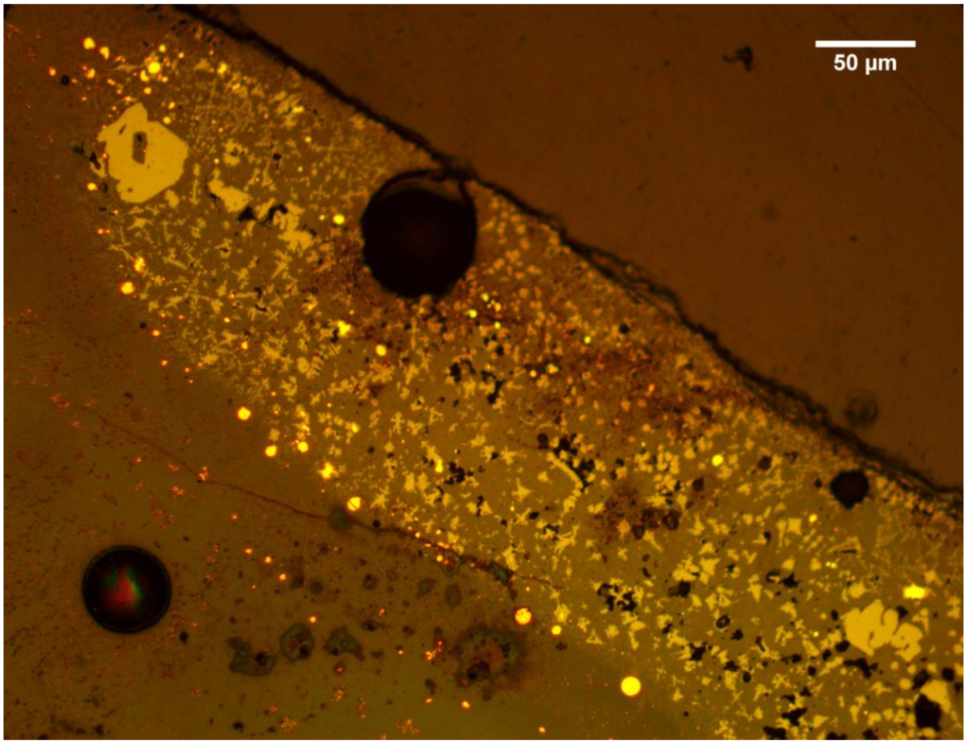

Figure I1c. Optical micrograph of bronze globular nodules fencing in wüstite and other iron and copper rich silicates

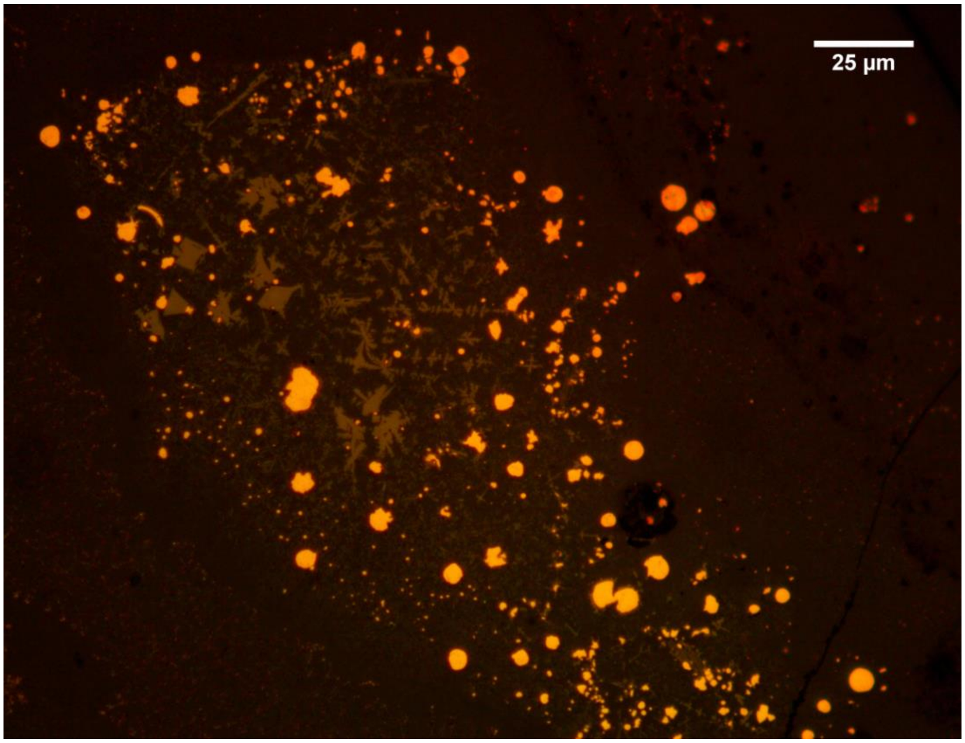

Figure I1d. Bronze globules associated with silicates, polarized

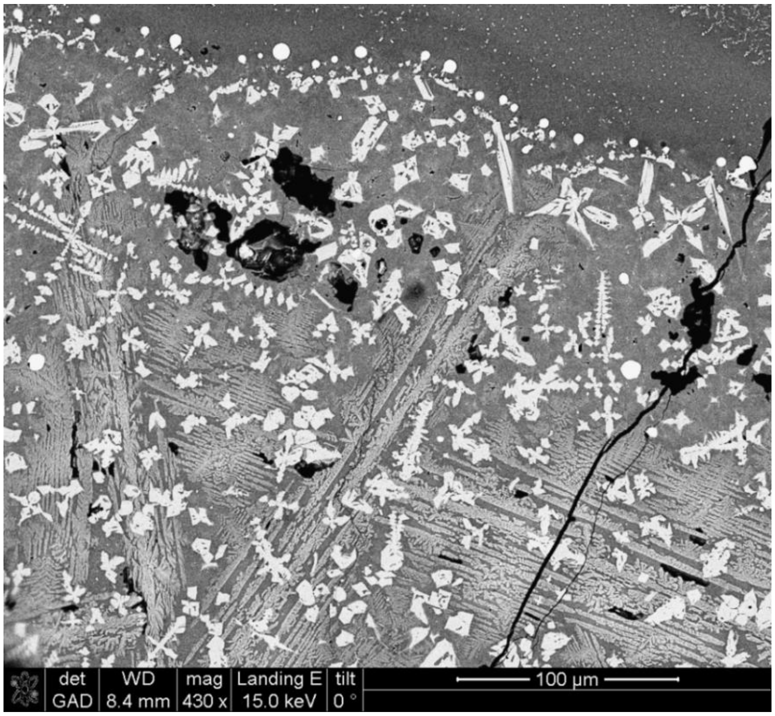

Figure I1e. Backscattered shot of bronze globules, wüstite, and silicates

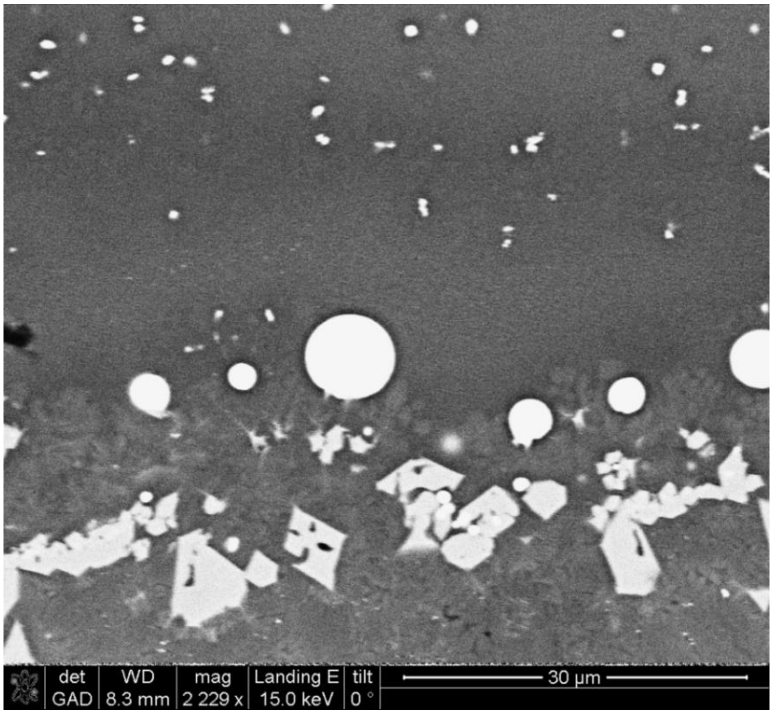

Figure I1f. Close-up of bronze globules

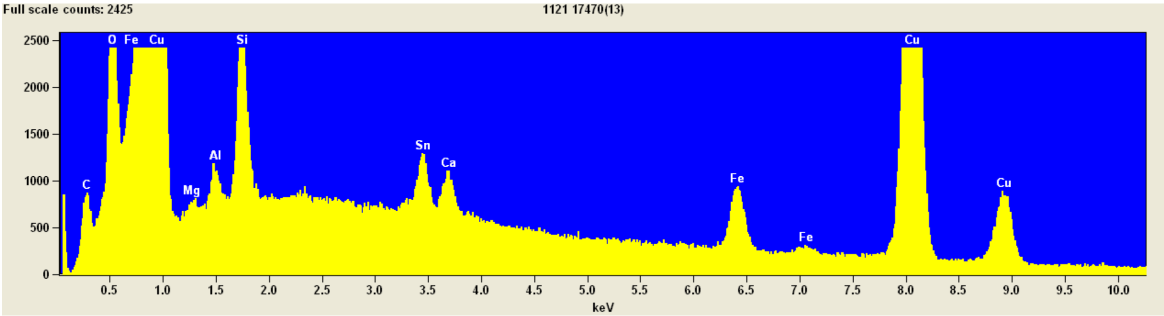

Figure I1g. Tin EDS peak of the largest metallic globule above in Figure I1f. 82.63Cu 2.39Sn 3.83Fe 0.37Ca 2.36Si 0.40Al 0.20Mg 4.52O 3.30C

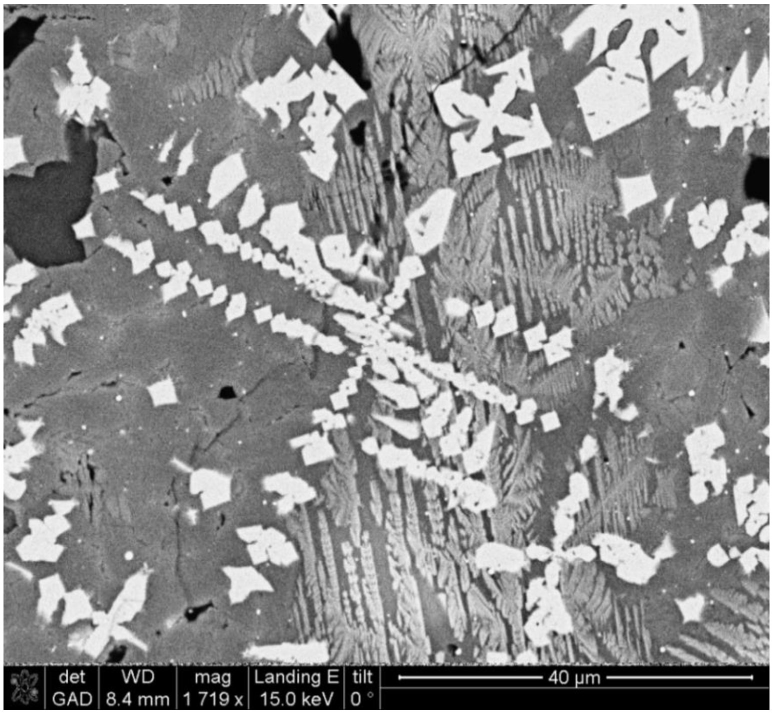

Figure I1h. Wüstite in bright white, in wt% 65.70Fe 0.46Ti 0.49Ca 2.28Si 1.52Al 0.21Mg 27.88O 1.45C. Impurities likely due to lack of ultrasonic cleaning

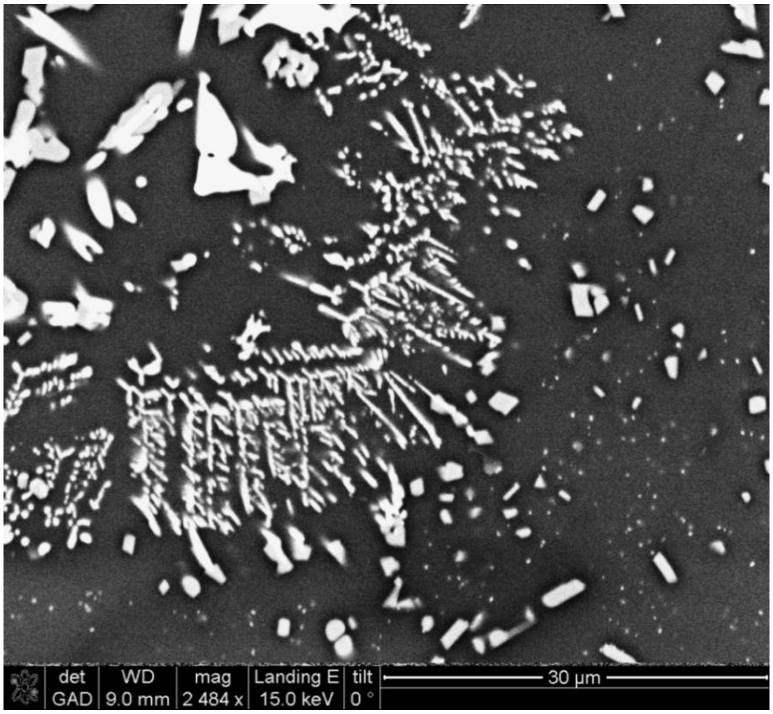

Figure I1i. Prill-like veins are tin-rich, in wt% 20.30Sn 8.28Cu 3.03Fe 0.41Mn 2.00Ca 0.29P 20.27Si 4.33Al 0.34Mg 38.31O 2.44C

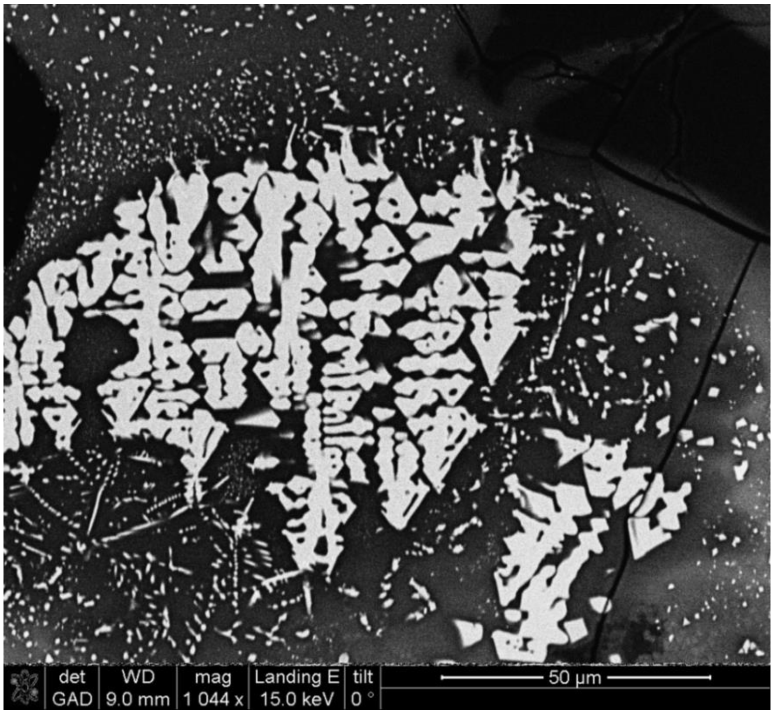

Figure I1j. Bimetallic iron-copper silicate in bright white, in wt% 12.77Cu 51.13Fe 1.87Mn 0.17Ti 0.24Ca 2.14Si 1.38Al 1.36Mg 27.16O 1.78C

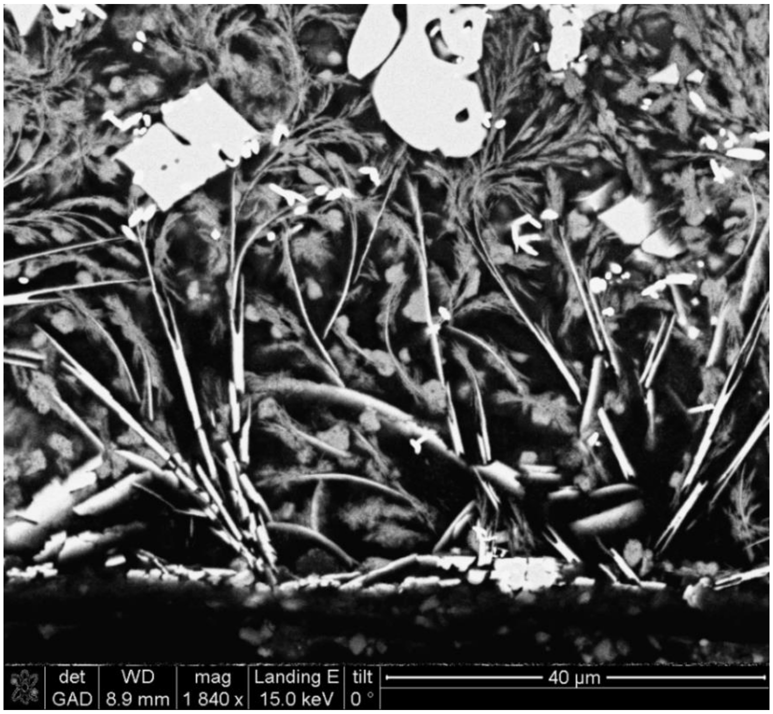

Figure I1k. Leafy microstructure wherein the stringy plant-like shoots contain in wt%11.48Cu 5.04Sn 10.96Fe 1.87Mn 0.26Ti 1.68Ca 1.71K 0.15Cl 0.27P 16.17Si 3.92Al 0.30Mg 37.27O 8.94C

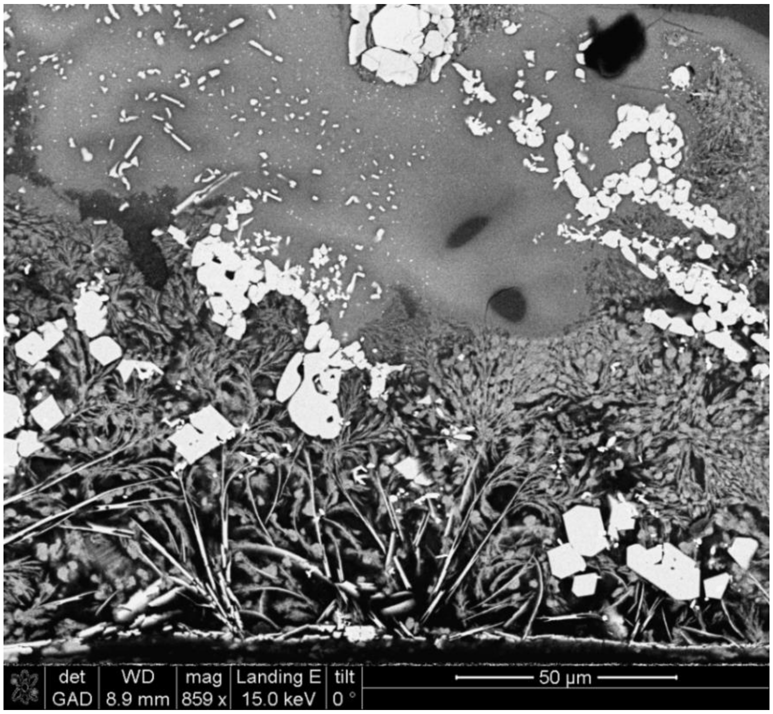

Figure I1l. Leafy microstructure

I2. Locus 1121, Artifact 17470

Context: 760-600 BC – "Layer below 1117 and next to 1122 (wall 1123); on top of floor 1127; contained many sherds, esp. in the NW corner: apparently a primary destruction layer." Further comments by Roald Docter – "1121 is a fill on top of a walked street or outdoor surface, dated to the period 550-450 BCE, but with a majority of residual material dating to c. 760-600 BC."

Overview: This piece of polymetallic slag is the earliest verified evidence for tin production at Carthage. The ceramic component is either a tuyère or a crucible. The slag is comprised of many different phases of iron silicates, phases with iron silicates and copper, as well as polymetallic inclusions of iron, copper, and tin. Droplets or nodules of bronze (visible with the naked eye) alongside iron silicates indicate that this tuyère or crucible was used both for ferrous smelting or smithing activities, as well as bronze recycling. Blue and green copper oxides are also visible with the naked eye in the polished cross section.

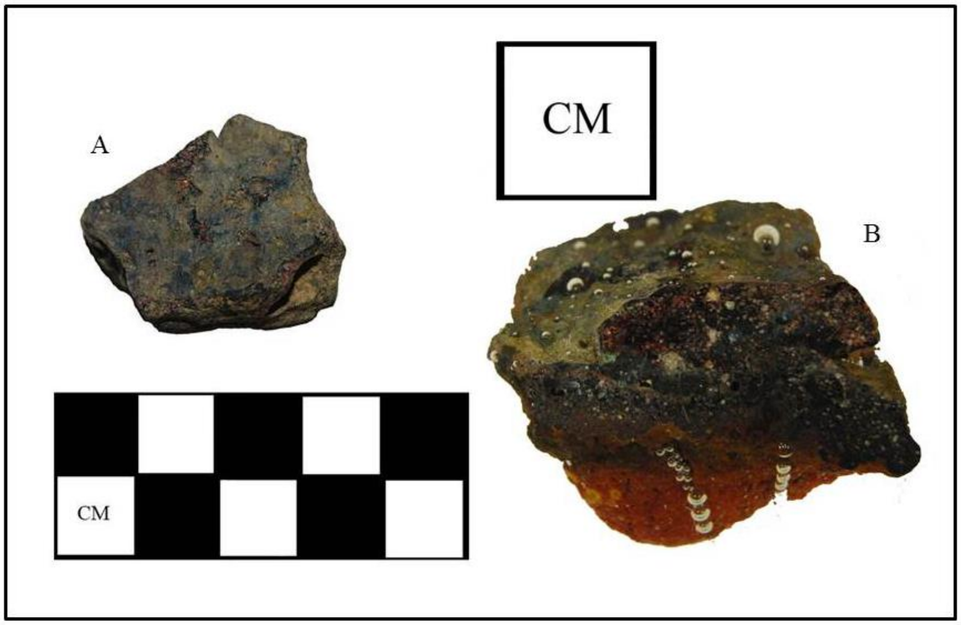

Figure I2a. L. 1121 17470 (A) unmounted; (B) mounted and polished cross section

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.1121 17470	760-600	1	9.89±0.086	5.075±0.113	25.965±0.226	2.526±0.056	0.708±0.038

S	Al	Mn	Zr	Cu
0.237±0.015	4.045±0.221	1.006±0.111	0.023±0.001	2.412±0.027

Sn	Zn	Pb	Ni	As
0.194±0.005	0.011±0.003	0.02±0.001	0.022±0.005	0.002±0.001

Table I2. pXRF slag composition

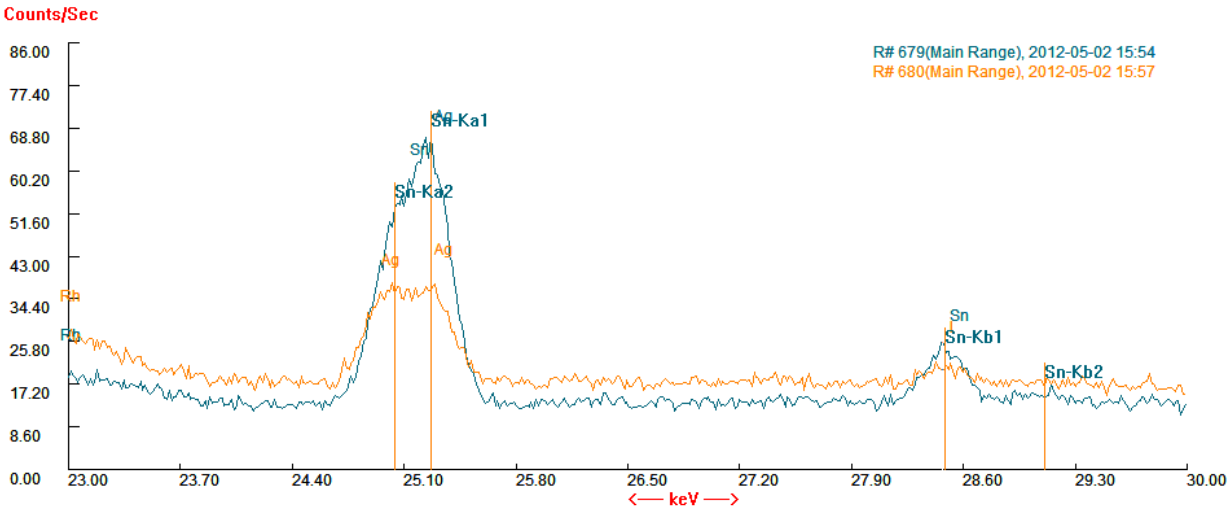

Figure I2b. pXRF - Overlapping spectral interference of the silver Kβ line and the tin Kα line

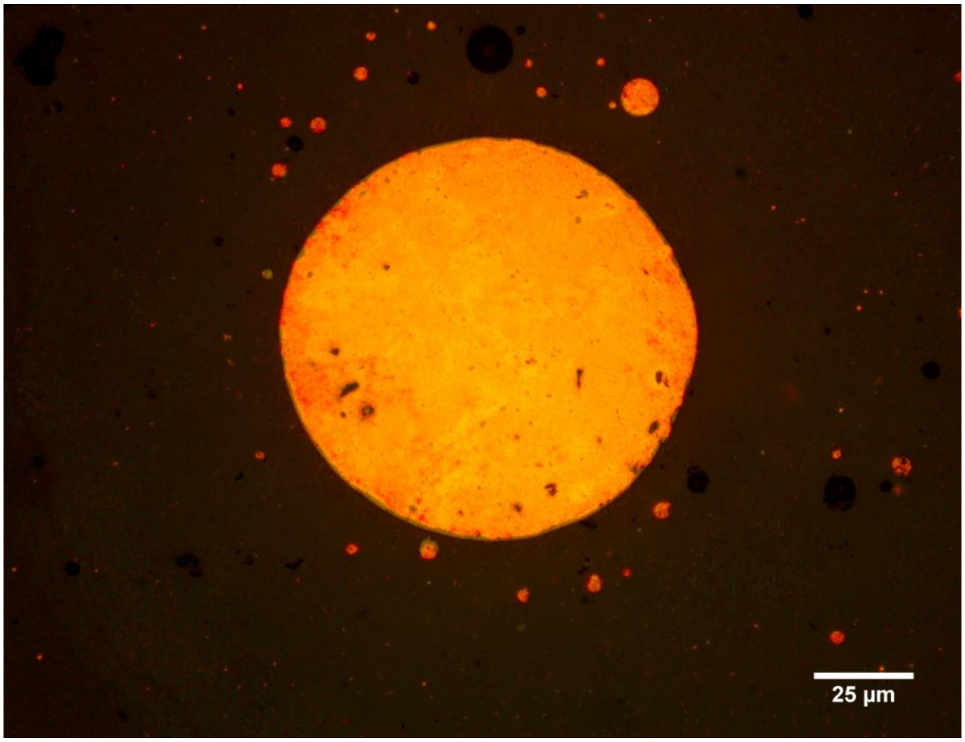

Figure I2c. Polarized optical micrograph of metallic nodules in glassy matrix

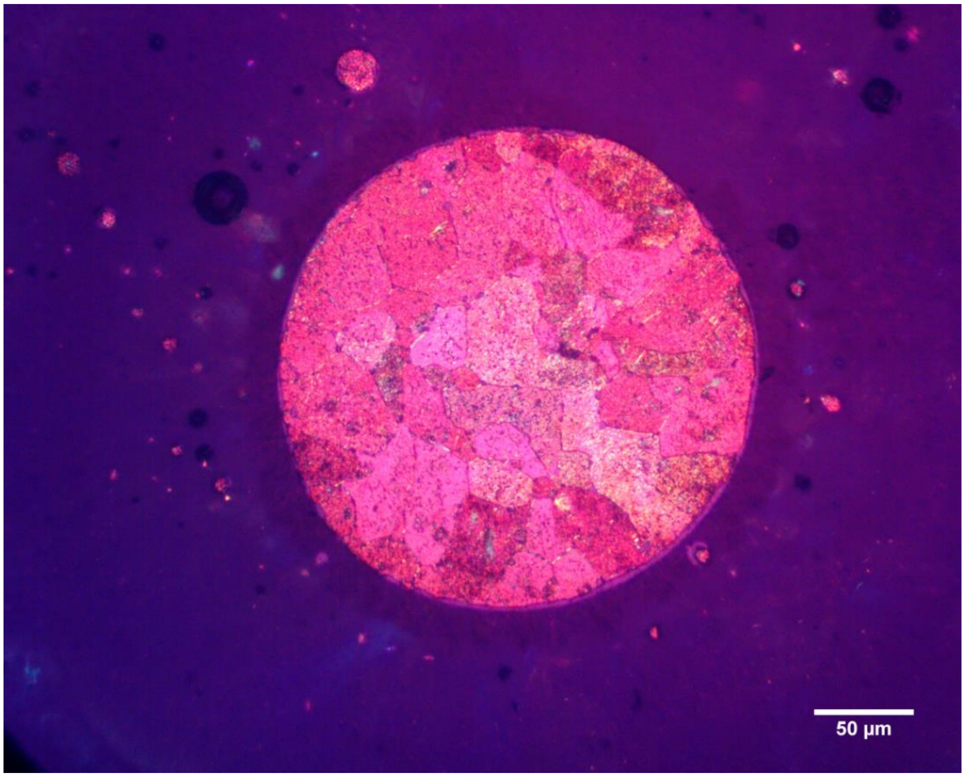

Figure I2d. Polarized red compensator plate micrograph of metallic nodules in glassy matrix, with visible grain formation

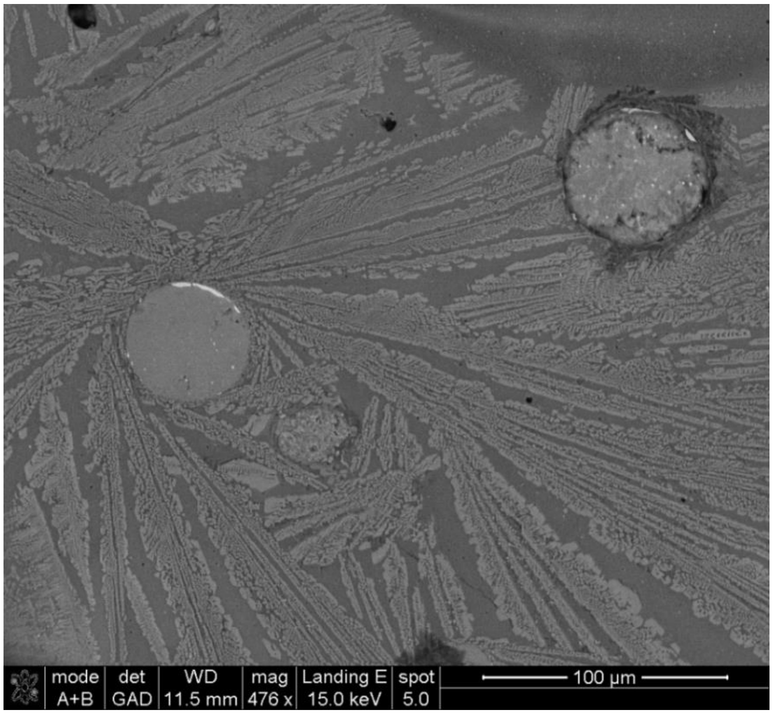

Figure I2e. Two tin-bearing nodules in iron silicate matrix

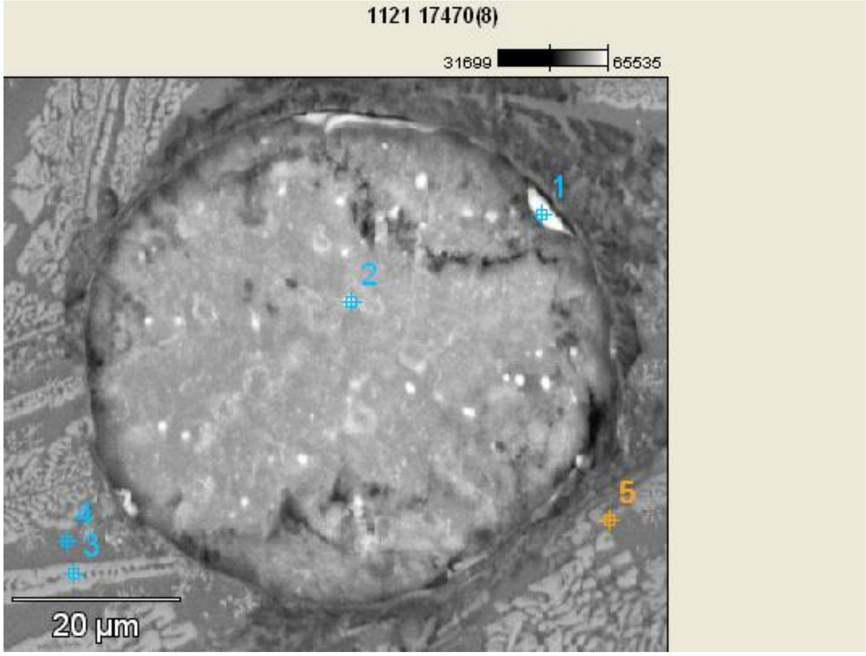

Figure I2f. Spots taken from nodule in upper right of Figure 4AIe; wt% spot 1: 68.98Cu 6.18Fe 0.39Ca 15.00S 2.88Si 0.47Al 4.14O 1.96C, spot 2: 9.00Cu 8.18Sn 21.11Fe 0.27Ca 1.00Cl 4.52S 0.35P 10.32Si 0.44Al 41.30O 3.50C, spot 3: 14.96Fe 0.40Ti 7.94Ca 1.48K 0.13Cl 0.32P 22.95Si 3.87Al 0.31Mg 1.28Na 44.20O 2.16Cl, spot 4: 31.89Fe 0.70Mn 2.99Ca 0.78K 0.16P 18.48Si 2.04Al 1.11Mg 40.11O 1.74C, spot 5 was subject to drift

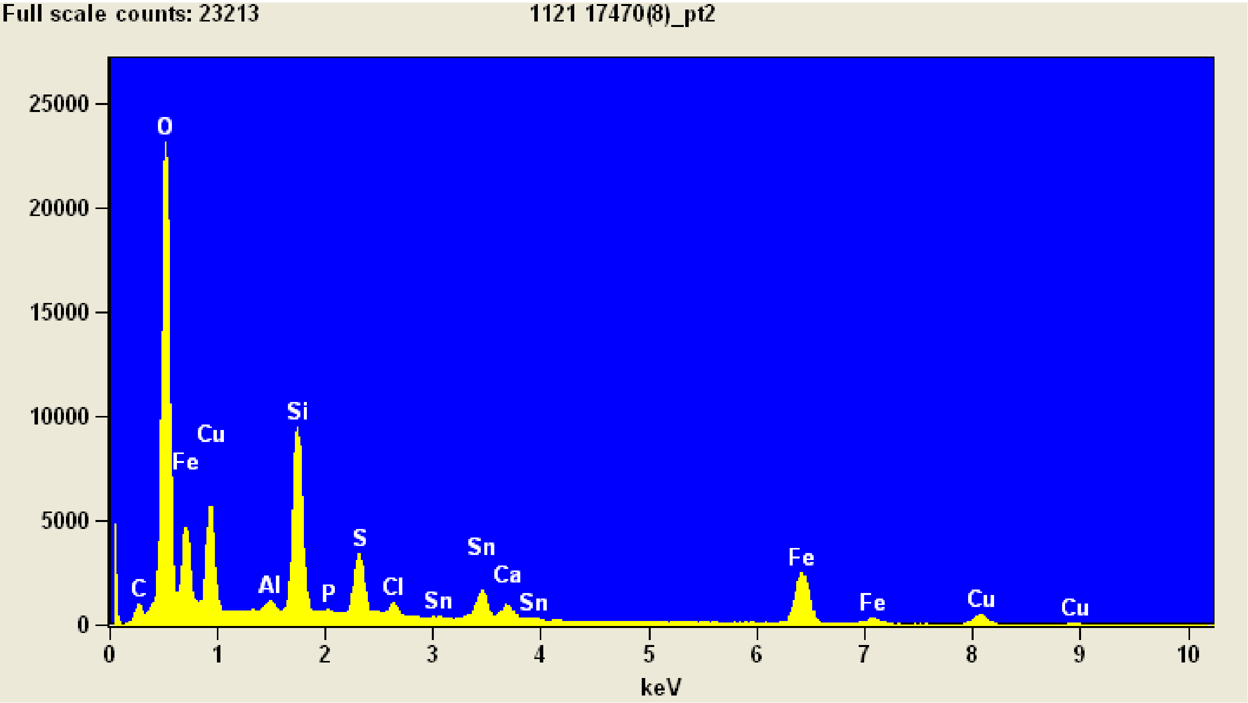

Figure I2g. EDS spectrum with tin L lines

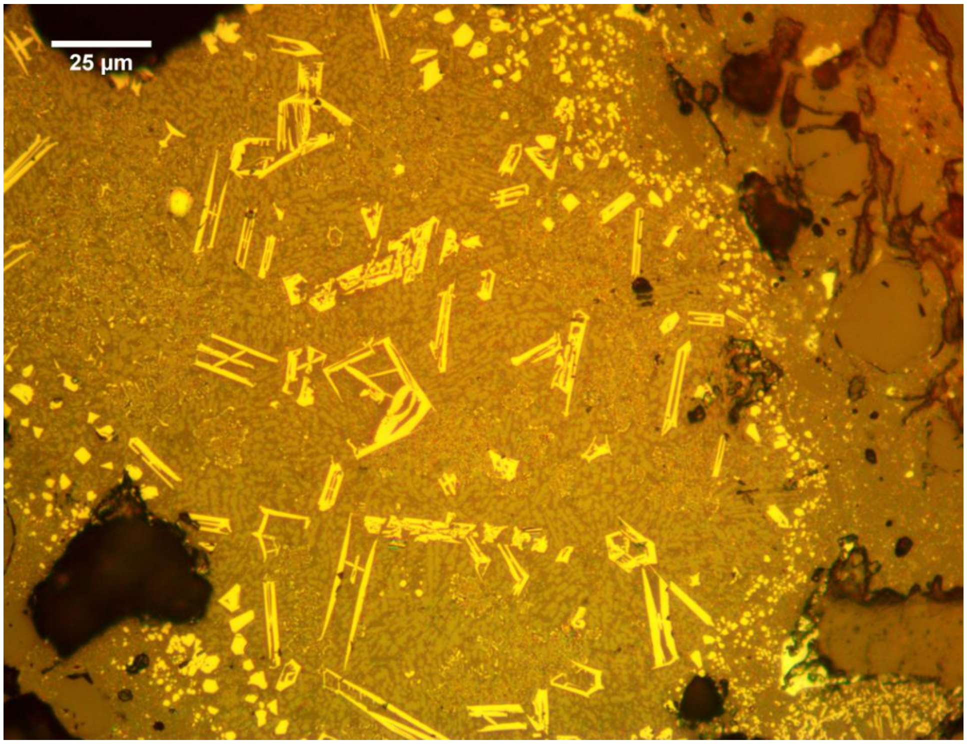

Figure I2h. Optical micrograph of various iron silicates

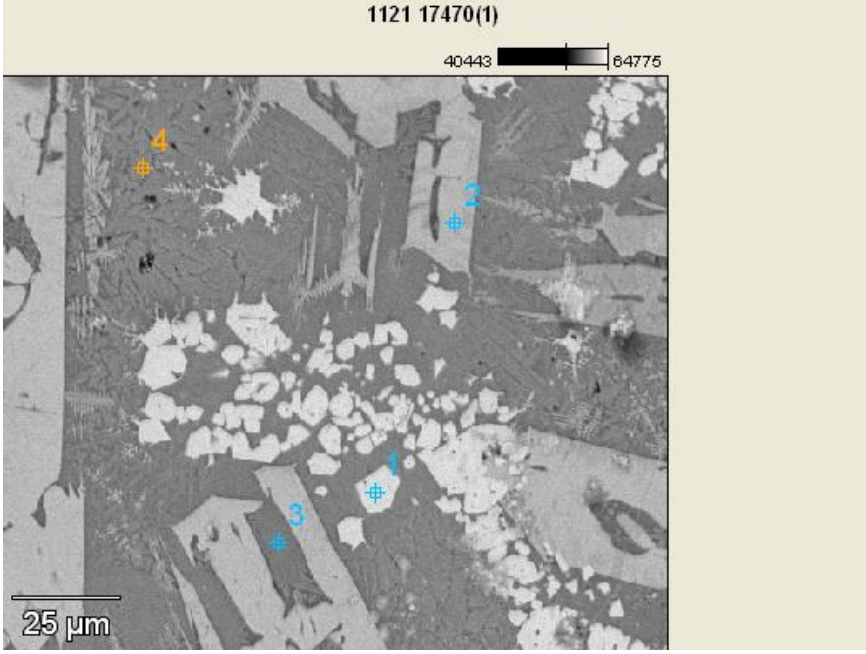

Figure I2i. Backscattered micrograph of various iron silicates, wt% spot 1: 64.17Fe 0.25Mn 1.40Ti 0.58Ca 0.14K 2.60Si 1.89Al 28.00O 0.97C, spot 2: 47.00Fe 0.83Mn 1.32Ca 0.15K 0.10P 14.65Si 0.47Al 1.52Mg 32.60O 1.35C, spot 3: 17.70Fe 0.31Mn 0.30Ti 9.52Ca 1.69K 0.07Cl 0.47P 21.93Si 4.87Al 0.07Mg 1.27Na 39.96O 1.86C, spot 4 26.65Fe 0.32Mn 0.35Ti 10.06Ca 0.78K 0.28P 18.66Si 2.95Al 0.37Mg 37.68O 1.89C

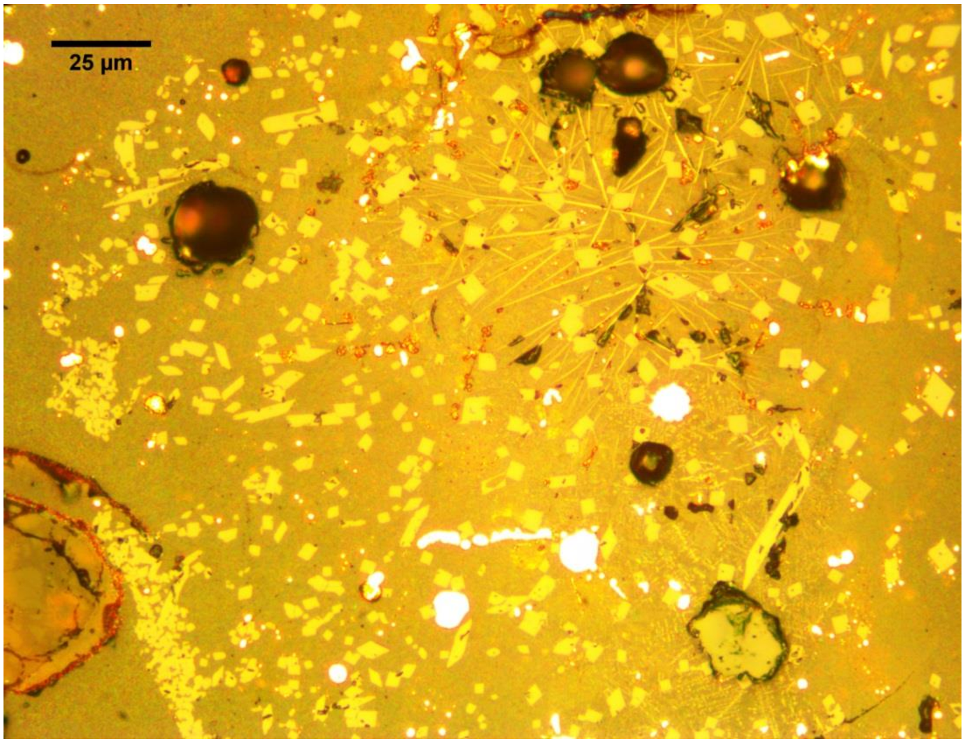

Figure I2j. Optical micrograph of unidentified geometric microstructure

I3. Locus 8066, Artifact 17267

Context: 700-500 BC – “= 8065, 8067, 8069: Levelling layer deposited after the kiln went out of use.”

Overview: Iron slag, one tunnel of the tuyère preserved.

Figure I3a. L. 8066 17267. Convex of tunnel terminating in slag to the left

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P	S	Al	Mn	Zr	Cu	Sn	Zn	Pb	Ni	As
L.8066 17267	700-500	1	8.291±0.07	4.69±0.1	23.577±0.219	2.116±0.049	0.889±0.036	0.067±0.011	3.954±0.186	—	0.018±0.001	0.006±0.002	—	0.007±0.001	—	—	0.006±0.001

Table I3. pXRF slag composition

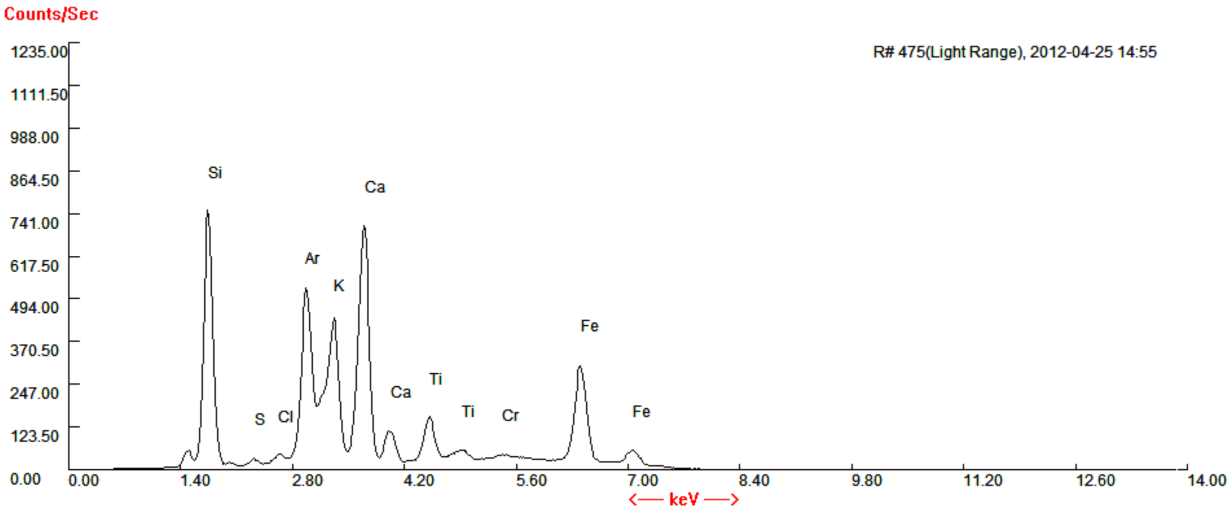

Figure I3b. pXRF spectrum of light elements

I4. Locus 8069, Artifact 16621

Context: 700-500 BC – “= 8065, 8066, 8067: Levelling layer deposited after the kiln went out of use.”

Overview: Iron slag, two tunnels of tuyère preserved.

Figure I4a. L. 8069 16621. Both tunnels preserved, with slag hood

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P	S	Al	Mn	Zr	Cu	Sn	Zn	Pb	Ni	As
L.8069 16621	700-500	1	10.974±0.085	3.521±0.091	14.049±0.161	1.399±0.044	0.463±0.027	0.051±0.01	1.853±0.131	0.806±0.101	0.021±0.001	±	—	0.002±0.001	—	0.012±0.004	0.003±0.001

Table I4. pXRF slag composition

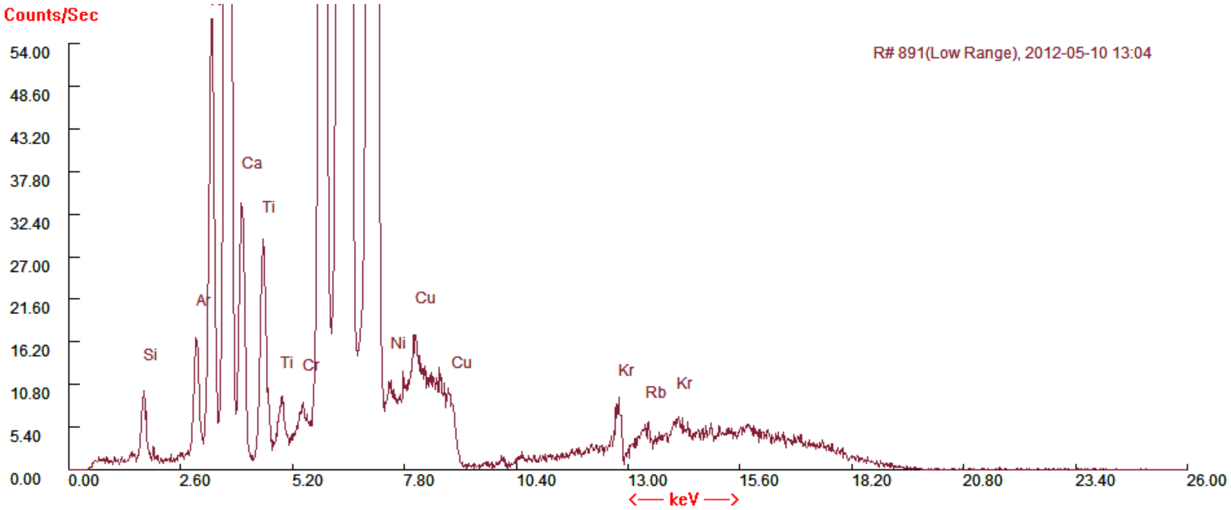

Figure I4b. pXRF spectrum showing nickel impurity

I5. Locus 8069, Artifact 16622

Context: 700-500 BC – “= 8065, 8066, 8067: Levelling layer deposited after the kiln went out of use.”

Overview: Iron slag, two(?) tunnels of tuyère preserved.

Figure I5a. L.8069 16622. One tunnel preserved, with slag on left

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P	S	Al	Mn	Zr	Cu	Sn	Zn	Pb	Ni	As
L.8069 16622	700-500	2	5.568±0.054	3.89±0.084	18.886±0.191	2.005±0.045	0.854±0.033	0.333±0.014	2.935±0.149	0.291±0.104	0.021±0.001	0.01±0.002	—	0.006±0.001	—	—	0.004±0.001

Table I5. pXRF slag composition

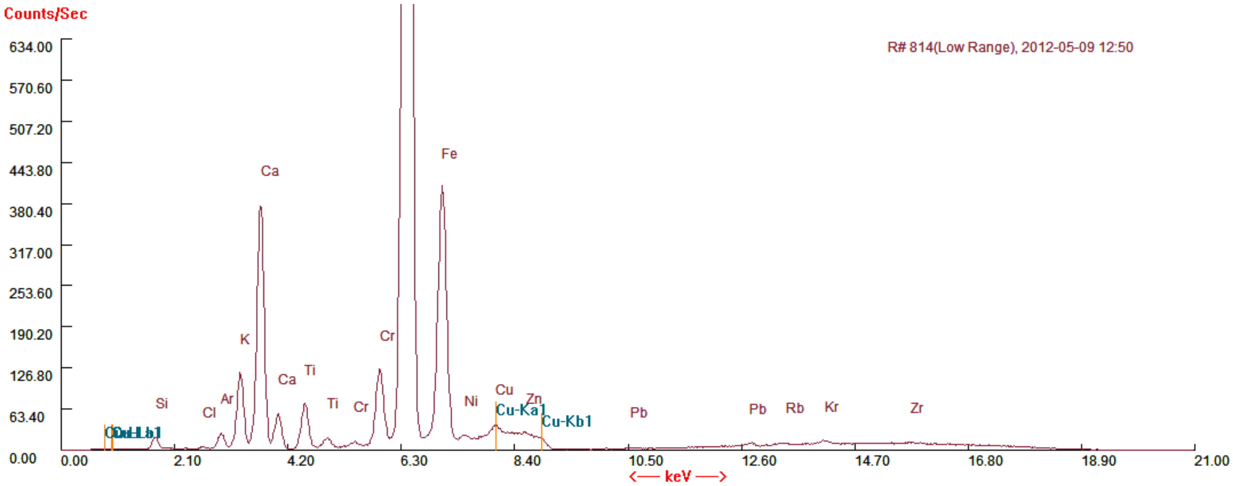

Figure I5b. pXRF spectrum showing traces of copper

I6. Locus 8069, Artifact 16624

Context: 700-500 BC – “= 8065, 8066, 8067: Levelling layer deposited after the kiln went out of use.”

Overview: Iron slag, two tunnels of tuyère preserved.

Figure I6a. L. 8069 16624. Two tunnels preserved, with slag on right

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P	S	Al	Mn	Zr	Cu	Sn	Zn	Pb	Ni	As
L.8069 16624	700-500	1	11.615±0.096	6.872±0.131	18.132±0.197	1.223±0.044	1.094±0.039	0.095±0.013	2.605±0.184	0.78±0.11	0.021±0.001	0.013±0.002	—	0.004±0.001	—	0.008±0.004	0.008±0.001

Table I6. pXRF slag composition

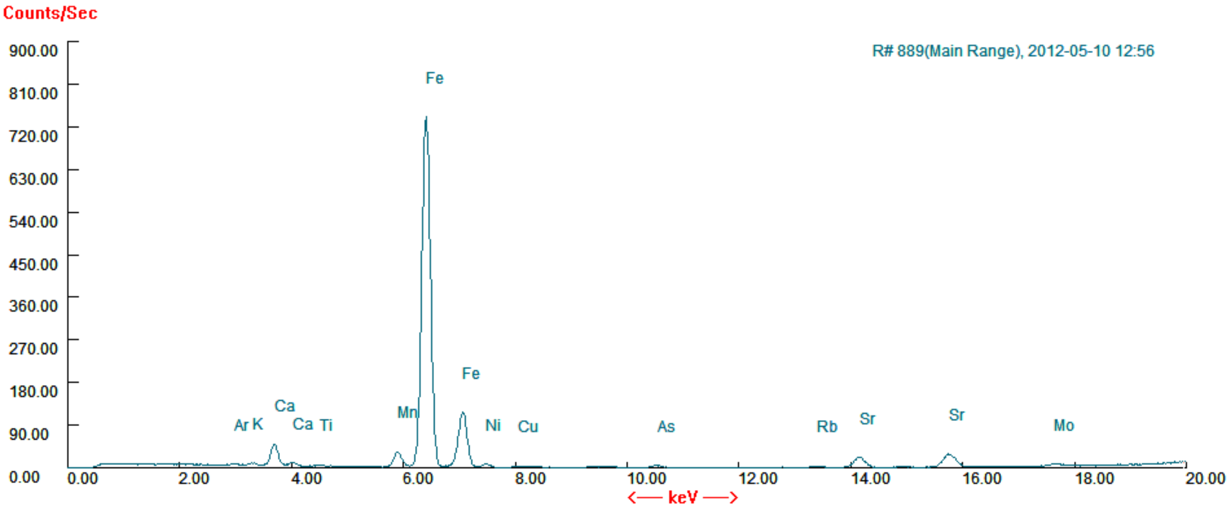

Figure I6b. pXRF spectrum showing traces of copper

I7. Locus 8069, Artifact 16627

Context: 700-500 BC – "= 8065, 8066, 8067: Levelling layer deposited after the kiln went out of use."

Overview: Iron slag, two tunnels of tuyère preserved.

Figure I7a. L. 8069 16627. Two tunnels preserved, with slag on top

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8069 16627	700-500	3	11.594±0.096	4.386±0.1	16.841±0.183	1.909±0.049	0.63±0.032

S	Al	Mn	Zr	Cu
0.21±0.014	3.272±0.178	0.346±0.108	0.018±0.001	0.017±0.002

Sn	Zn	Pb	Ni	As
—	0.005±0.001	—	—	0.007±0.001

Table I7. pXRF slag composition

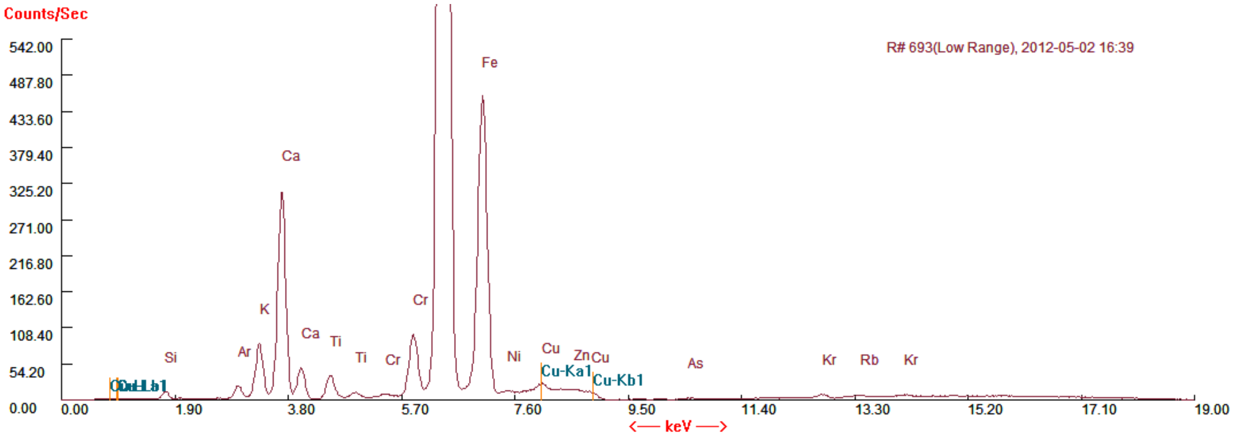

Figure I7b. pXRF showing traces of copper

I8. Locus 8069, Artifact 16628

Context: 700-500 BC – "= 8065, 8066, 8067: Levelling layer deposited after the kiln went out of use."

Overview: Iron slag with ceramic attached.

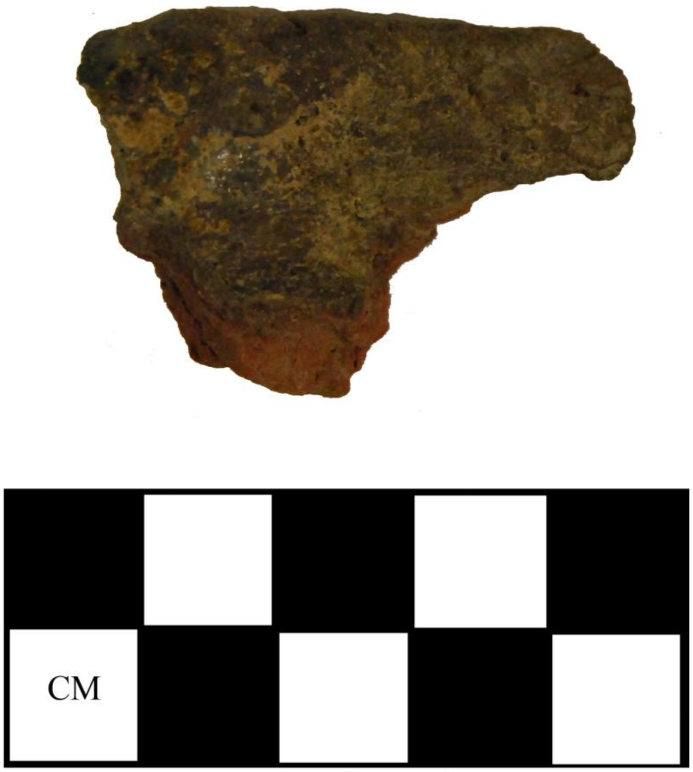

Figure I8a. L. 8069 16628

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8069 16628	700-500	1	9.208±0.071	5.464±0.11	18.03±0.187	1.555±0.045	1.132±0.036

S	Al	Mn	Zr	Cu
0.201±0.013	3.519±0.177	0.739±0.095	0.022±0.001	0.018±0.002

Sn	Zn	Pb	Ni	As
—	0.009±0.001	—	—	0.008±0.001

Table I8. pXRF slag composition

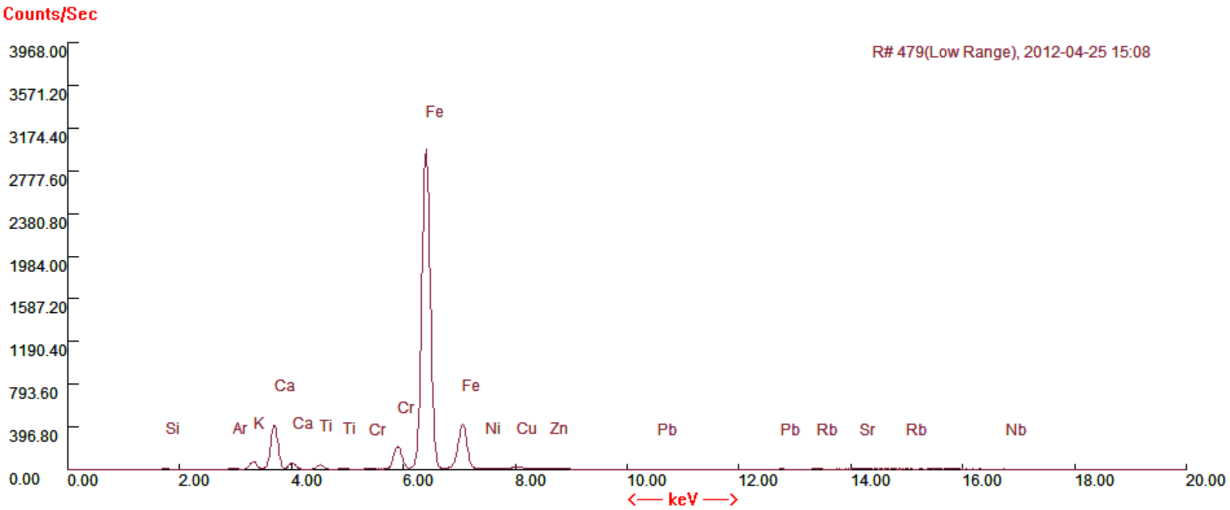

Figure I8b. pXRF spectrum

I9. Locus 8085, Artifact 17471

Context: 750-650 BC – “Levelling layer on top of 8084/8089.”

Overview: Iron slag, two tunnels of tuyère preserved.

Figure I9a. Tunnels of tuyère at top and bottom, terminating in slag to the left

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8085 17471	750-650	3	7.21±0.064	5.628±0.104	21.633±0.202	1.412±0.039	1.155±0.038

S	Al	Mn	Zr	Cu
0.082±0.012	3.293±0.173	0.369±0.104	0.019±0.001	0.058±0.003

Sn	Zn	Pb	Ni	As
—	0.013±0.001	0.003±0.001	0.019±0.004	0.003±0.001

Table I9. pXRF slag composition

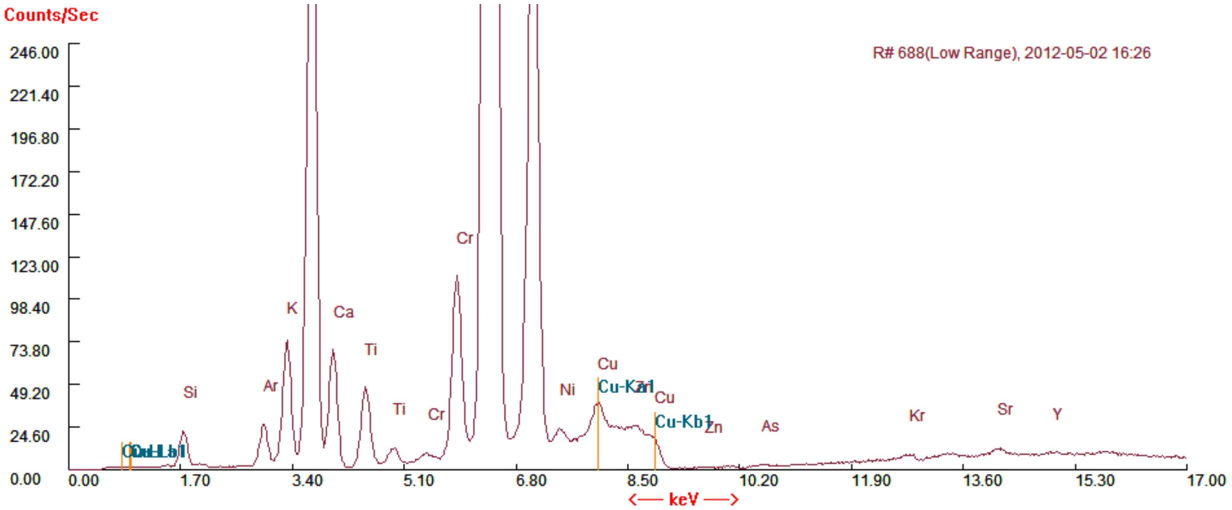

Figure I9b. pXRF spectrum showing traces of copper

I10. Locus 8091, Artifact 12679

Context: 700-500 BC – “Levelling layer in which the kiln had been set; = perhaps (below) 8068.”

Overview: Iron-rich silicates, likely fayalite or other olivine formations, predominate in this slag. It is difficult to distinguish whether the slag is attached to debris or a ceramic. An iron chunk, likely a corrosion product but perhaps slag, remains attached to another ceramic piece (Figure I10f). It is not a tuyère or crucible, and its utility is unclear. Figure I10c could indicate a bloom slag resultant from the production of pearlite.

Figure I10a. L. 8091 12679. Mounted

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8091 12679	700-500	1	9.088±0.076	7.867±0.133	10.854±0.146	1.098±0.040	1.075±0.036

S	Al	Mn	Zr	Cu
0.063±0.012	1.110±0.133	0.661±0.102	0.026±0.001	0.022±0.002

Sn	Zn	Pb	Ni	As
—	0.003±0.001	—	0.009±0.004	0.005±0.001

Table I10. pXRF slag composition

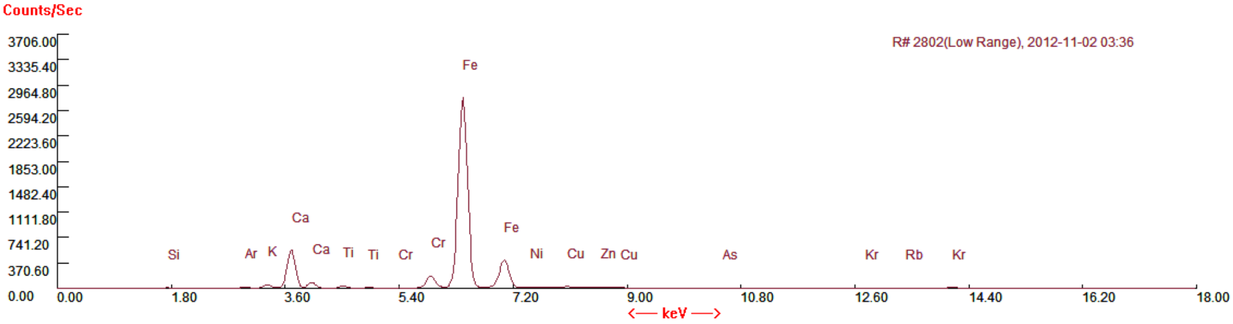

Figure I10b. pXRF spectrum

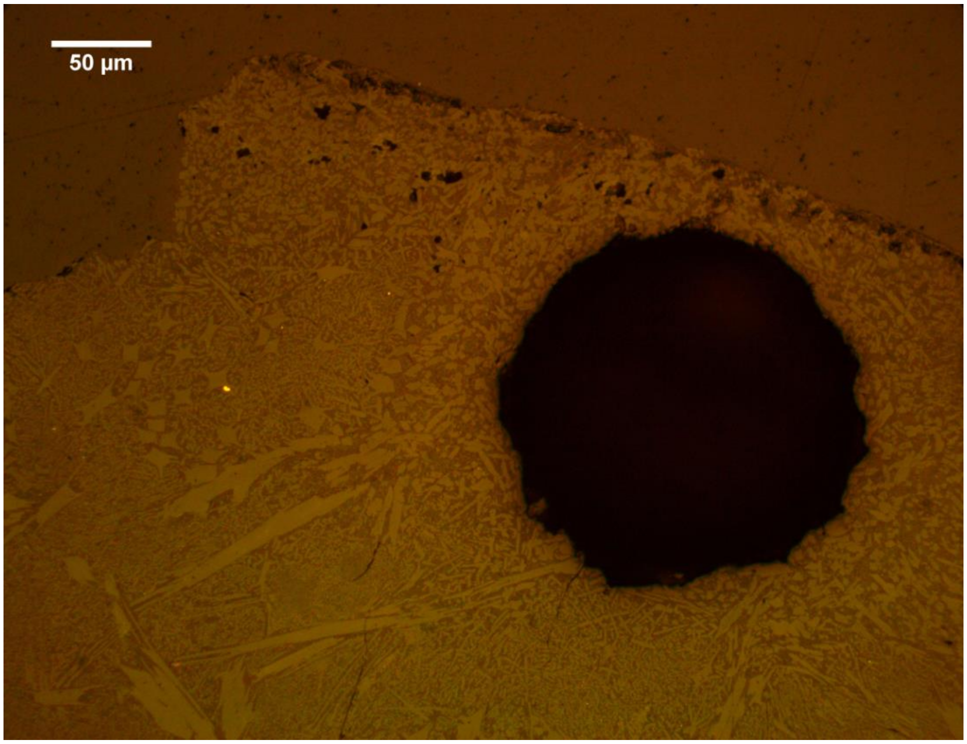

Figure I10c. Silicate phases

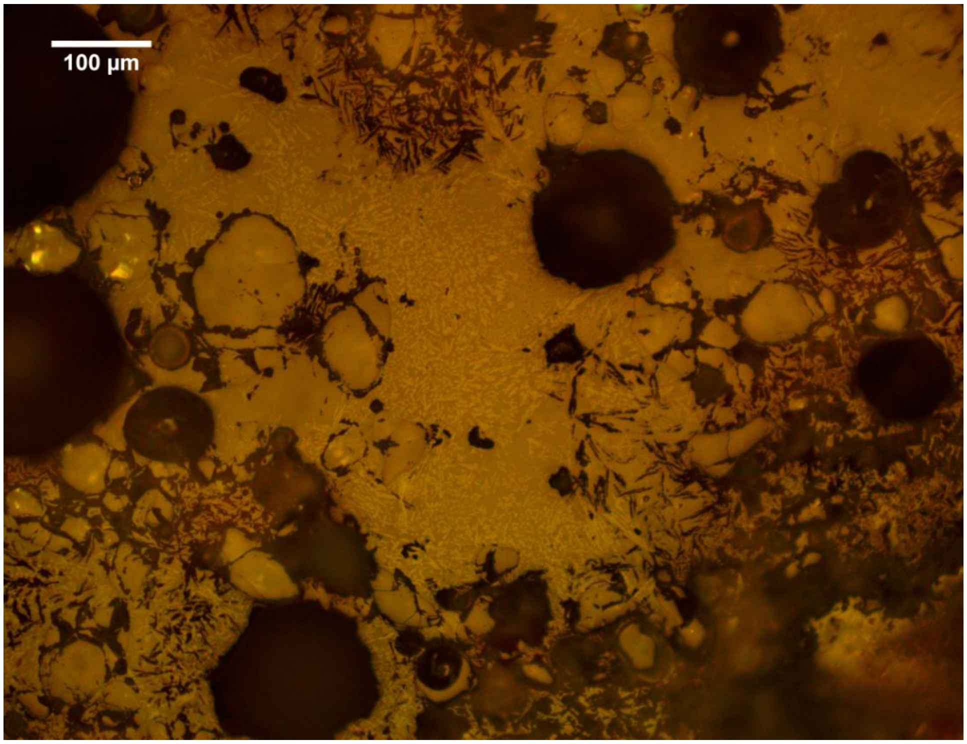

Figure I10d. Optical micrograph of interface between silicate phase and ceramic

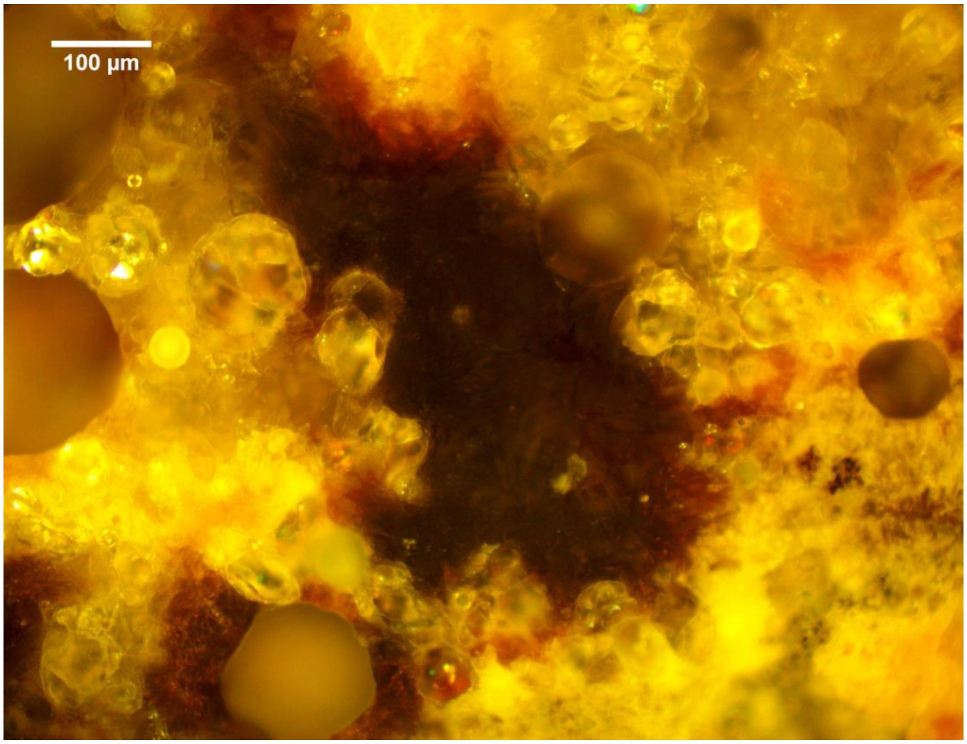

Figure I10e. Dark field micrograph of above Figure I10d

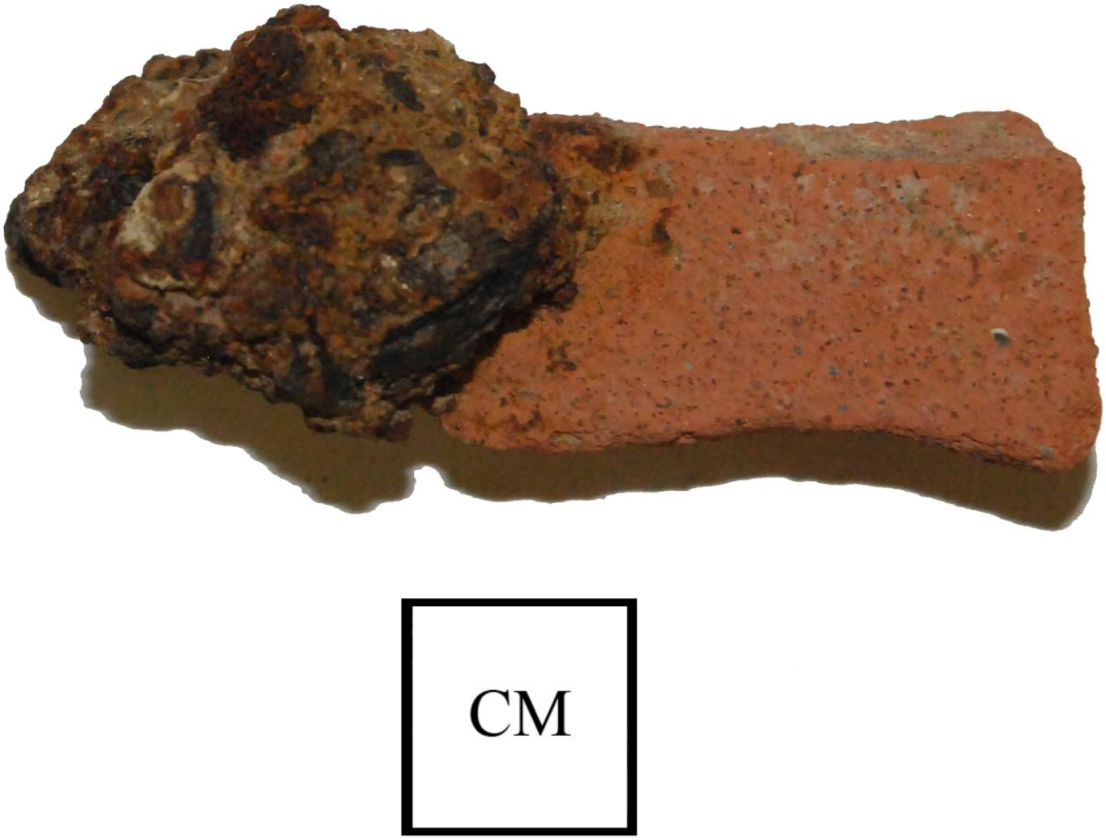

Figure I10f. Iron corrosion attached to ceramic

I11. Locus 8091, Artifact 17464

Context: 700-500 BC – "Levelling layer in which the kiln had been set; = perhaps (below) 8068."

Overview: Iron slag, end of tuyère completely intact preserving two toggled tunnels, and open holes penetrated at time of firing in viscous slag phase.

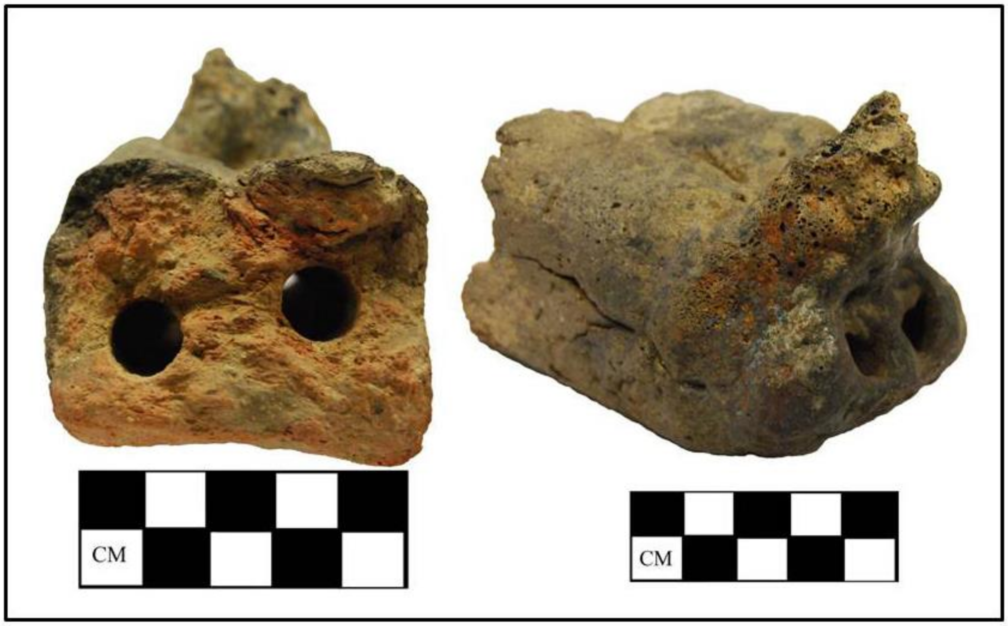

Figure I11a. L. 8091 17464

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8091 17464	700-500	3	14.383±0.119	6.186±0.127	15.985±0.185	1.578±0.049	1.079±0.039

S	Al	Mn	Zr	Cu
0.035±0.013	3.344±0.208	0.38±0.115	0.019±0.001	0.012±0.002

Sn	Zn	Pb	Ni	As
—	0.005±0.001	0.004±0.001	0.009±0.004	0.008±0.001

Table I11. pXRF slag composition

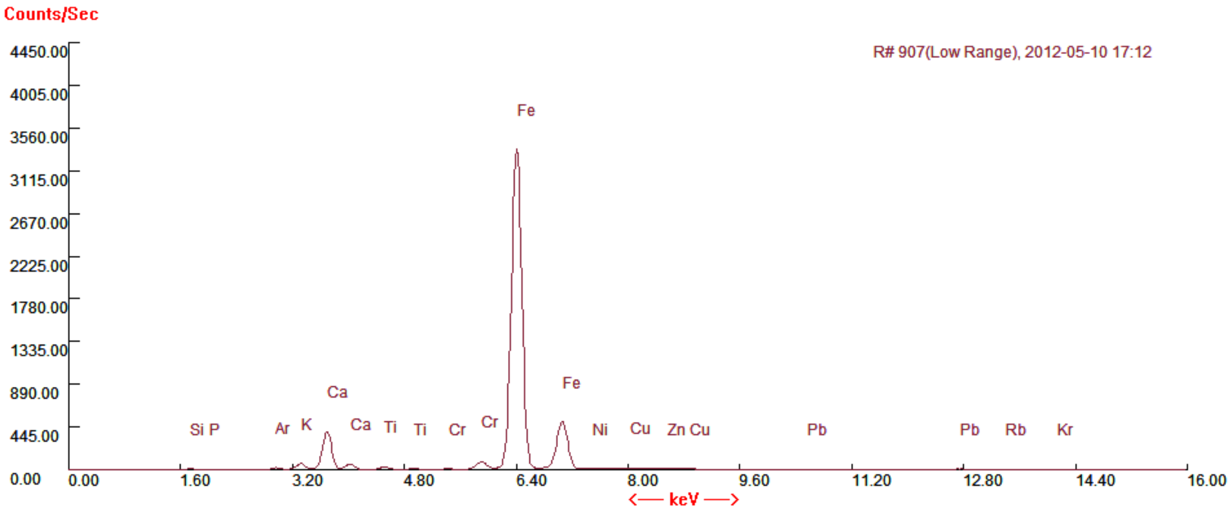

Figure I11b. pXRF spectrum

I12. Locus 8091, Artifact 17466

Context: 700-500 BC – "Levelling layer in which the kiln had been set; = perhaps (below) 8068."

Overview: No tunnels remain from this ceramic, but there is a slaggy hood with colored glassy zones. A portion of the slag and colored glassy phases was removed for analysis in the SEM-EDS. The copper content measured by pXRF could not be verified by EDS. Rather, titanium and zirconium inclusions were prevalent, with sodium, potassium, and phosphorus found as minor constituents throughout. The low iron content tested by the one spot on pXRF was found to be too low for the entire object. As opposed to the low iron content gauged by the pXRF, EDS verified generally a higher iron content, making it unclear as to whether this was a glass tuyère or a metal tuyère.

Figure I12a. L. 8091 17466. Green and blue glassy portions, with black slag on left (elevated and out of focus)

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8091 17466	700-500	1	1.401±0.037	4.685±0.077	26.783±0.216	2.987±0.043	0.298±0.032

S	Al	Mn	Zr	Cu
0.038±0.011	2.988±0.146	0.589±0.12	0.049±0.001	0.321±0.006

Sn	Zn	Pb	Ni	As
0.006±0.002	0.013±0.001	0.056±0.002	—	—

Table I12. pXRF slag composition

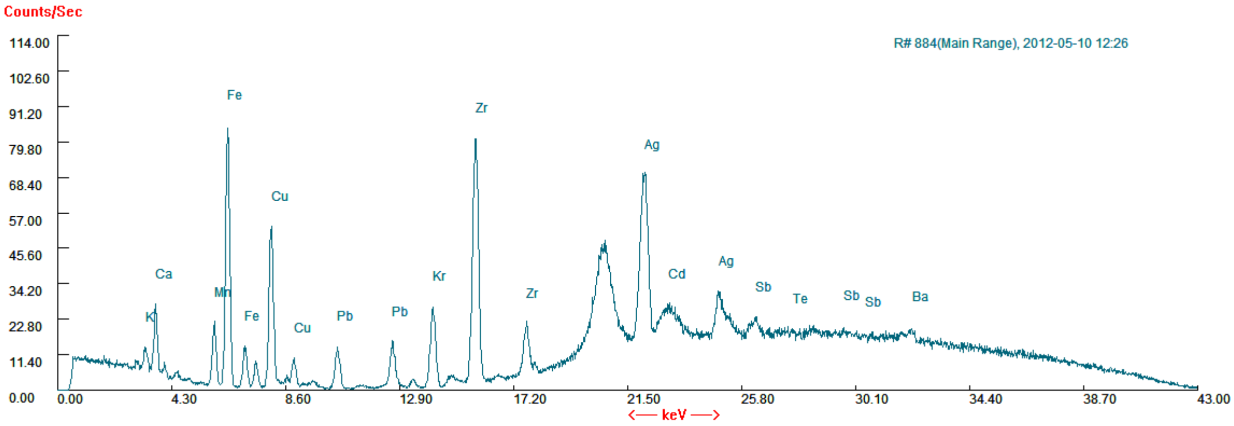

Figure I12b. pXRF spectrum with copper peaks

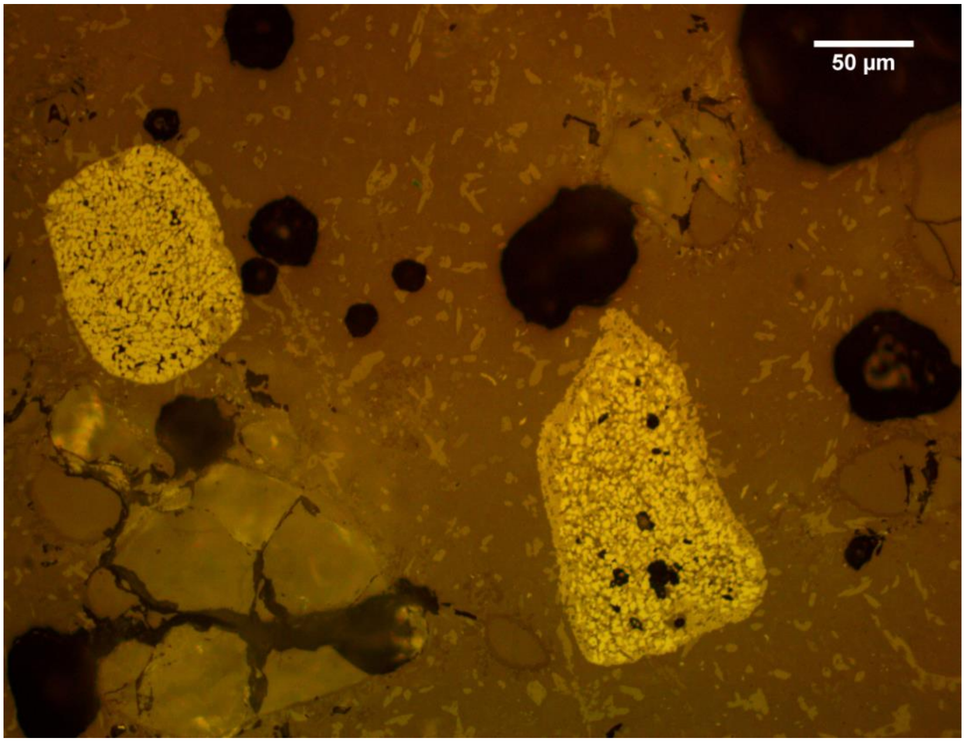

Figure I12c. Glassy phases, with large, bright titanium-rich inclusions

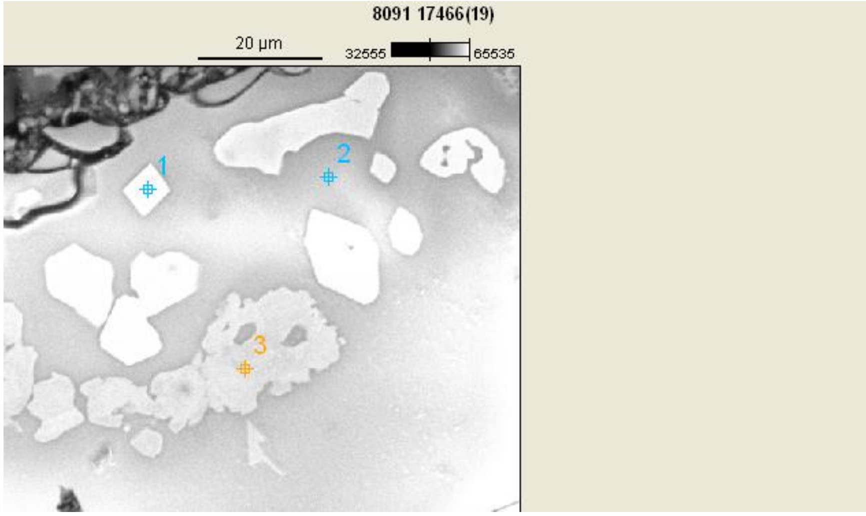

Figure I12d. In wt%, spot 1: 14.17Fe 8.34 Ti 22.08Ca 0.38K 14.09Si 1.67Al 0.53Mg 1.08Na 37.64O; spot 2: 5.03Fe 0.26Mn 0.93Ti 4.23Ca 3.68K 24.84Si 6.96Al 0.35Mg 7.64Na 43.26O; spot 3: 13.85Fe 0.59Mn 1.01Ti 16.62Ca 0.39K 19.66Si 3.57Al 3.73Mg 1.02Na 39.55O

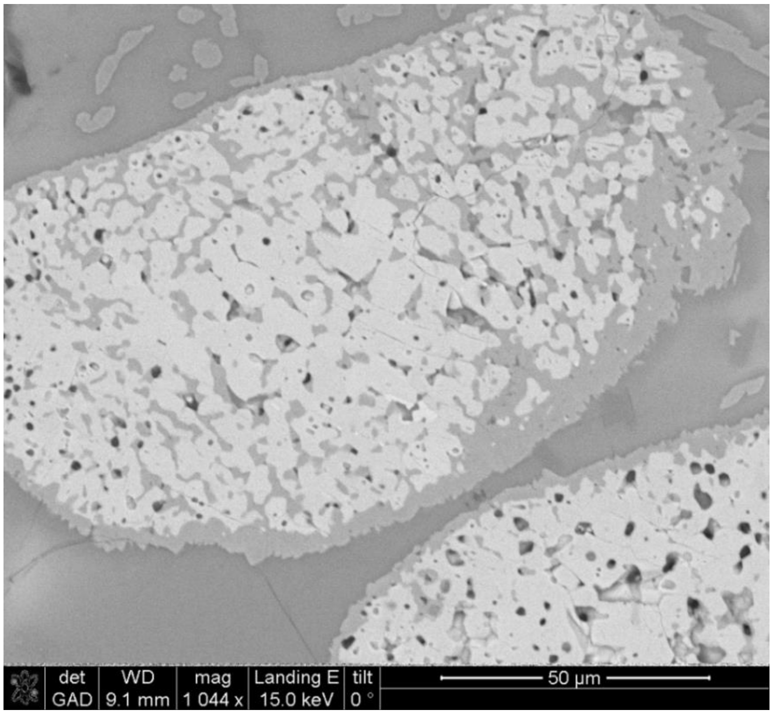

Figure I12e. Backscattered micrograph with bright white titanium inclusions

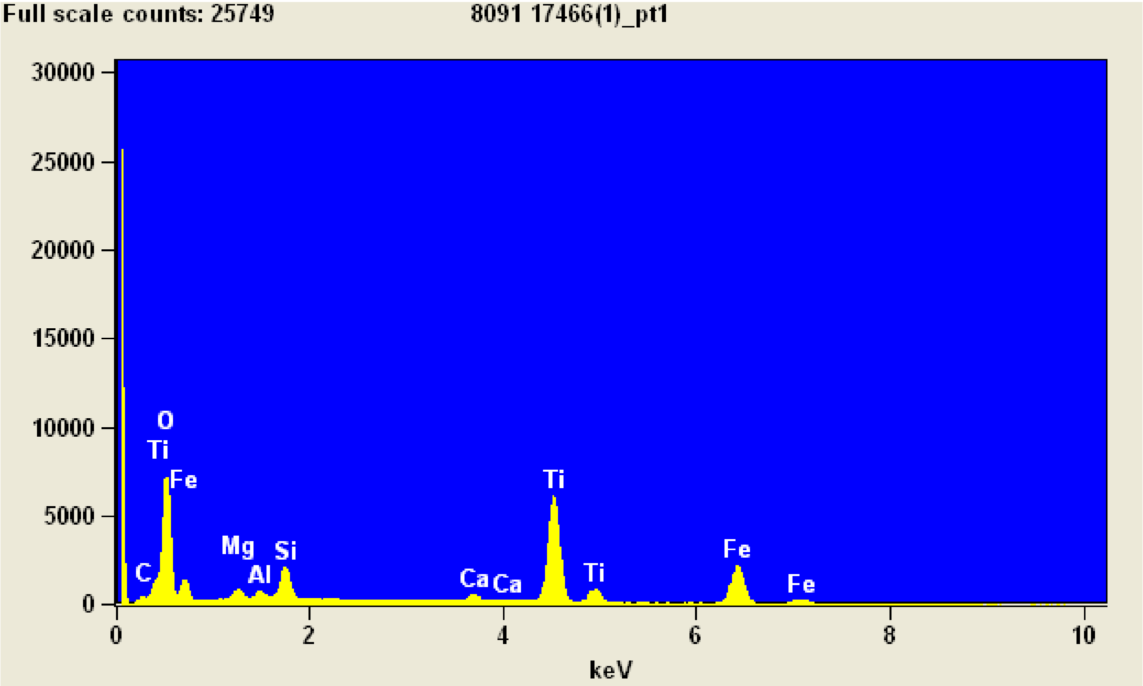

Figure I12f. EDS titanium peaks

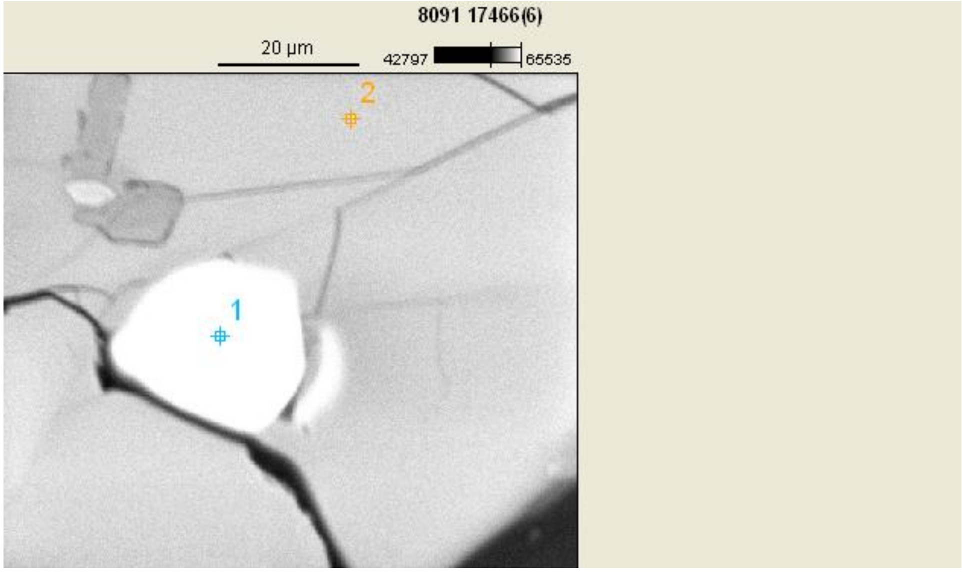

Figure I12g. In wt%, spot 1 has 45.66Zr; spot 2 4.00Na

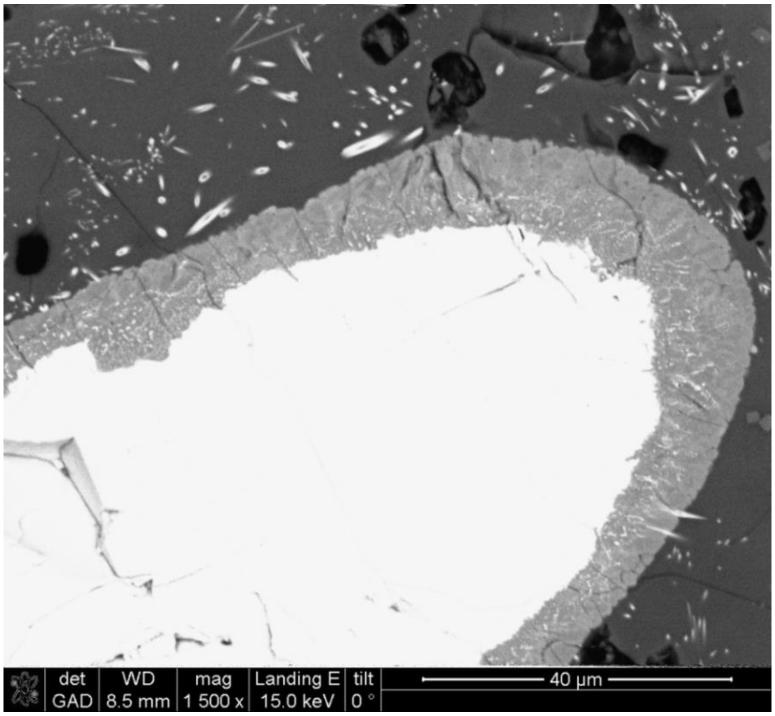

Figure I12h. The bright area includes in wt% 2.62Ag and 10.76P

I13. Locus 8091, Artifact 17468

Context: 700-500 BC – “Levelling layer in which the kiln had been set; = perhaps (below) 8068.”

Overview: Iron slag, one tunnel of tuyère preserved.

Figure I13a. L. 8091 17468. Lengthwise view of tuyère, side without tunnel preserved, terminating at slag to the right

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8091 17468	700-500	2	13.995±0.105	5.287±0.112	18.515±0.189	1.427±0.046	1.029±0.036

S	Al	Mn	Zr	Cu
0.054±0.011	4.145±0.206	0.656±0.1	0.024±0.001	0.01±0.002

Sn	Zn	Pb	Ni	As
—	0.005±0.001	—	0.008±0.004	0.003±0.001

Table I13. pXRF slag composition

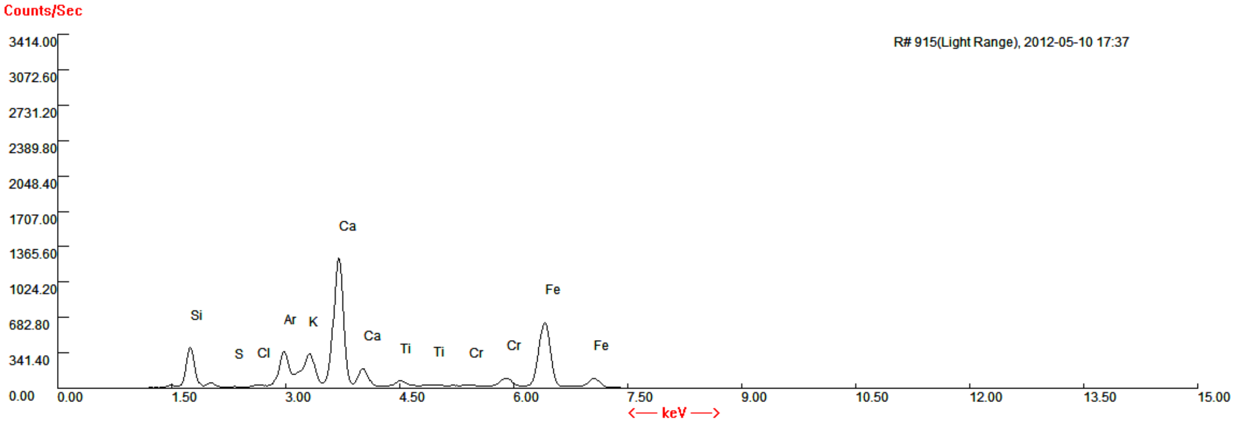

Figure I13b. pXRF spectrum of light elements

I14. Locus 8091, Artifact 17469

Context: 700-500 BC – “Levelling layer in which the kiln had been set; = perhaps (below) 8068.”

Overview: Iron slag, one tunnel of tuyère preserved.

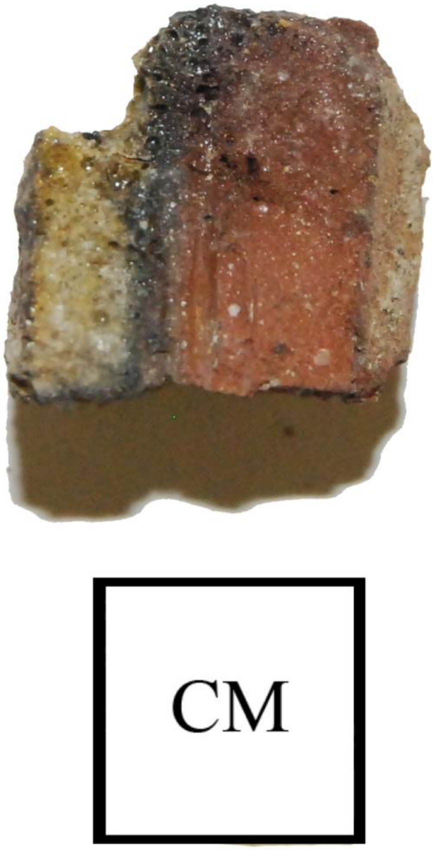

Figure I14a. L. 8091 17469. Tunnel to the right and slag bordering on left

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8091 17469	700-500	1	5.260±0.052	3.133±0.065	12.770±0.144	1.231±0.032	0.425±0.024

S	Al	Mn	Zr	Cu
—	1.175±0.093	0.399±0.100	0.022±0.001	0.016±0.002

Sn	Zn	Pb	Ni	As
—	0.005±0.001	—	—	0.002±0.001

Table I14. pXRF slag composition

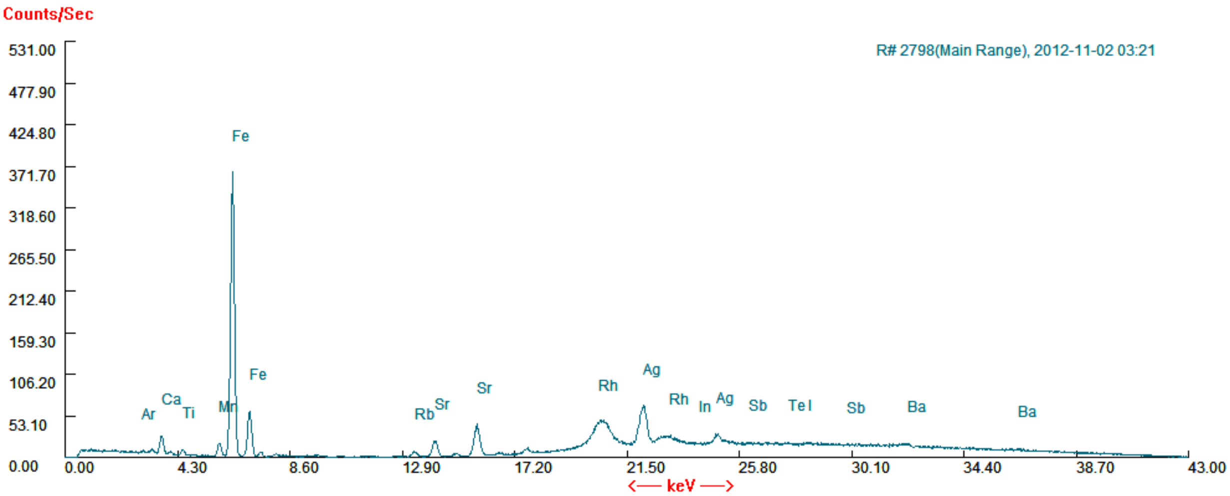

Figure I14b. pXRF spectrum

I15. Locus 8091, Artifact 17481

Context: 700-500 BC – “Levelling layer in which the kiln had been set; = perhaps (below) 8068.”

Overview: Iron slag, one tunnel of tuyère preserved.

Figure I15a. L. 8091 17481. Slag hood with one tunnel of tuyère preserved

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8091 17481	700-500	3	14.765±0.111	5.907±0.124	16.716±0.186	1.227±0.046	1.3±0.038

S	Al	Mn	Zr	Cu
0.062±0.011	2.998±0.185	0.647±0.102	0.019±0.001	0.015±0.002

Sn	Zn	Pb	Ni	As
—	0.005±0.001	0.003±0.001	0.01±0.004	0.008±0.001

Table I15. pXRF slag composition

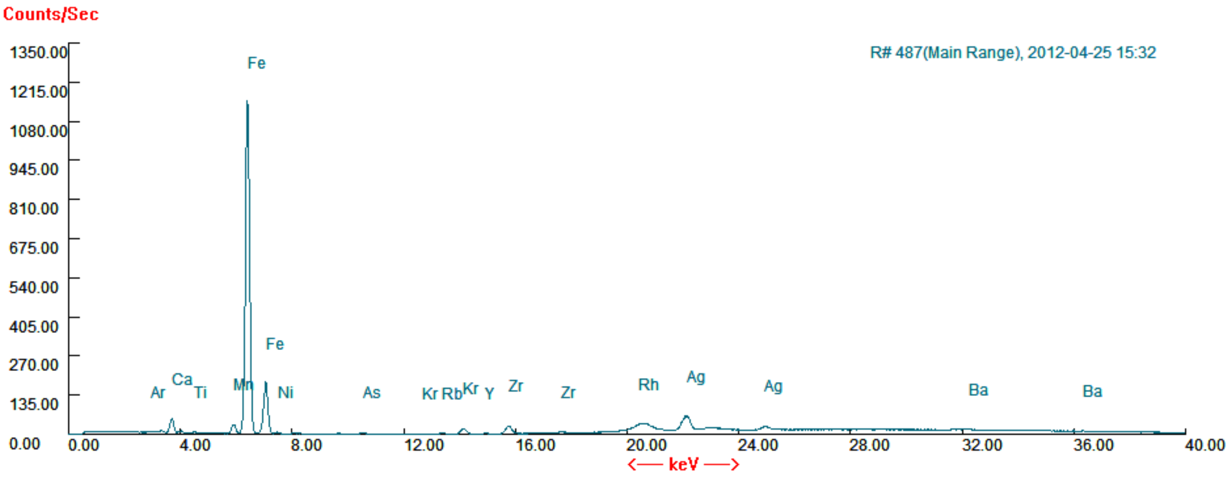

Figure I15b. pXRF spectrum

I16. Locus 8091, Artifact 17482

Context: 700-500 BC – “Levelling layer in which the kiln had been set; = perhaps (below) 8068.”

Overview: Iron slag, one tunnel of tuyère preserved.

Figure I16a. L. 8091 17482. Tunnel and slag preserved on top

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8091 17482	700-500	2	7.575±0.064	7.195±0.12	21.534±0.202	1.958±0.045	0.606±0.035

S	Al	Mn	Zr	Cu
0.07±0.012	4.404±0.211	0.561±0.097	0.02±0.001	0.008±0.002

Sn	Zn	Pb	Ni	As
—	0.003±0.001	—	—	0.004±0.001

Table I16. pXRF slag composition

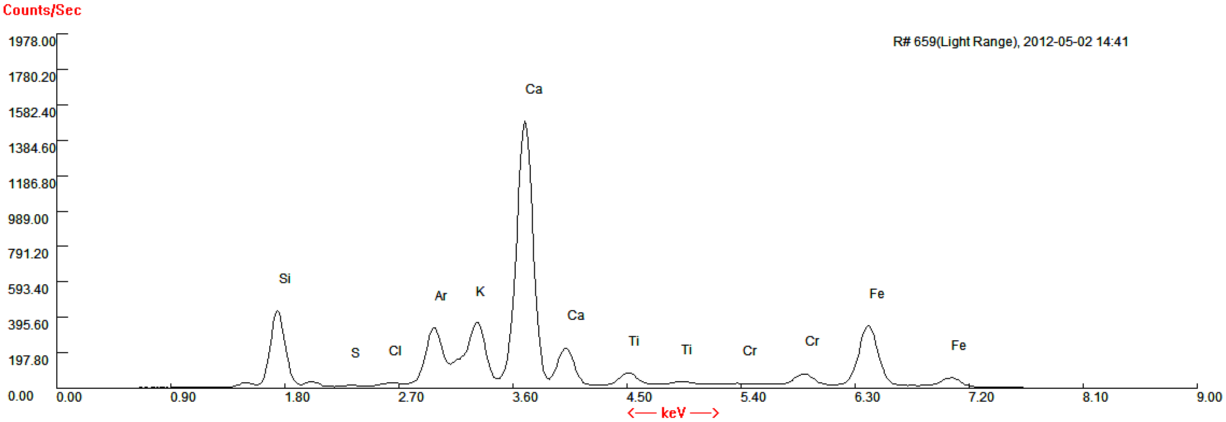

Figure I16b. pXRF spectrum

I17. Locus 8091, Artifact 18719

Context: 700-500 BC – “Levelling layer in which the kiln had been set; = perhaps (below) 8068.”

Overview: Iron slag, one tunnel of tuyère preserved.

Figure I17a. L. 8091 18719. Tunnel with slag on top

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8091 18719	700-500	3	12.224±0.093	6.512±0.126	18.092±0.19	1.244±0.044	0.882±0.035

S	Al	Mn	Zr	Cu
0.098±0.012	3.279±0.19	0.868±0.1	0.022±0.001	0.014±0.002

Sn	Zn	Pb	Ni	As
—	0.004±0.001	—	0.011±0.004	0.004±0.001

Table I17. pXRF slag composition

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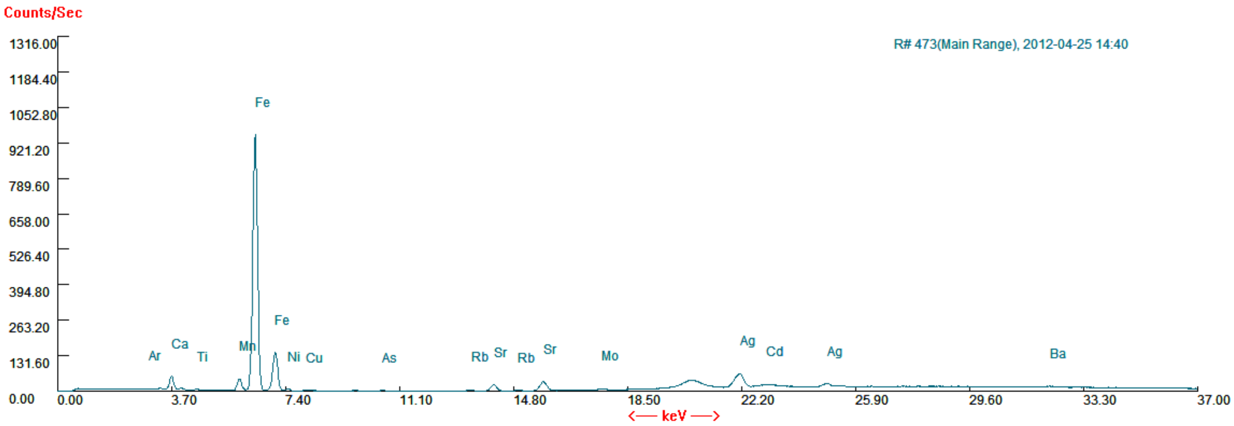

Figure I17b. pXRF spectrum

I18. Locus 8091, Artifact 30191

Context: 700-500 BC – “Levelling layer in which the kiln had been set; = perhaps (below) 8068.”

Overview: Iron slag, end of tuyère completely intact preserving two toggled tunnels, slag hood, and open holes cleared when slag was in its molten phase.

Figure I18a. L. 8091 30191

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8091 30191	700-500	2	12.316±0.093	4.629±0.107	20.622±0.199	1.931±0.05	1.339±0.039

S	Al	Mn	Zr	Cu
0.047±0.01	4.052±0.198	0.741±0.099	0.017±0.001	0.024±0.002

Sn	Zn	Pb	Ni	As
—	0.003±0.001	—	0.011±0.004	0.003±0.001

Table I18. pXRF slag composition

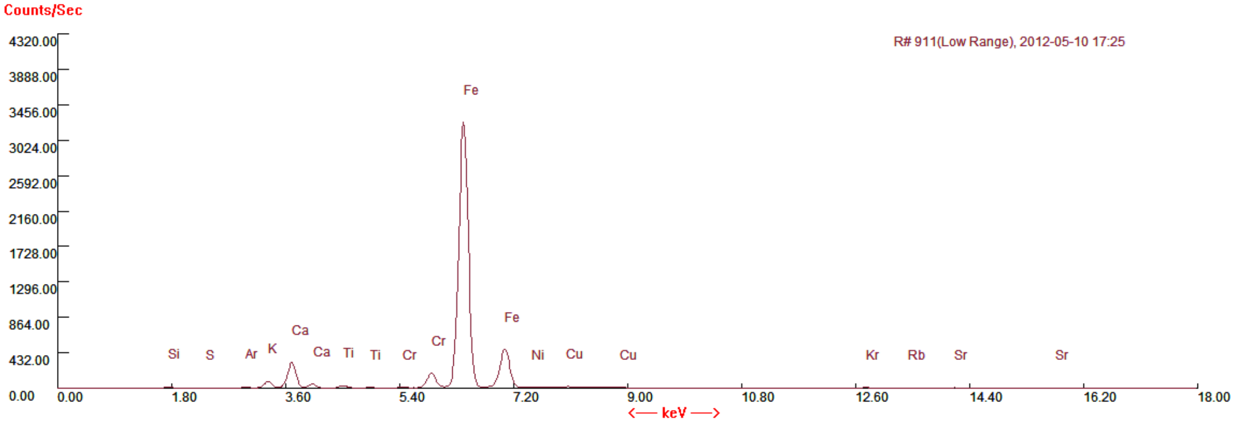

Figure I18b. pXRF spectrum

I19. Locus 8091, Artifact 37992

Context: 700-500 BC – “Levelling layer in which the kiln had been set; = perhaps (below) 8068.”

Overview: Iron slag, one tunnel of tuyère preserved.

Figure I19a. L. 8091 37992. Slag with tunnel preserved on right

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8091 37992	700-500	1	14.578±0.111	7.597±0.136	16.21±0.176	1.112±0.041	1.055±0.037

S	Al	Mn	Zr	Cu
0.063±0.011	3.715±0.212	1.643±0.103	0.015±0.001	0.034±0.003

Sn	Zn	Pb	Ni	As
—	0.008±0.001	0.005±0.001	0.017±0.004	0.005±0.001

Table I19. pXRF slag composition

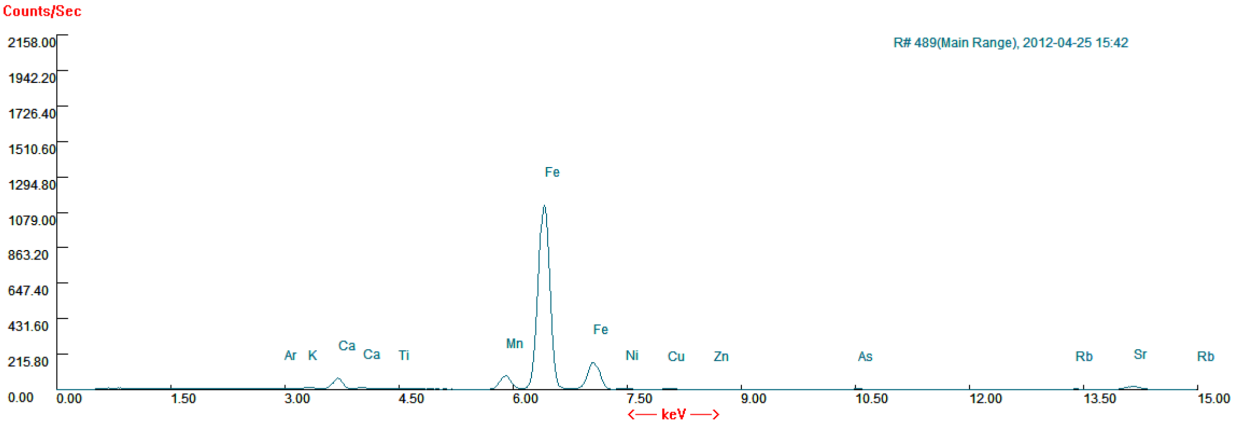

Figure I19b. pXRF spectrum

I20. Locus 8091, Artifact 38018

Context: 700-500 BC – “Levelling layer in which the kiln had been set; = perhaps (below) 8068.”

Overview: Iron slag, one tunnel of tuyère preserved.

Figure I20a. L. 8091 38018

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8091 38018	700-500	3	20.008±0.163	4.945±0.114	11.435±0.143	1.225±0.043	0.317±0.026

S	Al	Mn	Zr	Cu
0.041±0.011	2.611±0.175	0.64±0.104	0.017±0.001	0.025±0.003

Sn	Zn	Pb	Ni	As
—	0.005±0.001	—	0.013±0.005	0.007±0.001

Table I20. pXRF slag composition

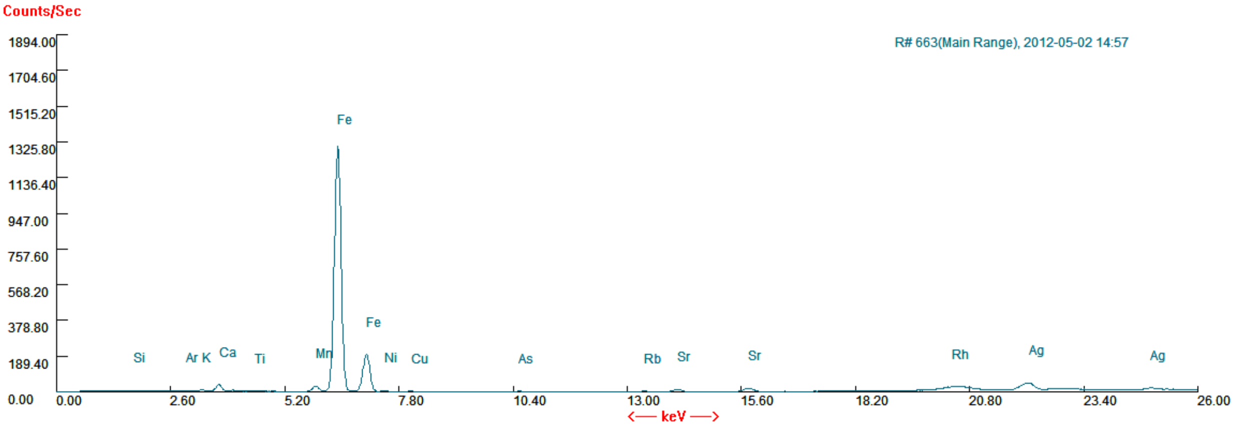

Figure I20b. pXRF spectrum

I21. Locus 8091, Artifact 38027

Context: 700-500 BC – “Levelling layer in which the kiln had been set; = perhaps (below) 8068.”

Overview: Iron slag, two tunnels of tuyère preserved.

Figure I21a. L. 8091 38027

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8091 38027	700-500	2	7.21±0.064	8.426±0.126	18.313±0.18	1.272±0.036	1.448±0.041

S	Al	Mn	Zr	Cu
0.106±0.012	3.695±0.191	0.398±0.103	0.021±0.001	0.007±0.002

Sn	Zn	Pb	Ni	As
—	0.006±0.001	0.026±0.001	—	0.01±0.001

Table I21. pXRF slag composition

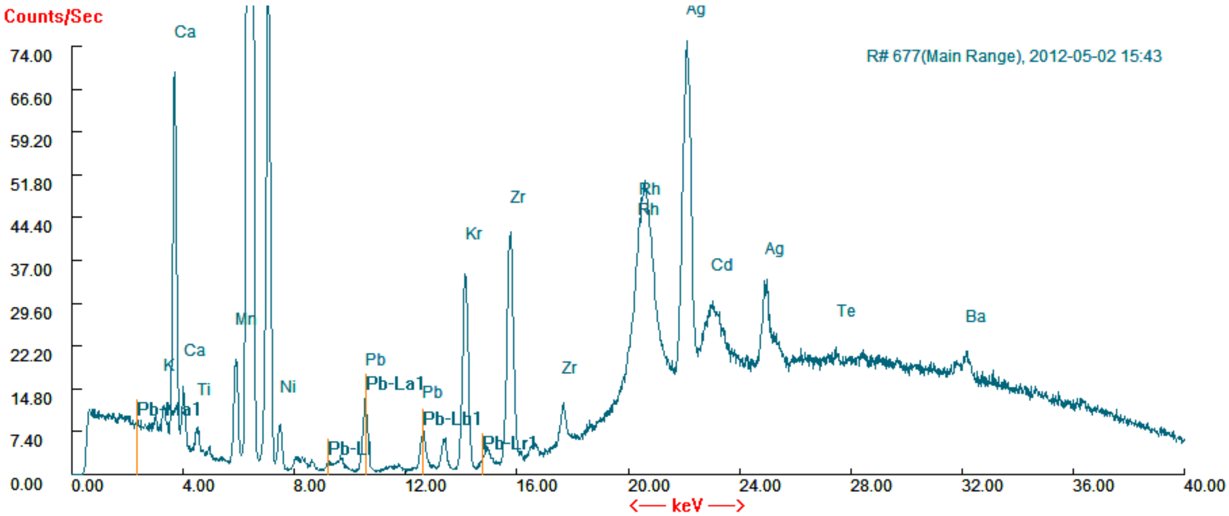

Figure I21b. pXRF spectrum with traces of lead

I22. Locus 8091, Artifact 38034

Context: 700-500 BC – “Levelling layer in which the kiln had been set; = perhaps (below) 8068.”

Overview: Iron slag with ceramic attached.

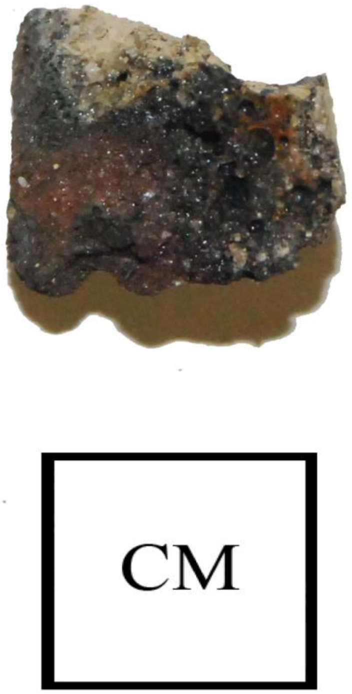

Figure I22a. L. 8091 38034

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8091 38034	700-500	1	4.714±0.103	1.543±0.109	17.359±0.316	1.244±0.049	0.403±0.048

S	Al	Mn	Zr	Cu
0.147±0.018	0.525±0.186	—	0.022±0.001	—

Sn	Zn	Pb	Ni	As
—	0.007±0.002	—	—	—

Table I22. pXRF slag composition

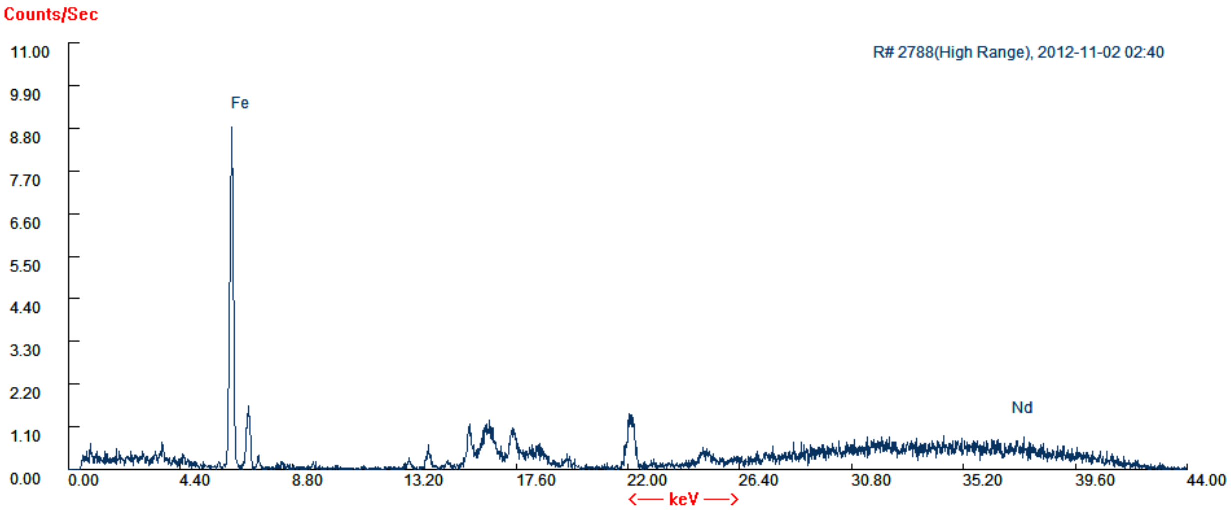

Figure I22b. pXRF spectrum

I23. Locus 8091, Artifact 38038

Context: 700-500 BC – “Levelling layer in which the kiln had been set; = perhaps (below) 8068.”

Overview: Iron slag with ceramic attached.

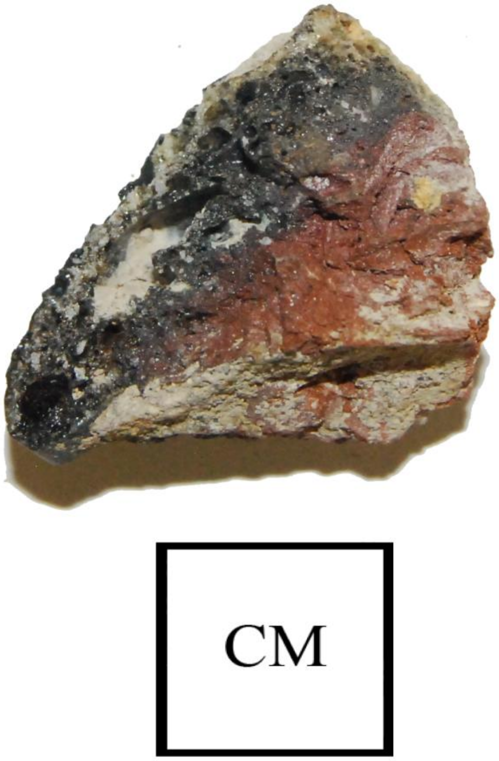

Figure I23a. L. 8091 38038

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8091 38038	700-500	1	5.177±0.098	1.097±0.092	18.643±0.302	1.225±0.044	0.122±0.041

S	Al	Mn	Zr	Cu
0.105±0.014	—	—	0.032±0.001	—

Sn	Zn	Pb	Ni	As
—	0.006±0.002	—	—	—

Table I23. pXRF slag composition

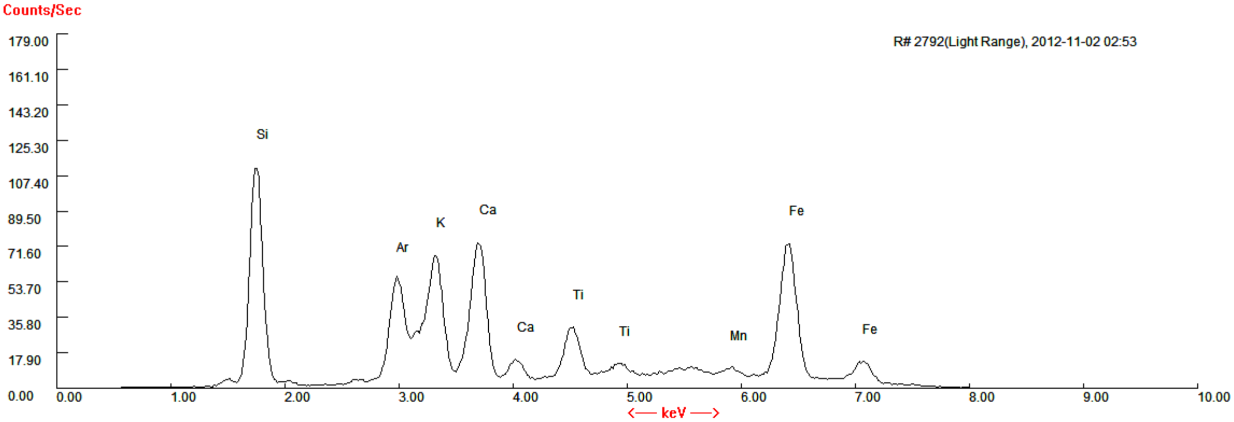

Figure I23b. pXRF spectrum

I24. Locus 8091, Artifact 38039

Context: 700-500 BC – “Levelling layer in which the kiln had been set; = perhaps (below) 8068.”

Overview: Iron slag, with one tunnel of tuyère preserved (not shown in image).

Figure I24a. L. 8091 38039. Iron slag with tuyère to the right

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8091 38039	700-500	3	6.483±0.064	6.552±0.116	22.834±0.213	2.6±0.051	1.129±0.041

S	Al	Mn	Zr	Cu
0.046±0.012	4.014±0.205	0.253±0.11	0.023±0.001	0.007±0.002

Sn	Zn	Pb	Ni	As
—	0.004±0.001	—	—	0.004±0.001

Table I24. pXRF slag composition

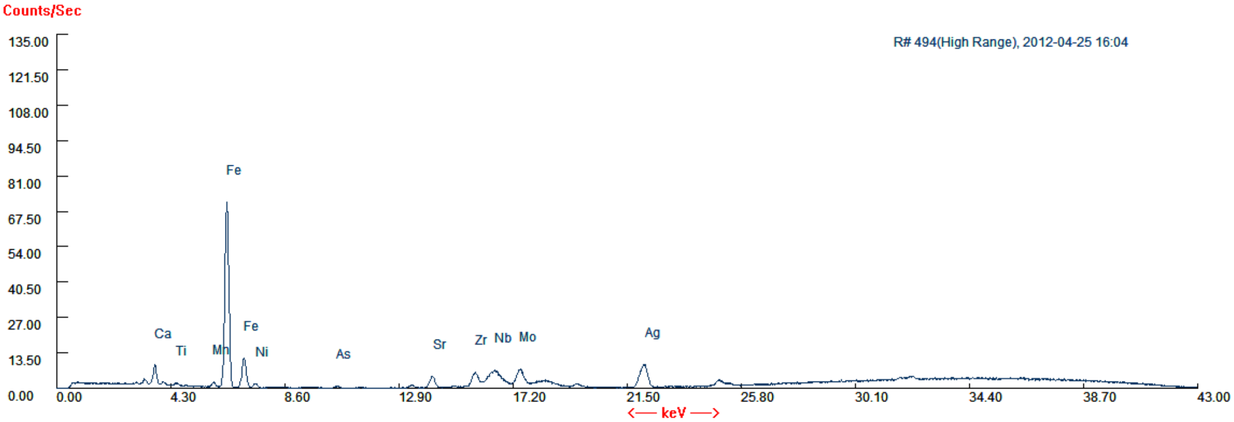

Figure I24b. pXRF spectrum

I25. Locus 8091, Artifact 38042

Context: 700-500 BC – “Levelling layer in which the kiln had been set; = perhaps (below) 8068.”

Overview: Iron slag with ceramic attached. Optical micrograph shows secondary wüstite formations in a glassy matrix.

Figure I25a. L. 8091 38042

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8091 38042	700-500	3	5.274±0.053	4.956±0.09	23.471±0.208	1.468±0.037	0.914±0.035

S	Al	Mn	Zr	Cu
0.044±0.01	3.962±0.168	0.242±0.106	0.024±0.001	0.022±0.002

Sn	Zn	Pb	Ni	As
—	0.006±0.001	0.002±0.001	—	0.006±0.001

Table I25. pXRF slag composition

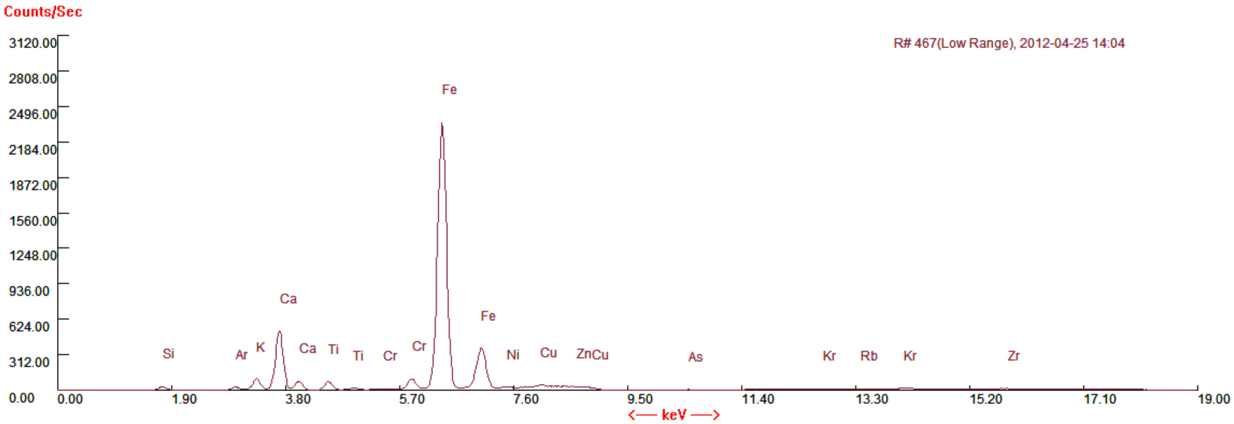

Figure I25b. pXRF spectrum

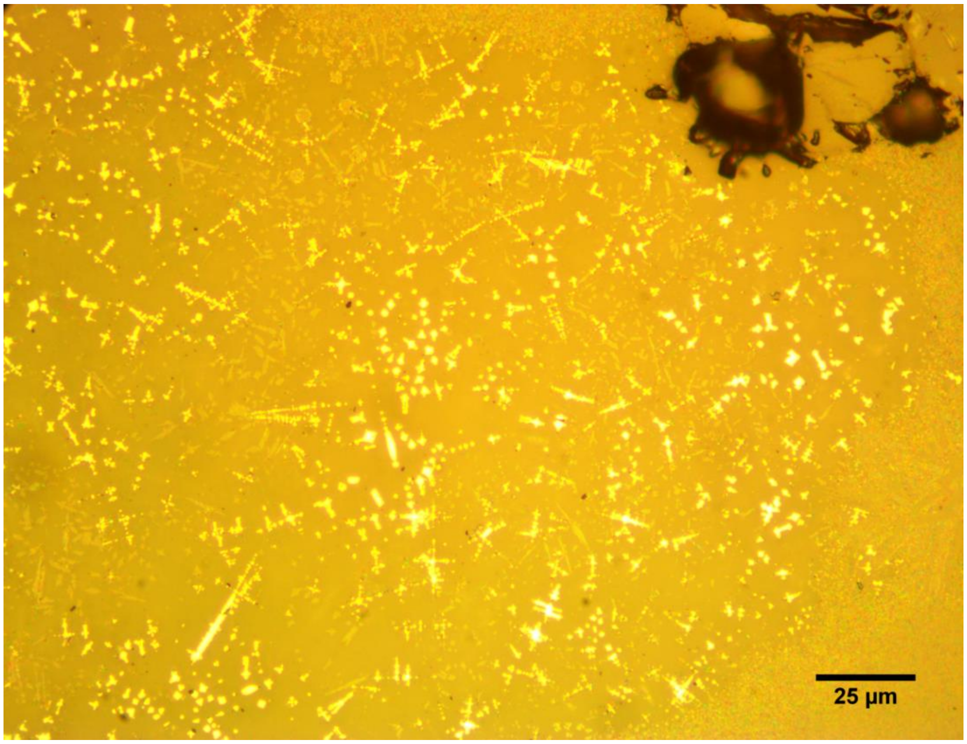

Figure I25c. Optical micrograph showing secondary wüstite formations

I26. Locus 8091, Artifact 38096

Context: 700-500 BC – "Levelling layer in which the kiln had been set; = perhaps (below) 8068."

Overview: Iron slag with ceramic attached (not shown in image).

Figure I26a. L. 8091 38096

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8091 38096	700-500	1	4.969±0.050	2.346±0.054	11.460±0.130	0.783±0.026	0.321±0.021

S	Al	Mn	Zr	Cu
—	0.938±0.080	—	0.018±0.001	—

Sn	Zn	Pb	Ni	As
—	0.005±0.001	—	—	—

Table I26. pXRF slag composition

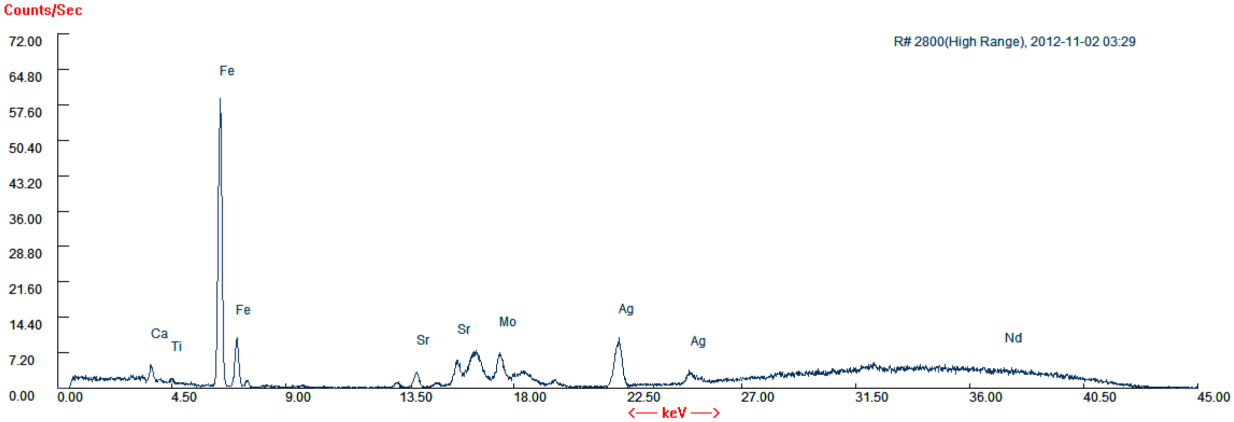

Figure I26b. pXRF spectrum

I27. Locus 8091, Artifact 38111

Context: 700-500 BC – “Levelling layer in which the kiln had been set; = perhaps (below) 8068.”

Overview: Iron slag with one tunnel of tuyère preserved.

Figure I27a. L. 8091 38111

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8091 38111	700-500	2	7.038±0.059	4.801±0.094	21.787±0.195	1.647±0.041	0.515±0.03

S	Al	Mn	Zr	Cu
0.025±0.009	4.182±0.172	0.358±0.097	0.019±0.001	0.008±0.002

Sn	Zn	Pb	Ni	As
—	0.011±0.001	0.005±0.001	—	0.006±0.001

Table I27. pXRF slag composition

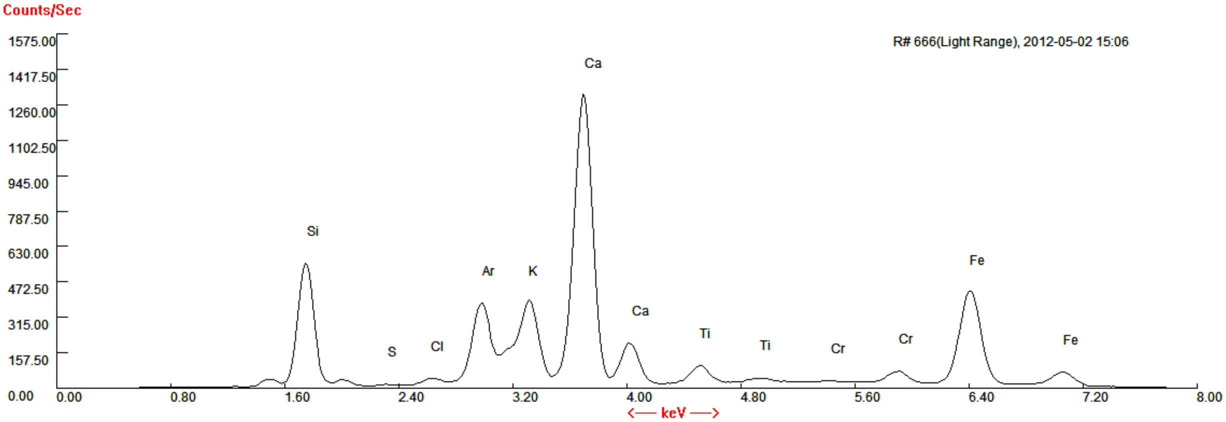

Figure I27b. pXRF spectrum

I28. Locus 8091, Artifact 38118

Context: 700-500 BC – “Levelling layer in which the kiln had been set; = perhaps (below) 8068.”

Overview: Iron slag, one tunnel of tuyère preserved. Optical micrograph show interface between the slag and ceramic.

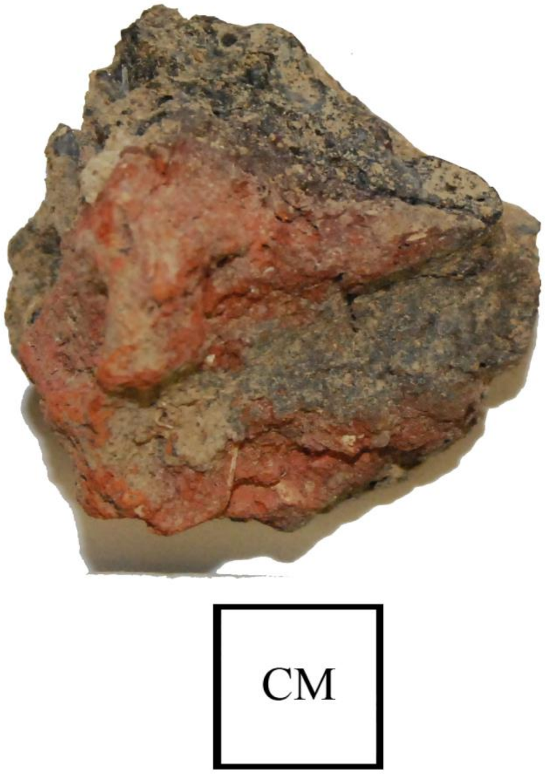

Figure I28a. L. 8091 38118. Tunnel running up diagonally to right with slag on top

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8091 38118	700-500	3	12.762±0.102	6.381±0.122	19.279±0.195	1.429±0.044	0.345±0.031

S	Al	Mn	Zr	Cu
0.024±0.011	4.583±0.216	0.246±0.108	0.02±0.001	0.04±0.003

Sn	Zn	Pb	Ni	As
—	0.006±0.001	±	0.011±0.004	0.003±0.001

Table I28. pXRF slag composition

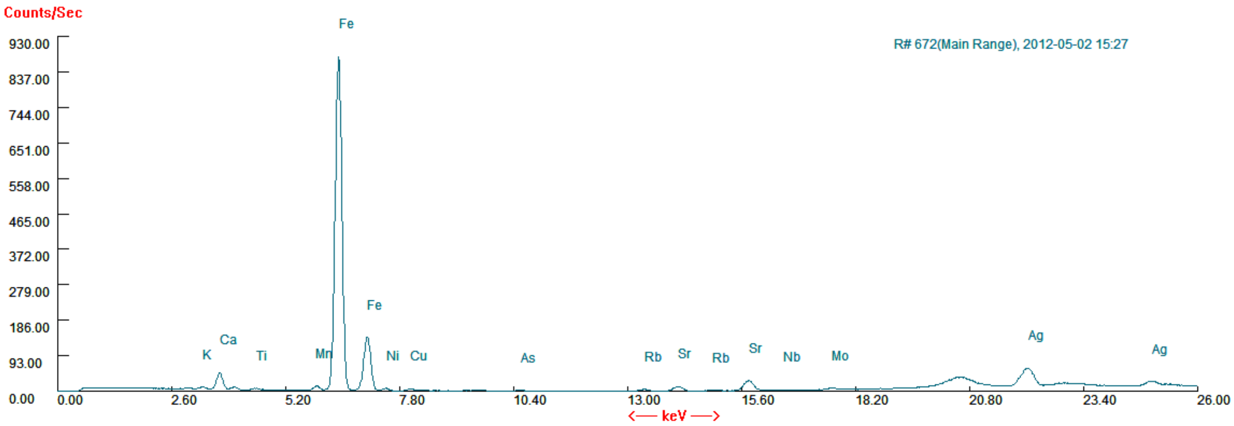

Figure I28b. pXRF spectrum

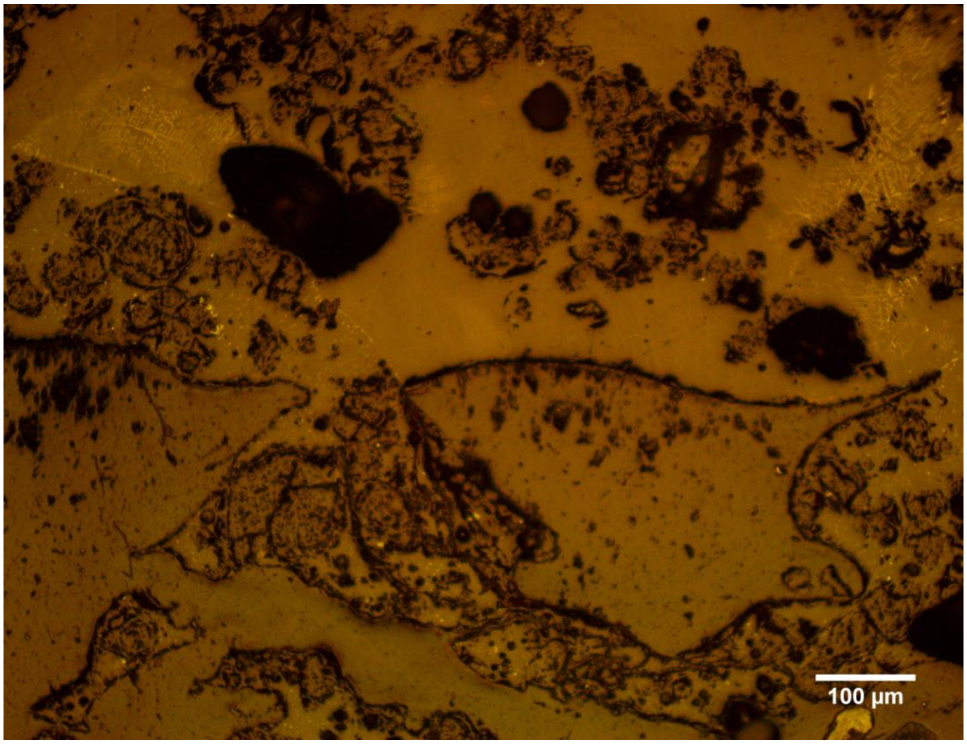

Figure I28c. Optical micrograph showing interface between ceramic (bottom half) and slag (top half), in this case secondary wüstite formations

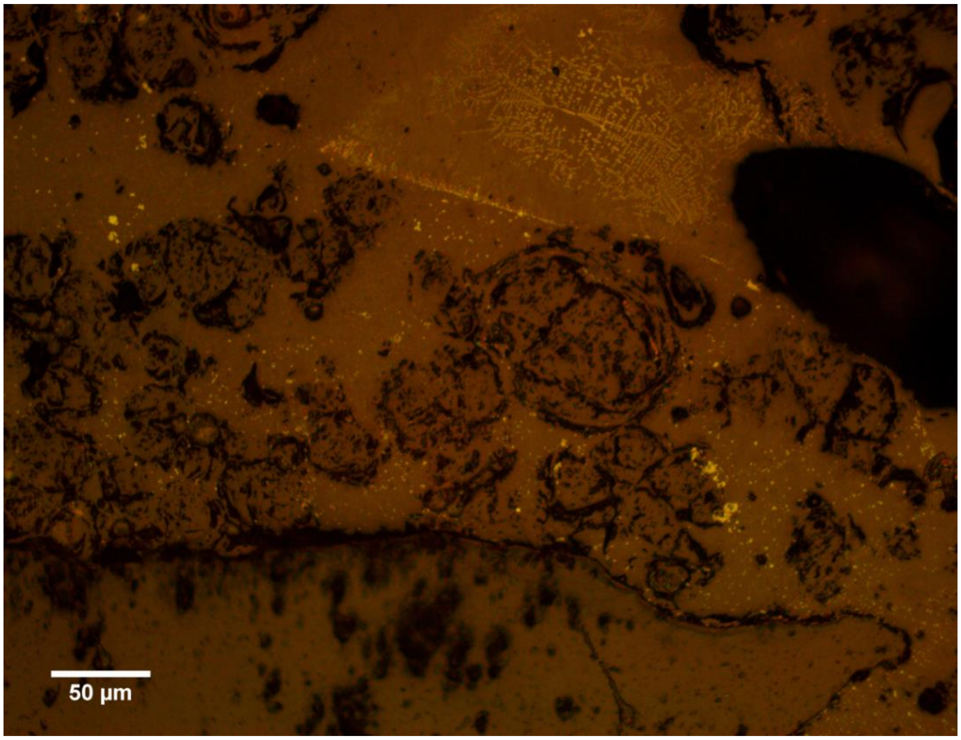

Figure I28d. Optical micrograph of ceramic and slag interface

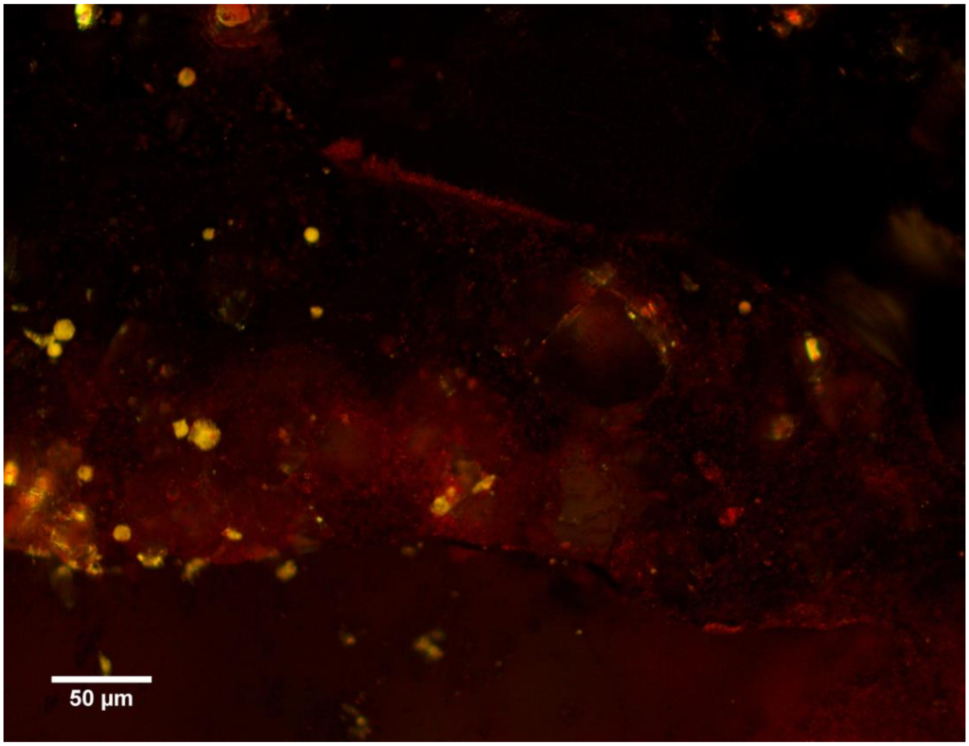

Figure I28e. Dark field micrograph of above Figure I28d, with smoother red ceramic on bottom, and wüstite stringer as bright red line

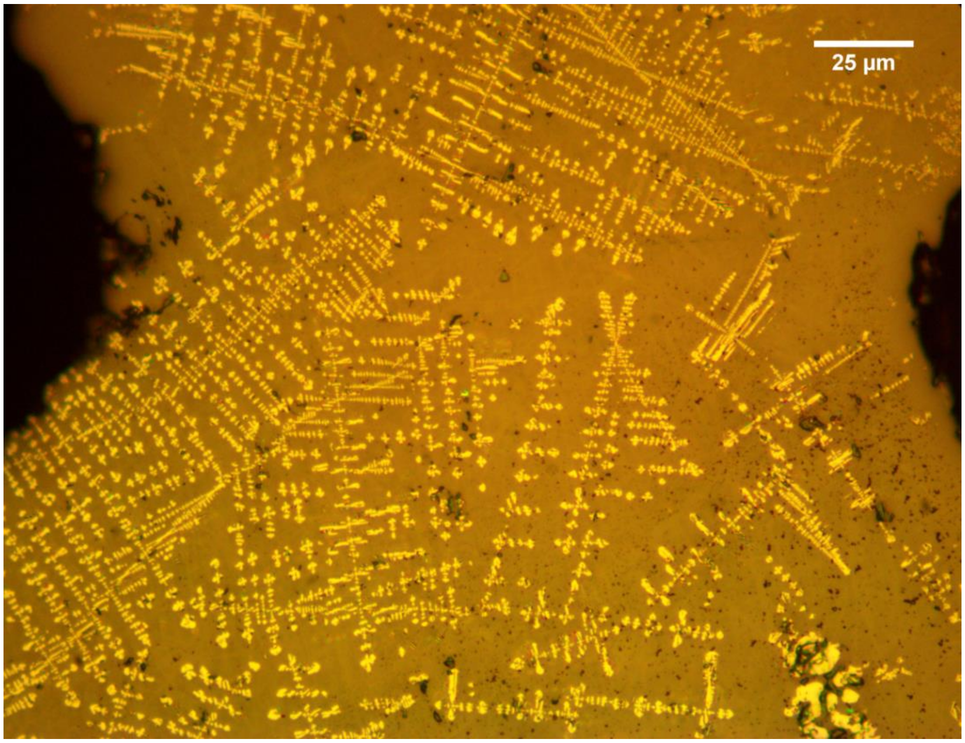

Figure I28f. Secondary wüstite formations

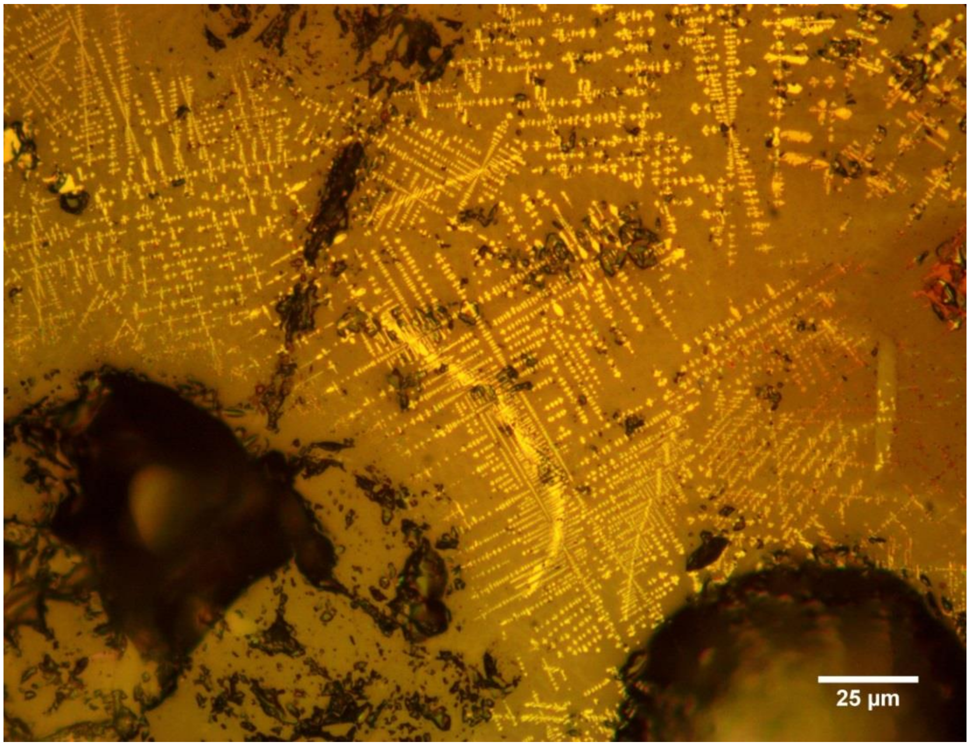

Figure I28g. Secondary wüstite formations

I29. Locus 8091, Artifact 38212

Context: 700-500 BC – “Levelling layer in which the kiln had been set; = perhaps (below) 8068.”

Overview: Iron slag with ceramic attached.

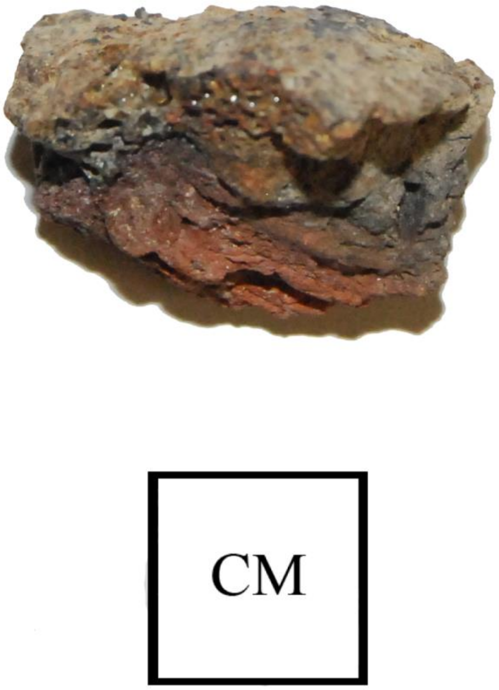

Figure I29a. L. 8091 38212

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8091 38212	700-500	1	21.564±0.161	4.992±0.116	8.201±0.116	0.728±0.039	0.309±0.022

S	Al	Mn	Zr	Cu
—	1.385±0.130	0.363±0.096	0.016±0.001	0.004±.002

Sn	Zn	Pb	Ni	As
—	0.004±0.001	—	0.015±0.004	0.006±0.001

Table I29. pXRF slag composition

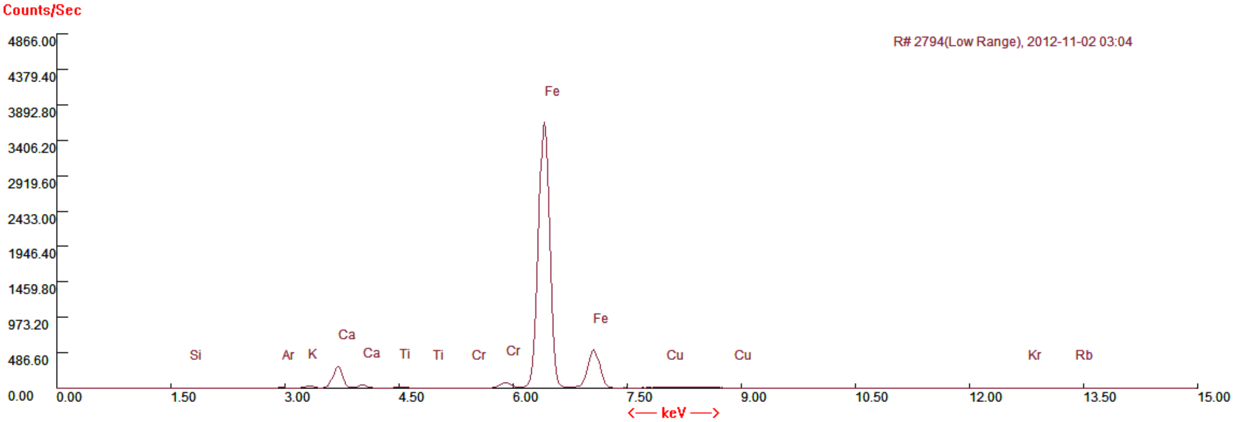

Figure I29b. pXRF spectrum

I30. Locus 8091, Artifact 38214

Context: 700-500 BC – “Levelling layer in which the kiln had been set; = perhaps (below) 8068.”

Overview: Iron slag, two tunnels of tuyère preserved.

Figure I30a. L. 8091 38214. Slag face, one tunnel lower left, the other upper left

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8091 38214	700-500	2	6.542±0.062	5.205±0.095	23.699±0.214	1.498±0.038	0.259±0.031

S	Al	Mn	Zr	Cu
0.092±0.012	4.427±0.194	—	0.018±0.001	0.005±0.002

Sn	Zn	Pb	Ni	As
—	0.006±0.001	—	—	0.003±0.001

Table I30. pXRF slag composition

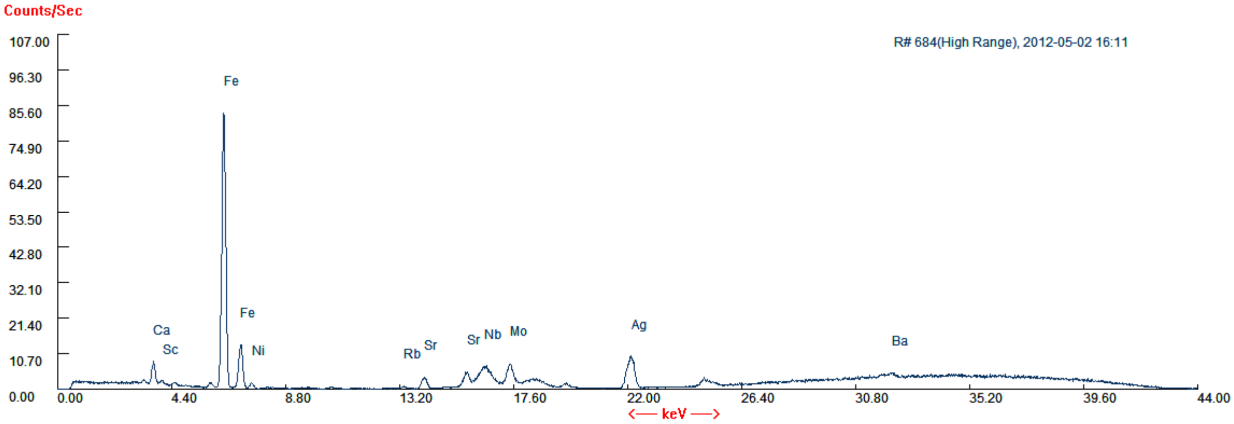

Figure I30b. pXRF spectrum

I31. Locus 8091, Artifact 38215

Context: 700-500 BC – “Levelling layer in which the kiln had been set; = perhaps (below) 8068.”

Overview: Iron slag with ceramic attached.

Figure I31a. L. 8091 38215

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8091 38215	700-500	1	20.496±0.153	3.196±0.107	21.716±0.223	2.571±0.067	0.538±0.034

S	Al	Mn	Zr	Cu
0.323±0.015	5.431±0.256	0.54±0.096	0.016±0.001	0.035±0.003

Sn	Zn	Pb	Ni	As
—	0.003±0.001	—	0.009±0.004	0.003±0.001

Table I31. pXRF slag composition

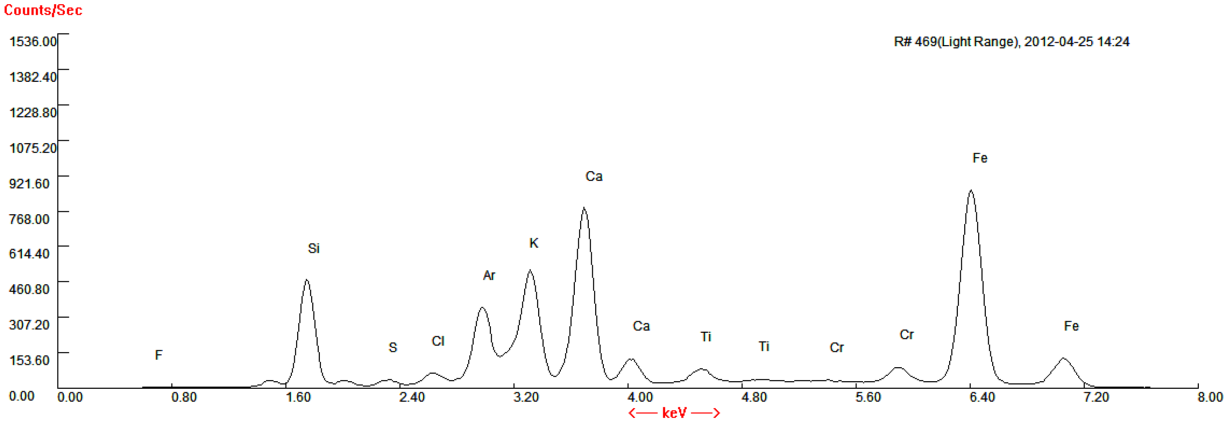

Figure I31b. pXRF spectrum

I32. Locus 8210, Artifact 49138

Context: 750-600 BC – “Fill (*BABesch* 2003, 48-51, cat. 1-3, fig. 6; *Carthage Studies* 2007, 48, No. 65).”

Overview: Iron slag, two tunnels of tuyère preserved. The ceramic fracture occurred at the location of the second tunnel – its hollowness susceptible to fracture.

Figure I32a. L. 8210 49138. Showing fractured tunnel and slag hood

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P	S	Al	Mn	Zr	Cu	Sn	Zn	Pb	Ni	As
L.8210 49138	750-600	3	8.657±0.074	9.173±0.138	17.39±0.183	1.178±0.039	1.261±0.04	0.054±0.012	3.046±0.19	0.571±0.107	0.026±0.001	0.005±0.002	—	0.004±0.001	—	—	0.007±0.001

Table I32. pXRF slag composition

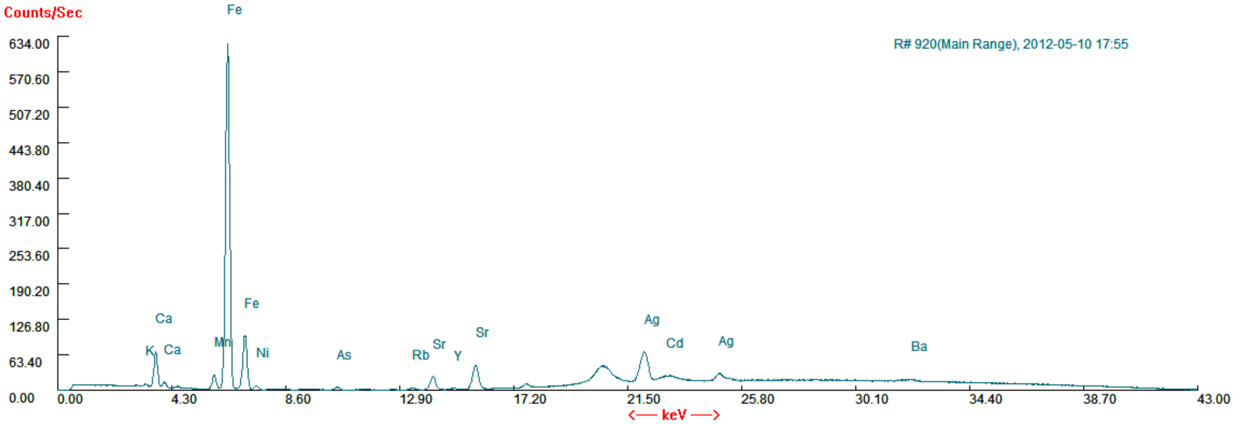

Figure I32b. pXRF spectrum

I33. Locus 8210, Artifact 49141

Context: 750-600 BC – “Fill (*BABesch* 2003, 48-51, cat. 1-3, fig. 6; *Carthage Studies* 2007, 48, No. 65).”

Overview: Iron slag, two tunnels of tuyère preserved. Slight slag hood. Textured/indented surface along tunnels.

Figure I33a. L. 8210 49141. Showing external indented surface moving lengthwise

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8210 49141	750-600	2	10.846±0.092	11.059±0.16	16.406±0.184	1.433±0.042	1.364±0.044

S	Al	Mn	Zr	Cu
0.084±0.014	3.383±0.226	0.391±0.112	0.027±0.001	0.018±0.002

Sn	Zn	Pb	Ni	As
—	0.006±0.001	0.012±0.001	—	0.01±0.001

Table I33. pXRF slag composition

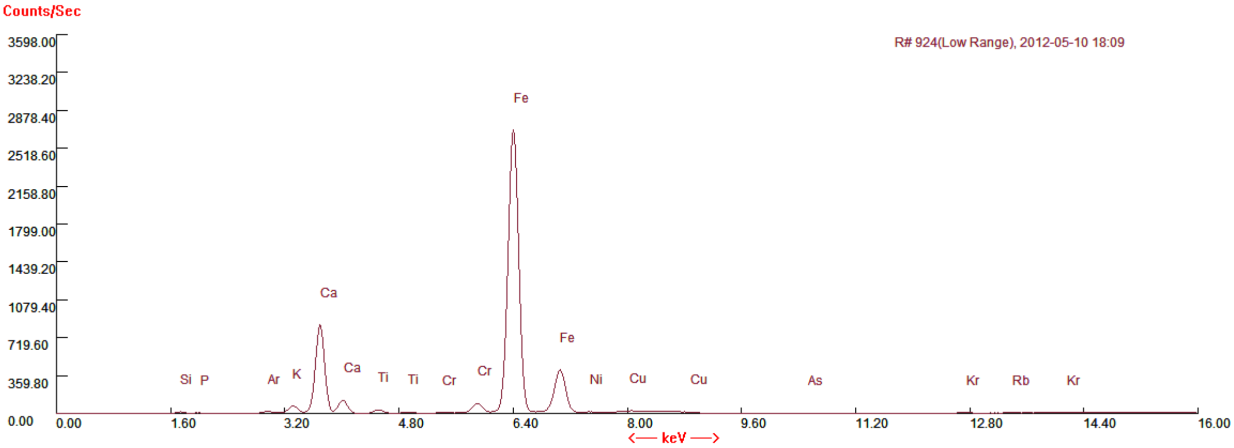

Figure I33b. pXRF spectrum

I34. Locus 8217, Artifact 32232

Context: 800-530 BC – “Fill of metallurgical hearth (*BABesch* 2003, 45, 60-63, figs. 3, 12; *Carthage Studies* 2007, 48, No. 72).”

Overview: Iron slag, end of tuyère completely intact preserving two toggled tunnels, and open holes penetrated at time of firing in viscous slag phase.

Figure I34a. L. 8217 32232. Only ceramic showing, ending in unseen slag terminal point

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8217 32232	800-530	1	9.348±0.076	5.56±0.109	19.371±0.195	1.523±0.043	0.945±0.036

S	Al	Mn	Zr	Cu
0.041±0.011	3.94±0.194	—	0.021±0.001	0.01±0.002

Sn	Zn	Pb	Ni	As
—	0.003±0.001	—	—	0.009±0.001

Table I34. pXRF slag composition

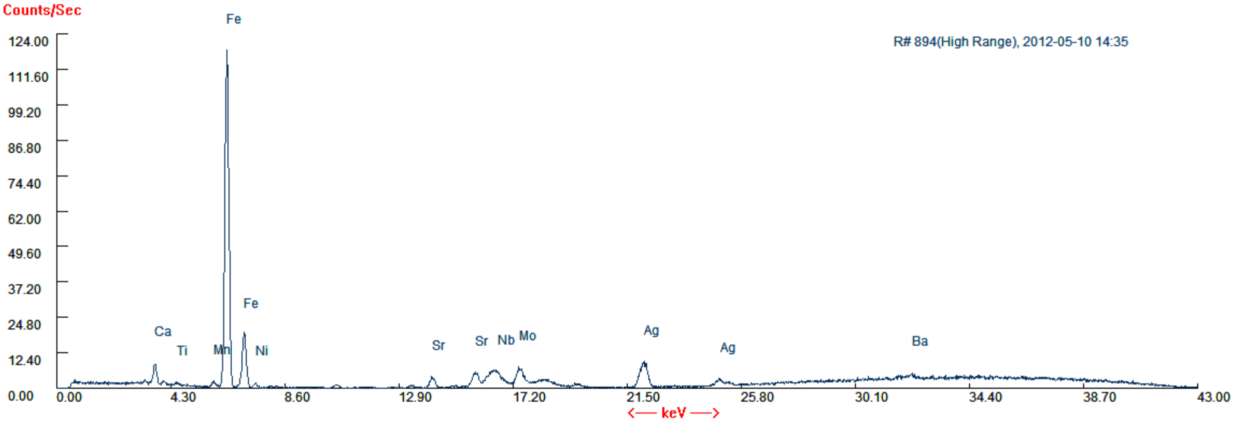

Figure I34b. pXRF spectrum

I35. Locus 8217, Artifact 32233

Context: 800-530 BC – “Fill of metallurgical hearth (*BABesch* 2003, 45, 60-63, figs. 3, 12; *Carthage Studies* 2007, 48, No. 72).”

Overview: Iron slag, end of tuyère completely intact preserving two toggled tunnels, and open holes penetrated at time of firing in viscous slag phase.

Figure I35a. L. 8217 32233

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8217 32233	800-530	3	10.023±0.08	5.133±0.104	21.635±0.201	1.907±0.047	1.339±0.04

S	Al	Mn	Zr	Cu
0.171±0.013	2.629±0.164	0.712±0.102	0.024±0.001	0.011±0.002

Sn	Zn	Pb	Ni	As
—	0.004±0.001	—	—	0.011±0.001

Table I35. pXRF slag composition

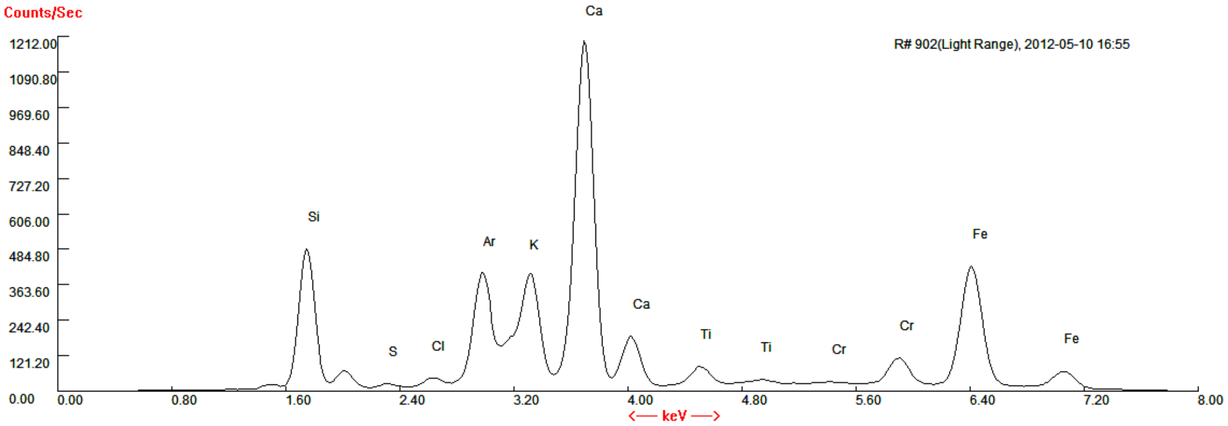

Figure I35b. pXRF spectrum

I36. Locus 8217, Artifact 49145

Context: 800-530 BC – “Fill of metallurgical hearth (*BABesch* 2003, 45, 60-63, figs. 3, 12; *Carthage Studies* 2007, 48, No. 72).”

Overview: Iron slag, end of tuyère mostly intact preserving two toggled tunnels, and open holes penetrated at time of firing in viscous slag phase. Due to ceramic break, internal view of tunnel is possible. Slag hood visible.

Figure I36a. L. 8217 49145. Internal tunnel visible on bottom right, with slag hood

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P	S	Al	Mn	Zr	Cu	Sn	Zn	Pb	Ni	As
L.8217 49145	800-530	1	8.008±0.067	6.115±0.117	23.431±0.215	2.09±0.049	1.837±0.045	0.047±0.011	3.762±0.194	0.67±0.103	0.023±0.001	0.009±0.002	—	0.003±0.001	0.006±0.001	—	0.009±0.001

Table I36. pXRF slag composition

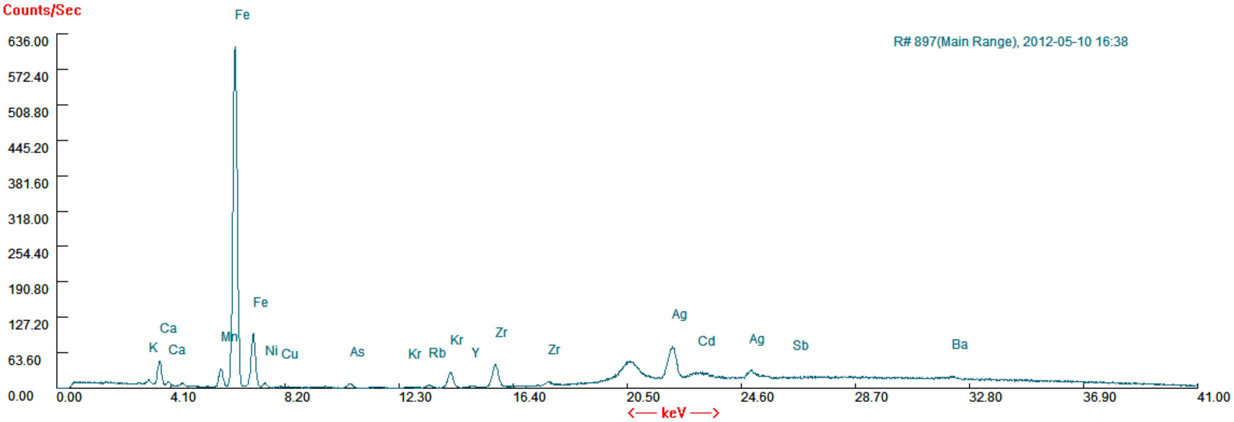

Figure I36b. pXRF spectrum

I37. Locus 8217, Artifact 49154

Context: 800-530 BC – "Fill of metallurgical hearth (*BABesch* 2003, 45, 60-63, figs. 3, 12; *Carthage Studies* 2007, 48, No. 72)."

Overview: Iron slag, end of tuyère mostly intact preserving one complete tunnel and one exposed tunnel. Open holes penetrated at time of firing in viscous slag phase. Due to ceramic break, internal view of tunnel is possible. Slag hood visible.

Figure I37a. L. 8217 49154. Exposed tunnel visible, slag hood

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8217 49154	800-530	1	5.022±0.051	4.622±0.08	22.817±0.2	1.333±0.033	0.276±0.029

S	Al	Mn	Zr	Cu
—	5.53±0.198	—	0.018±0.001	—

Sn	Zn	Pb	Ni	As
—	0.005±0.001	—	—	—

Table I37. pXRF slag composition

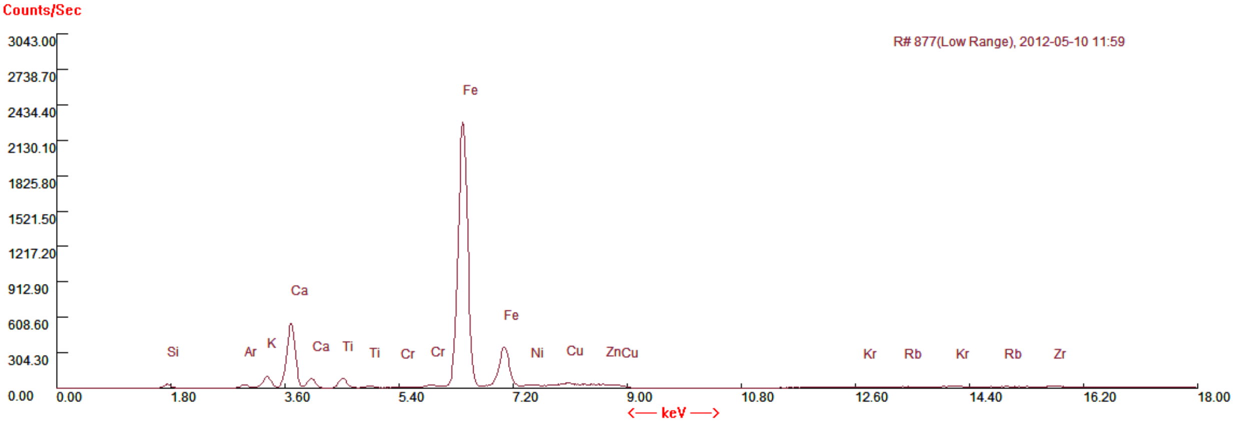

Figure I37b. pXRF spectrum

B. *800-400 BC*

I38. Locus 1093, Artifact 38011

Context: 450-425 BC – "= (above) 1111, 1112, 1115, 1116: Compact levelling layer below floor 1068 (removal of this floor); in part same as 1074; very dirty layer with faeces; many metal (working?) finds."

Overview: Iron slag, one tunnel of tuyère preserved. This tuyère found in same locus as the cobalt-rich artifact.

Figure I38a. L. 1093 38011

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.1093 38011	450-425	2	4.066±0.045	5.738±0.095	26.878±0.217	1.739±0.038	0.662±0.036

S	Al	Mn	Zr	Cu
0.101±0.012	2.817±0.158	0.909±0.099	0.023±0.001	0.003±0.001

Sn	Zn	Pb	Ni	As
—	0.004±0.001	0.004±0.001	—	0.002±0.001

Table I38. pXRF slag composition

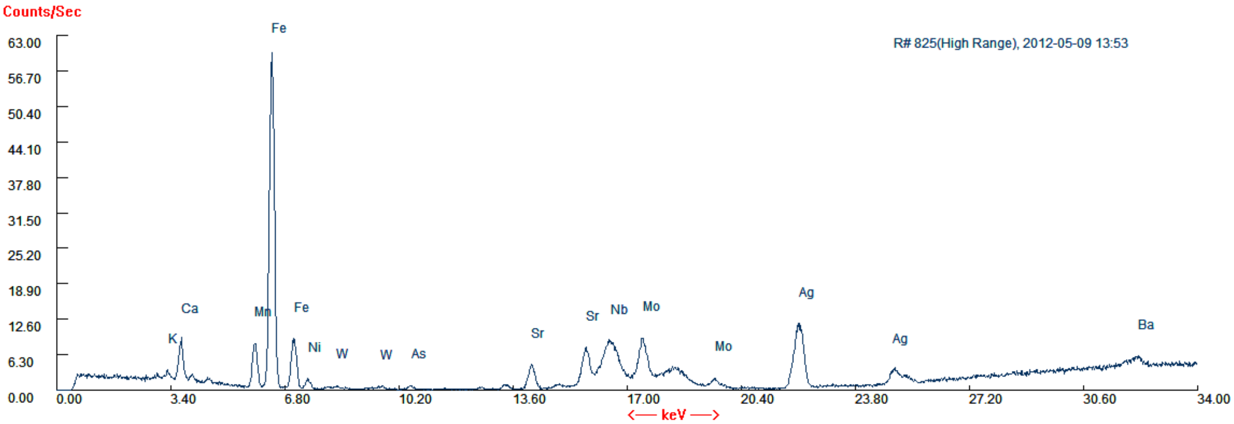

Figure I38b. pXRF spectrum

I39. Locus 8020, Artifact 17459

Context: 750-400 BC – “Layer.”

Overview: Iron slag, two tunnels of tuyère preserved.

Figure I39a. L. 8020 17459. Two tunnels at top and bottom

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8020 17459	750-400	2	15.957±0.121	5.149±0.119	15.520±0.179	1.369±0.049	0.663±0.031

S	Al	Mn	Zr	Cu
0.185±0.012	2.589±0.170	1.197±0.107	0.034±0.001	0.012±0.002

Sn	Zn	Pb	Ni	As
—	0.009±0.001	0.003±0.001	0.015±0.004	0.007±0.001

Table I39. pXRF slag composition

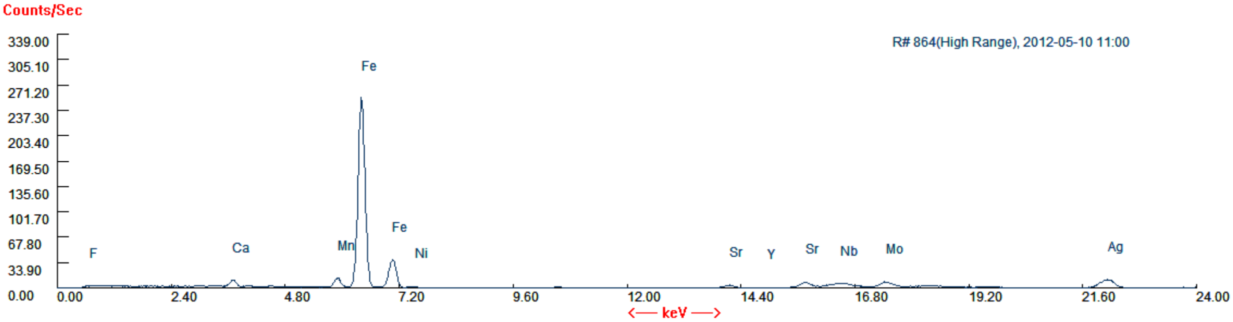

Figure I39b. pXRF spectrum

I40. Locus 8020, Artifact 17475

Context: 750-400 BC – “Layer.”

Overview: Iron slag, one tunnel of tuyère preserved.

Figure I40a. L. 8020 17475

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8020 17475	750-400	2	8.364±0.072	6.682±0.121	19.292±0.195	1.890±0.046	0.467±0.032

S	Al	Mn	Zr	Cu
0.245±0.014	3.363±0.185	1.241±0.105	0.023±0.001	0.010±0.002

Sn	Zn	Pb	Ni	As
—	0.007±0.001	0.005±0.001	0.009±0.004	0.005±0.001

Table I40. pXRF slag composition

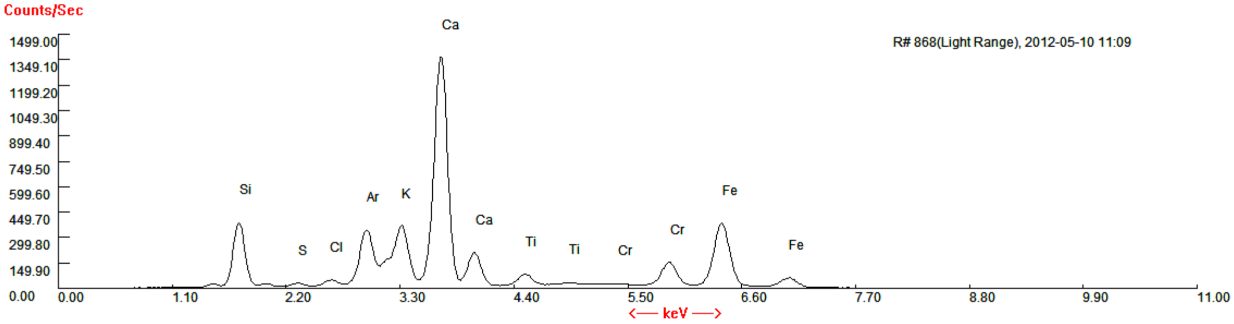

Figure I40b. pXRF spectrum

I41. Locus 8068, Artifact 37993

Context: 800-450 BC – “Layer in which kiln was set.”

Overview: Iron slag with ceramic attached. This artifact is likely earlier than 5th century BC, but since it is not verified it is most conservative to include it in this later EP/MP chronology.

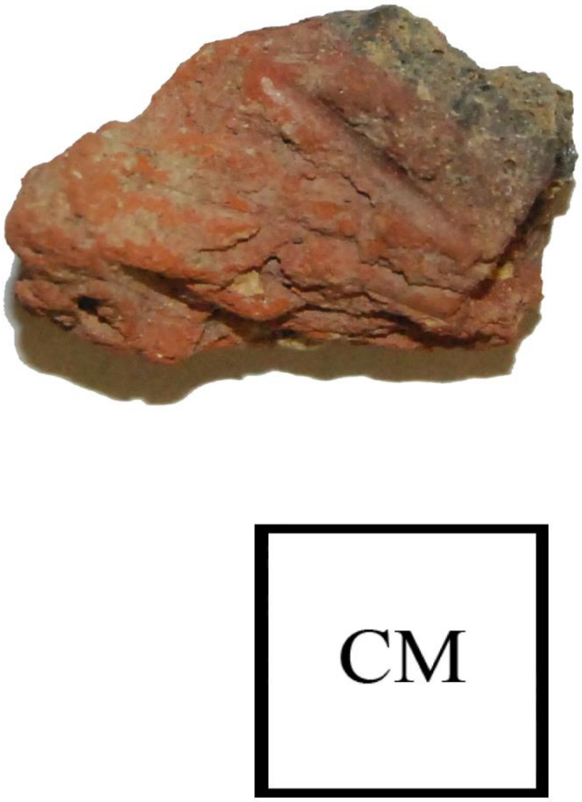

Figure I41a. L. 8068 37993

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8068 37993	800-450	1	4.45±0.047	3.143±0.066	25.583±0.217	1.405±0.034	0.131±0.027

S	Al	Mn	Zr	Cu
0.041±0.009	6.992±0.209	—	0.029±0.001	—

Sn	Zn	Pb	Ni	As
—	0.008±0.001	—	—	—

Table I41. pXRF slag composition

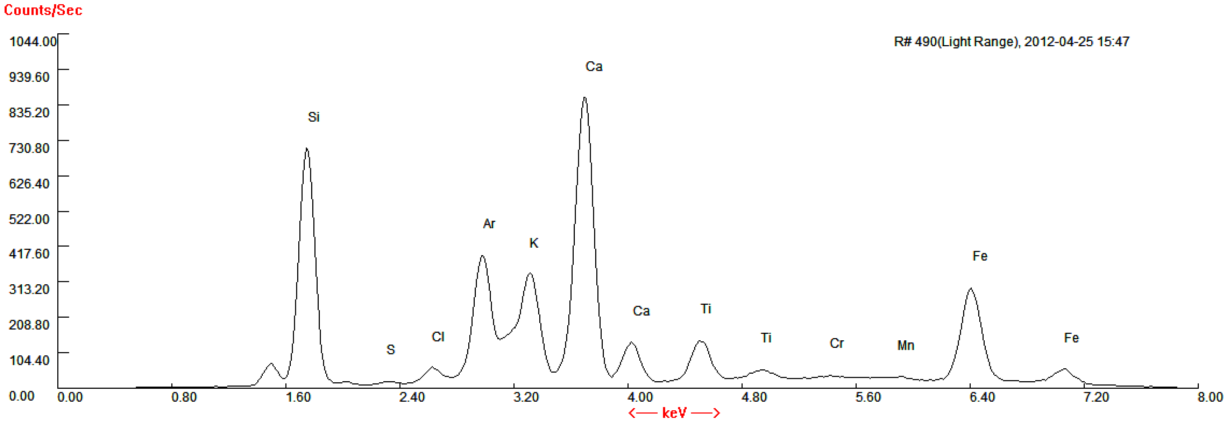

Figure I41b. pXRF spectrum

I42. Locus 8089, Artifact 16903

Context: 750-400 BC – “Floor make up including material on top of it (= 8084).”

Overview: Iron slag, one tunnel of tuyère preserved.

Figure I42a. L. 8089 16903

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8089 16903	750-400	2	11.195±0.090	6.323±0.120	22.435±0.206	1.852±0.047	0.842±0.036

S	Al	Mn	Zr	Cu
0.034±0.011	4.544±0.216	0.542±0.106	0.020±0.001	0.035±0.003

Sn	Zn	Pb	Ni	As
—	0.006±0.001	—	0.008±0.004	0.004±0.001

Table I42. pXRF slag composition

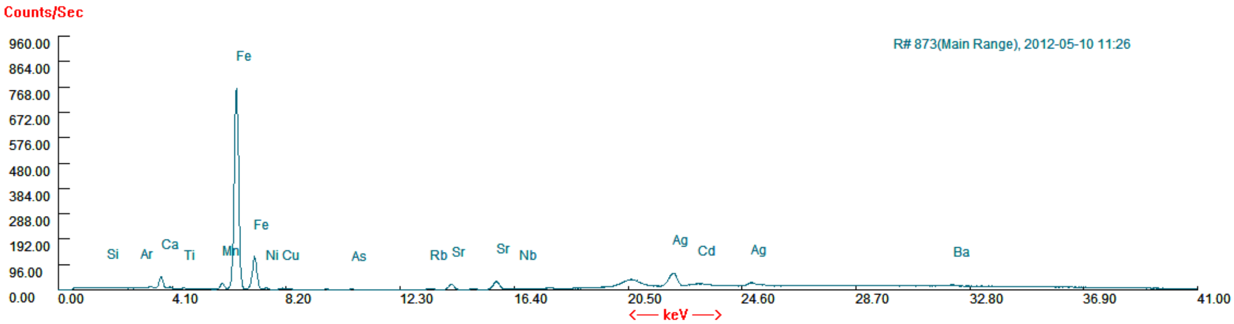

Figure I42b. pXRF spectrum

I43. Locus 8089, Artifact 17486

Context: 750-400 BC – “Floor make up including material on top of it (= 8084).”

Overview: Iron slag, two tunnels of tuyère preserved.

Figure I43a. L. 8089 17486. With partially preserved tunnel on far right

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8089 17486	750-400	1	17.128±0.132	6.423±0.141	20.741±0.222	1.580±0.054	1.492±0.046

S	Al	Mn	Zr	Cu
0.049±0.012	3.574±0.233	0.771±0.105	0.016±0.001	0.027±0.003

Sn	Zn	Pb	Ni	As
—	0.007±0.001	0.006±0.001	0.017±0.004	0.006±0.001

Table I43. pXRF slag composition

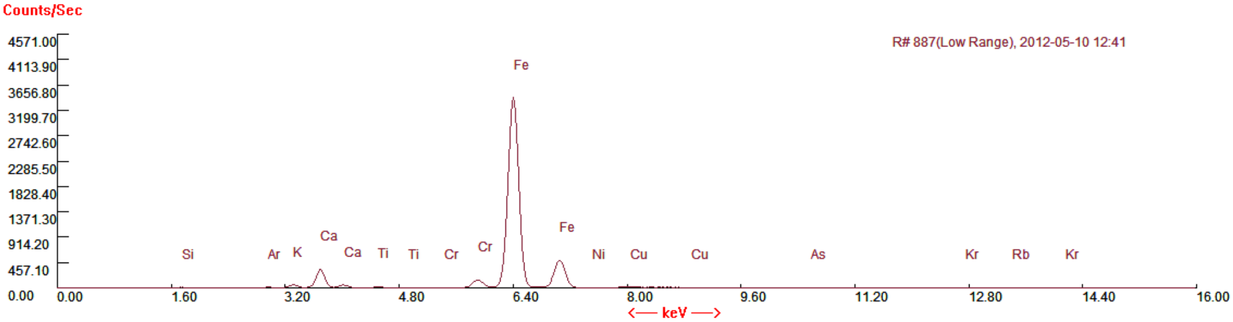

Figure I43b. pXRF spectrum

I44. Locus 8089, Artifact 38106

Context: 750-400 BC – “Floor make up including material on top of it (= 8084).”

Overview: Iron slag with ceramic attached.

Figure I44a. L. 8089 38106

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8089 38106	750-400	1	7.465±0.069	3.840±0.083	16.833±0.179	1.022±0.035	0.349±0.027

S	Al	Mn	Zr	Cu
—	1.323±0.113	—	0.022±0.001	0.008±0.002

Sn	Zn	Pb	Ni	As
—	0.005±0.001	—	—	—

Table I44. pXRF slag composition

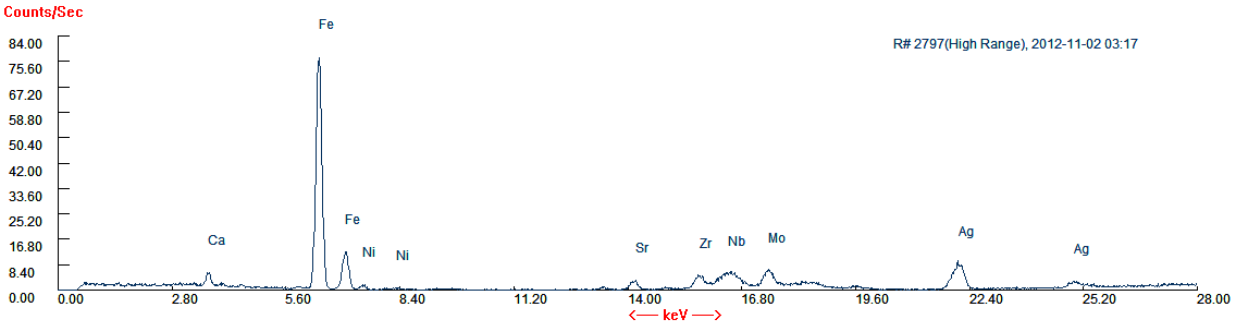

Figure I44b. pXRF spectrum

I45. Locus 8092

Context: 750-400 BC – “Kiln construction.”

Overview: Iron slag, at least one and perhaps two tunnels of tuyère preserved.

Figure I45a. L. 8092. Showing external portion of ceramic and slag interface

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P	S	Al	Mn	Zr	Cu	Sn	Zn	Pb	Ni	As
L.8092	750-400	1	10.463±0.083	5.787±0.118	16.802±0.183	1.256±0.043	0.434±0.031	0.028±0.011	1.894±0.15	0.995±0.1	0.018±0.001	0.006±0.002	—	—	—	0.015±0.004	0.004±0.001

Table I45. pXRF slag composition

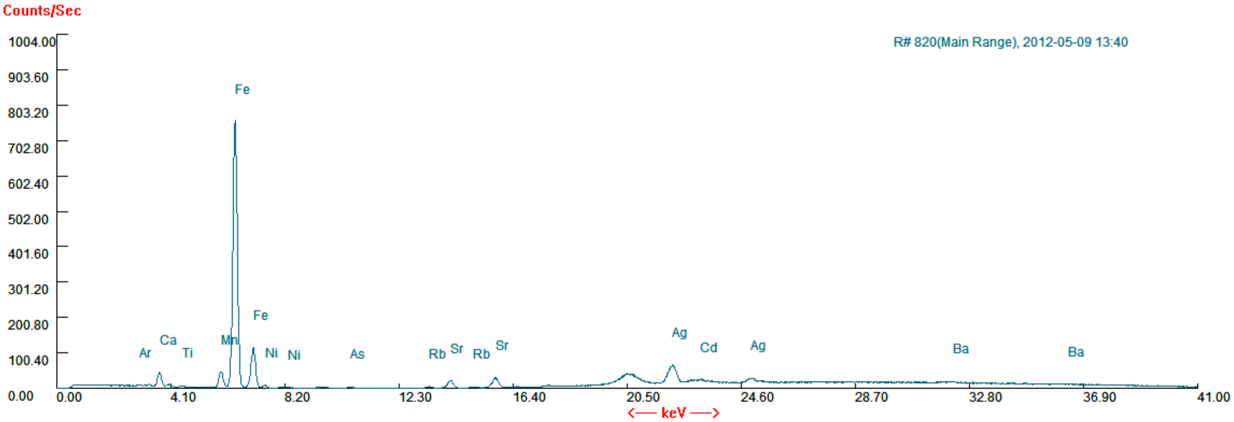

Figure I45b. pXRF spectrum

I46. Locus 8092, Artifact 17472

Context: 750-400 BC – “Kiln construction.”

Overview: Iron slag, one tunnel of tuyère preserved. The tunnel is stained with soot from firing activities.

Figure I46a. L. 8092 17472

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8092 17472	750-400	2	14.208±0.115	5.013±0.114	21.004±0.203	2.094±0.052	0.339±0.032

S	Al	Mn	Zr	Cu
0.124±0.012	4.223±0.215	0.447±0.108	0.02±0.001	0.021±0.002

Sn	Zn	Pb	Ni	As
—	0.01±0.001	—	0.014±0.004	0.004±0.001

Table I46. pXRF slag composition

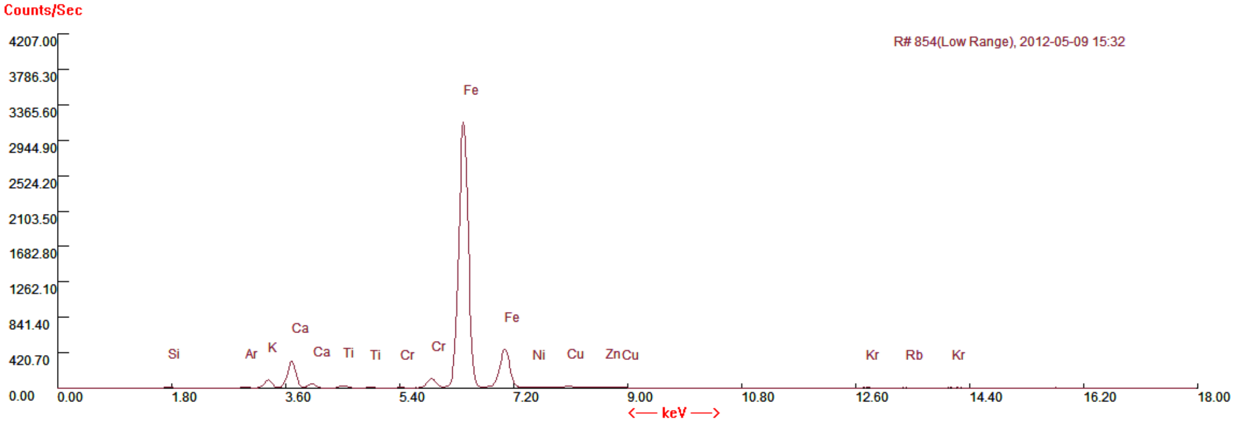

Figure I46b. pXRF spectrum

I47. Locus 8092, Artifact 17473

Context: 750-400 BC – “Kiln construction.”

Overview: Iron slag, with one tunnel completely preserved and one partially preserved.

Figure I47a. L. 8092 17473. Showing completely preserved tunnel

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P	S	Al	Mn	Zr	Cu	Sn	Zn	Pb	Ni	As
L.8092 17473	750-400	2	12.05±0.093	5.907±0.116	15.696±0.166	1.354±0.042	0.426±0.028	0.063±0.01	3.118±0.168	0.729±0.102	0.016±0.001	0.012±0.002	—	0.005±0.001	—	—	0.006±0.001

Table I47. pXRF slag composition

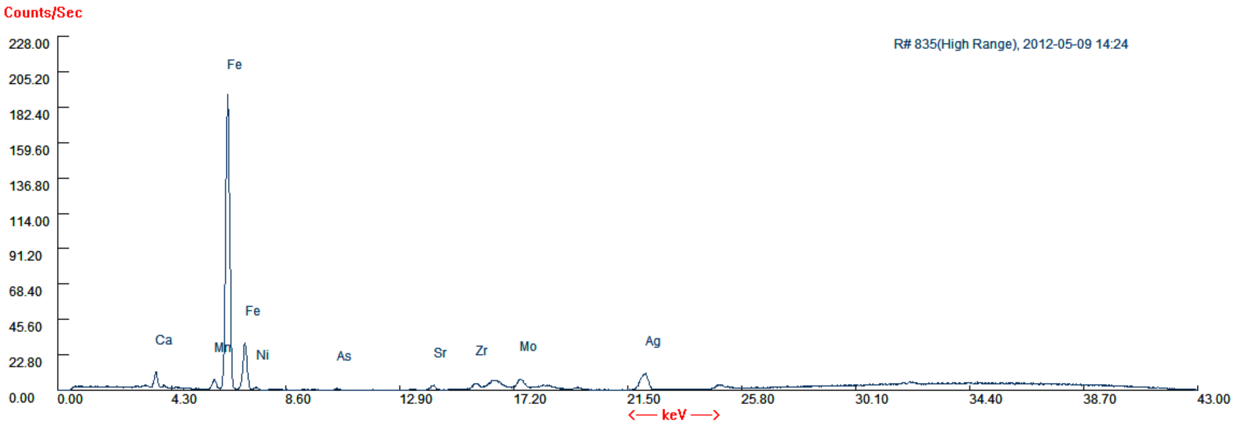

Figure I47b. pXRF spectrum

I48. Locus 8092, Artifact 17479

Context: 750-400 BC – “Kiln construction.”

Overview: Iron (poor) slag with ceramic attached.

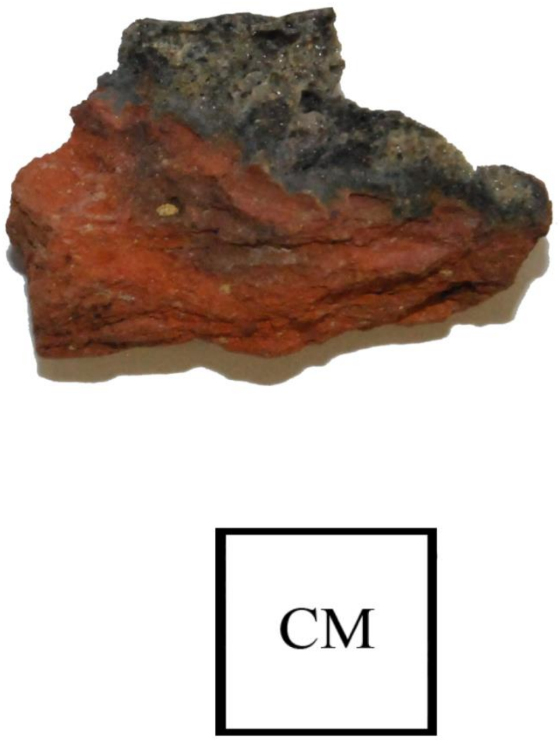

Figure I48a. L. 8092 17479

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8092 17479	750-400	1	4.992±0.052	2.852±0.072	23.047±0.215	2.266±0.047	0.627±0.031

S	Al	Mn	Zr	Cu
—	5.779±0.2	0.412±0.108	0.021±0.001	0.004±0.001

Sn	Zn	Pb	Ni	As
—	0.007±0.001	—	—	—

Table I48. pXRF slag composition

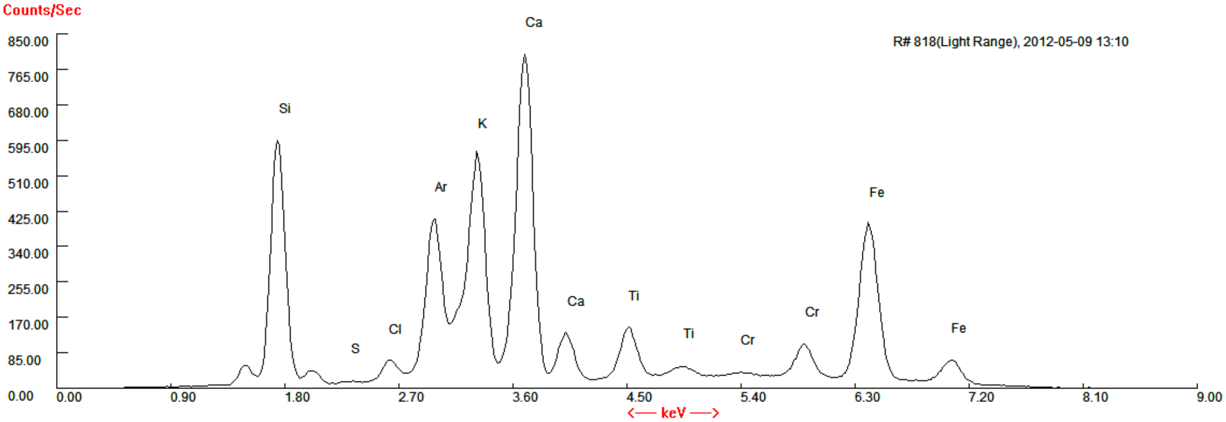

Figure I48b. pXRF spectrum

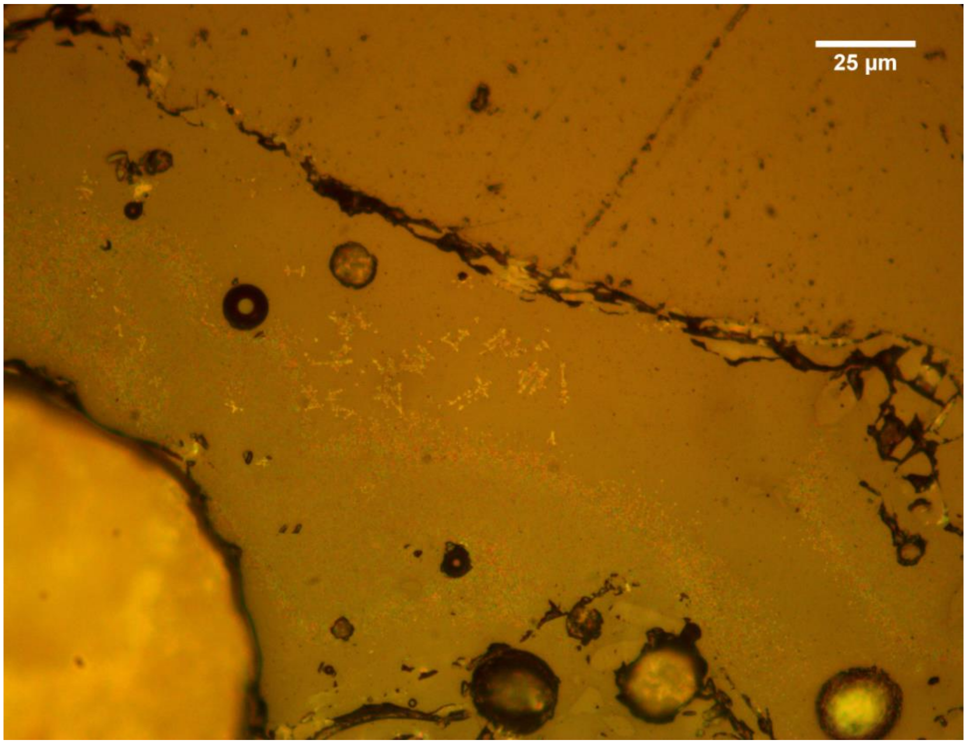

Figure I48c. Iron poor slag, perhaps secondary wüstite formations

I49. Locus 8092, Artifact 17480

Context: 750-400 BC – “Kiln construction.”

Overview: Iron slag, one tunnel of tuyère preserved. Optical micrographs show primary and secondary wüstite formations, and fayalite. Components of both wüstite rich and fayalitic areas indicating a heterogeneous ferritic and pearlitic product. Figure I49d is likely the result of a tap slag, with Figure I49e representative of pearlite production.

Figure I49a. L. 8092 17480

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8092 17480	750-400	2	10.858±0.094	7.347±0.132	27.262±0.241	1.608±0.046	0.221±0.036

S	Al	Mn	Zr	Cu
—	5.471±0.256	—	0.019±0.001	0.004±0.002

Sn	Zn	Pb	Ni	As
—	0.006±0.001	—	—	0.004±0.001

Table I49. pXRF slag composition

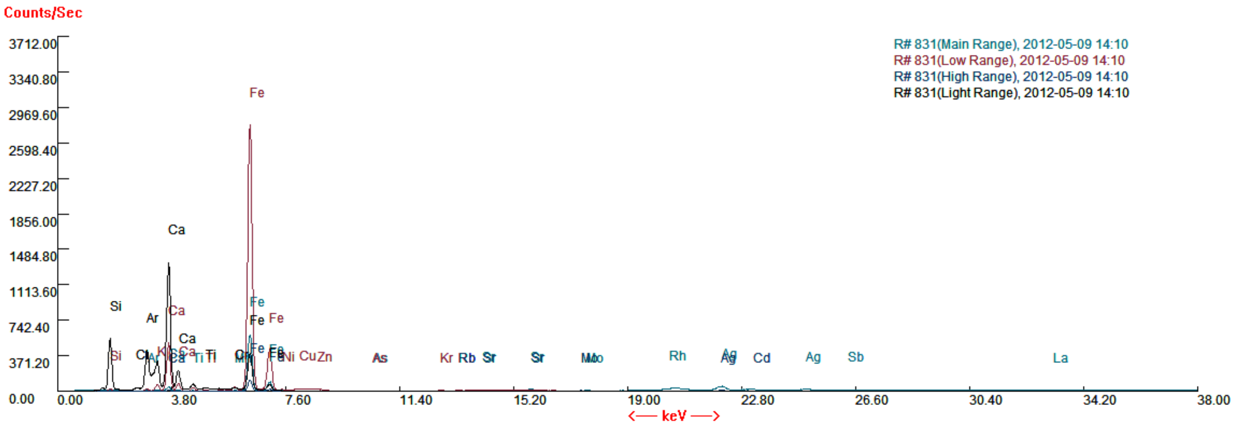

Figure I49b. pXRF spectrum of all ranges

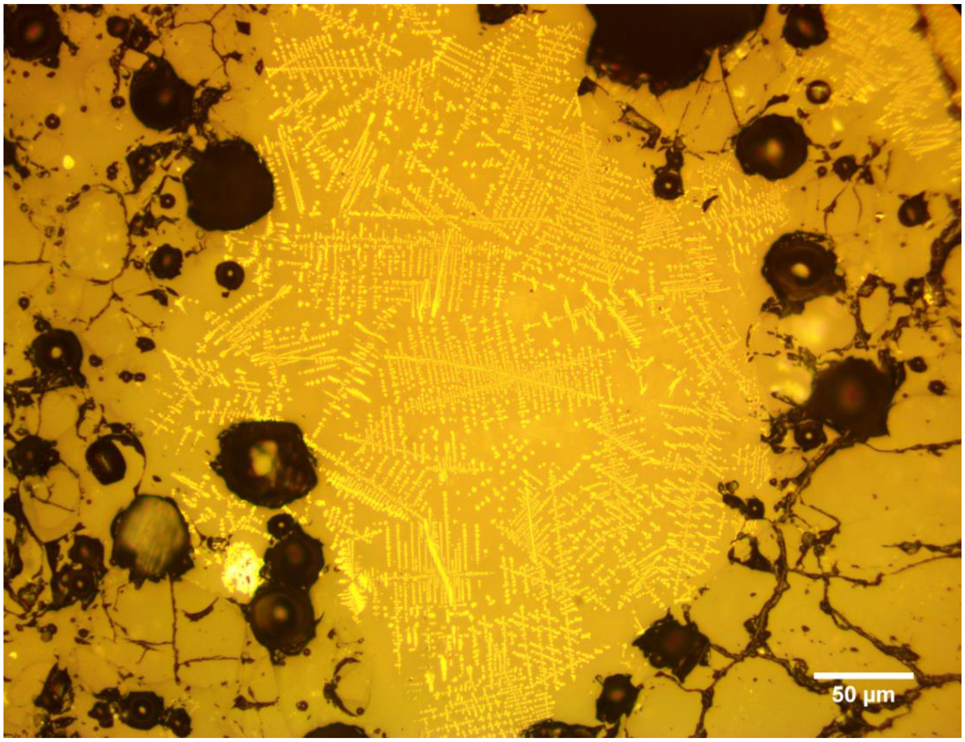

Figure I49c. Secondary wüstite formations

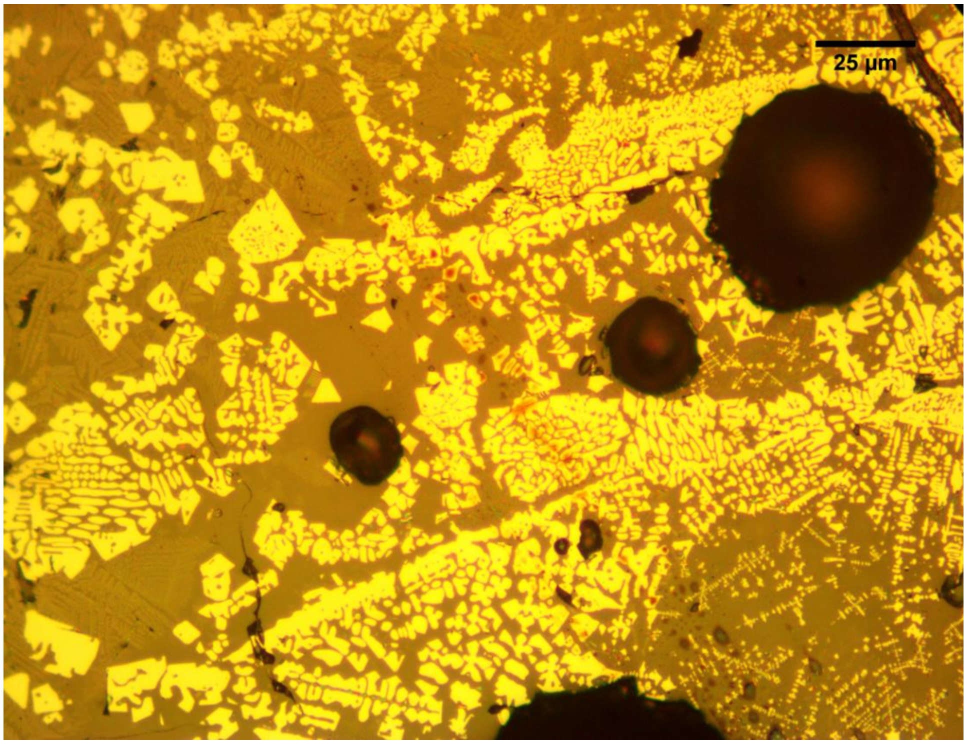

Figure I49d. Primary and secondary wüstite formations, and fayalite in glassy matrix

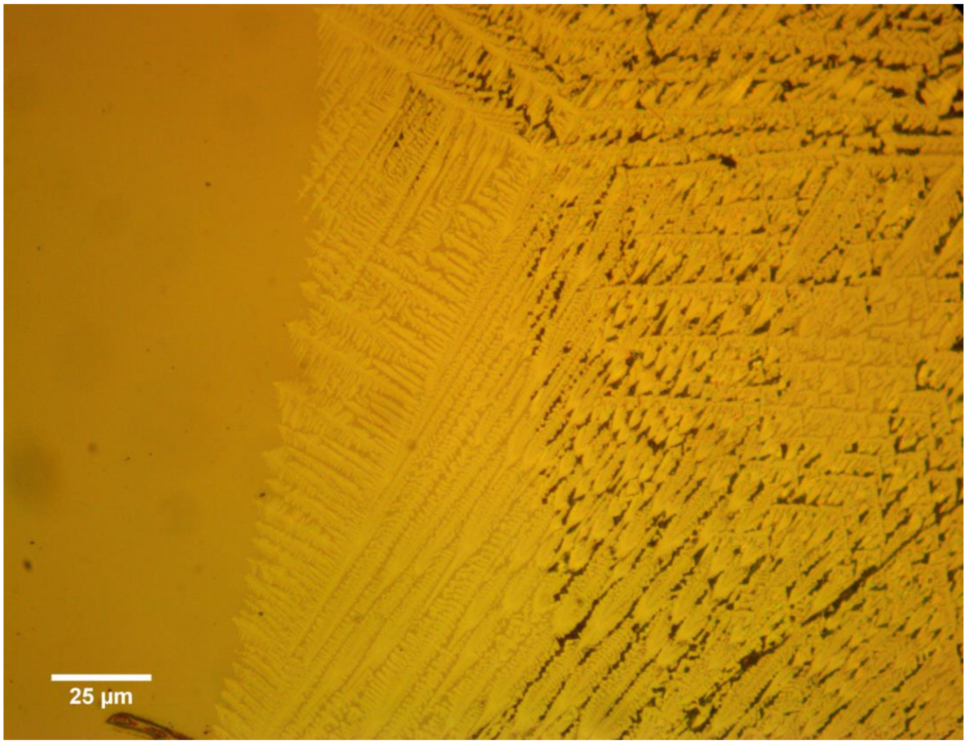

Figure I49e. Fayalite on right bordering on glassy phase

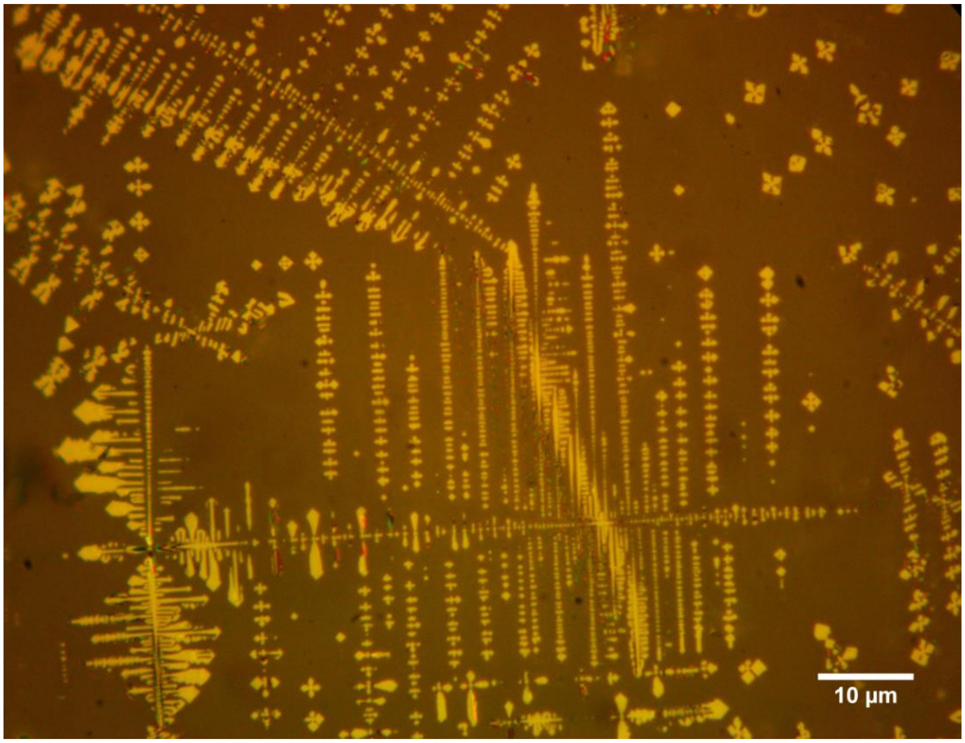

Figure I49f. Secondary wüstite formations

I50. Locus 8092, Artifact 38015

Context: 750-400 BC – “Kiln construction.”

Overview: Iron slag, two tunnels of tuyère preserved. Textured/indented surface along tunnels.

Figure I50a. L. 8092 38015

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8092 38015	750-400	2	24.653±0.201	7.303±0.141	14.652±0.17	1.048±0.043	0.387±0.03

S	Al	Mn	Zr	Cu
0.094±0.012	3.986±0.243	0.406±0.106	0.012±0.001	0.026±0.003

Sn	Zn	Pb	Ni	As
—	0.005±0.001	0.022±0.002	—	0.011±0.001

Table I50. pXRF slag composition

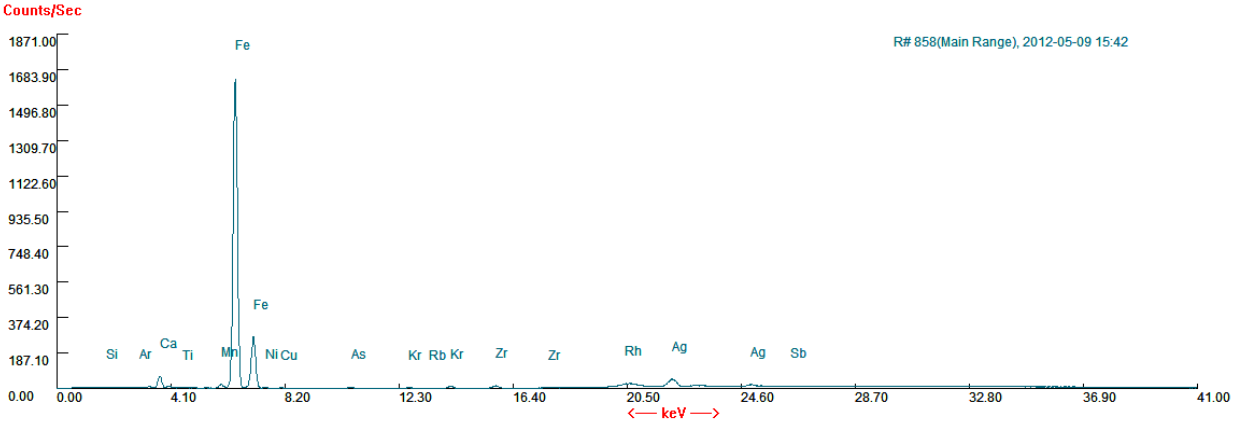

Figure I50b. pXRF spectrum

I51. Locus 8099, Artifact 38086

Context: 750-400 BC – “= 8093, 8094, 8095: Levelling layer.”

Overview: Iron slag with ceramic attached.

Figure I51a. L. 8099 38086

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.8099 38086	750-400	1	4.516±0.048	3.229±0.070	19.733±.192	0.912±0.031	0.329±0.026

S	Al	Mn	Zr	Cu
—	1.561±0.104	—	0.021±0.001	0.005±0.001

Sn	Zn	Pb	Ni	As
—	0.006±0.001	—	—	—

Table I51. pXRF slag composition

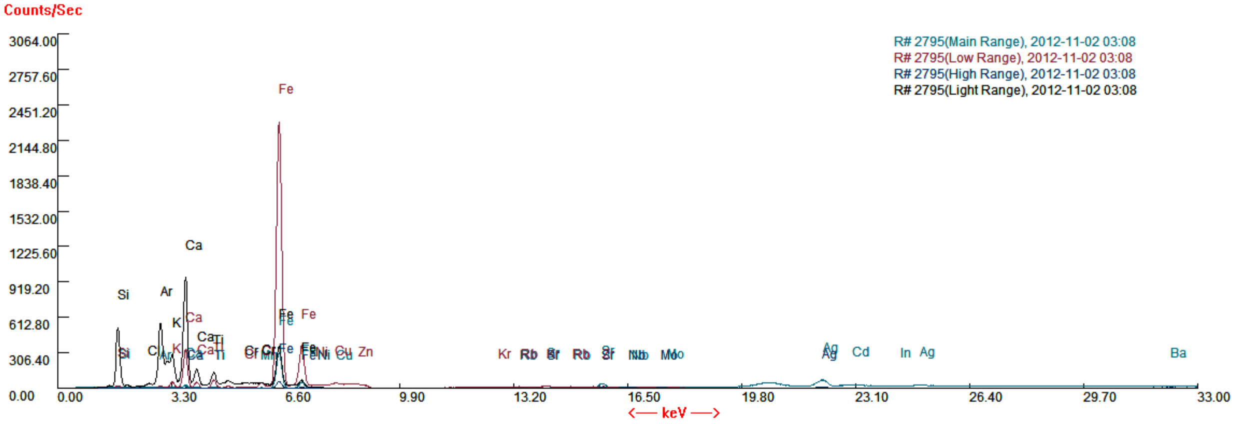

Figure I51b. pXRF spectrum of all ranges

C. *200-146 BC*

I52. Locus 1060, Artifact 17477

Context: 200-146 BC – “= more or less 1095 [= more or less 1060: Either fill of robber trench of wall next to floor 1077 or layer; below 1072]: Layer below 1025, but probably still the same layer; (partly) on top of floor 1068, floor 1077 (southern extension), and 1096.”

Overview: Iron slag, one tunnel of tuyère preserved.

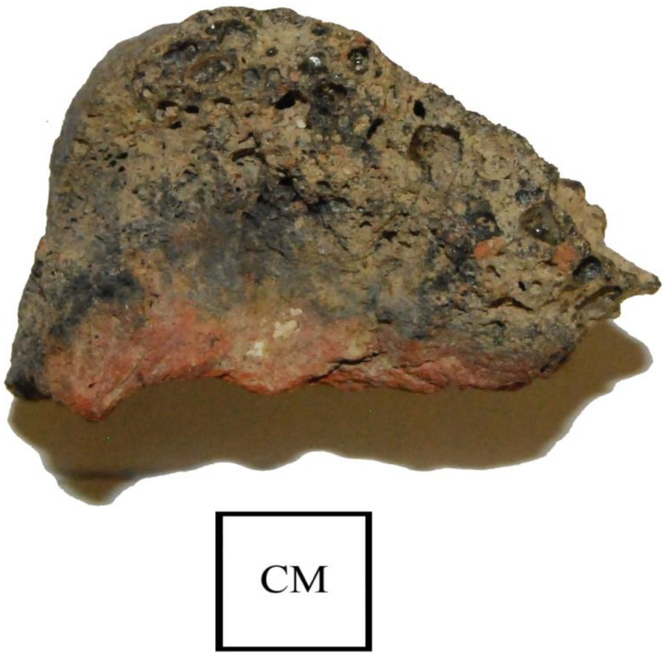

Figure I52a. L. 1060 17477. Preserved tunnel on bottom left

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.1060 17477	200-146	3	9.535±0.082	6.263±0.115	18.072±0.183	1.591±0.043	1.1±0.037

S	Al	Mn	Zr	Cu
0.163±0.013	3.579±0.184	0.289±0.103	0.019±0.001	0.006±0.002

Sn	Zn	Pb	Ni	As
—	0.005±0.001	0.003±0.001	—	0.004±0.001

Table I52. pXRF slag composition

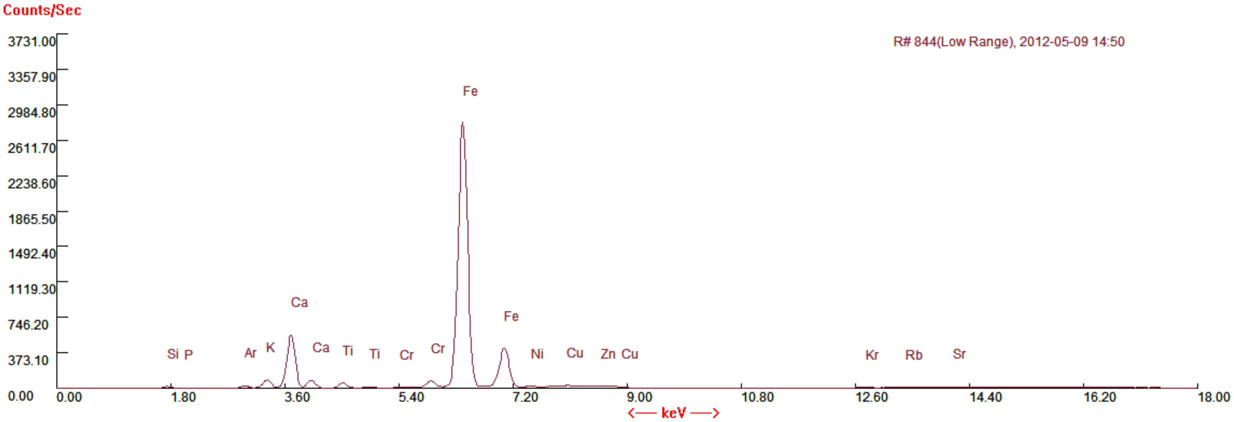

Figure I52b. pXRF spectrum

I53. Locus 1060, Artifact 17478

Context: 200-146 BC – “= more or less 1095 [= more or less 1060: Either fill of robber trench of wall next to floor 1077 or layer; below 1072]: Layer below 1025, but probably still the same layer; (partly) on top of floor 1068, floor 1077 (southern extension), and 1096.”

Overview: Iron slag with ceramic attached. Optical micrographs and SEM-EDS verify iron-rich silicates. The high silica content (second highest in the corpus after L. 8092 38015) makes it difficult to delineate specific phases, despite the fact the microstructure of the iron-rich phases seems to be primary wüstite.

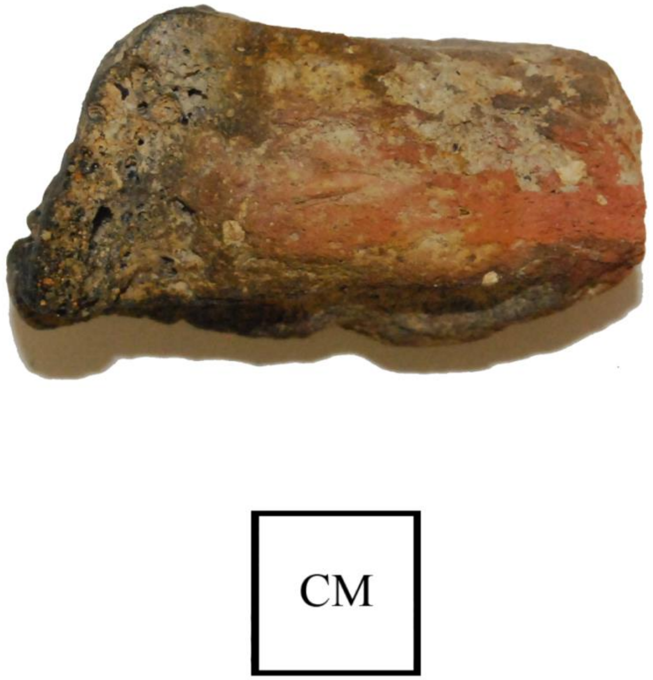

Figure I53a. L. 1060 17478

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.1060 17478	200-146	1	21.84±0.171	7.09±0.146	20.126±0.208	1.021±0.045	0.535±0.036

S	Al	Mn	Zr	Cu
0.127±0.015	4.728±0.284	1.163±0.104	0.016±0.001	0.057±0.004

Sn	Zn	Pb	Ni	As
—	0.006±0.001	—	0.035±0.005	0.004±0.001

Table I53. pXRF slag composition

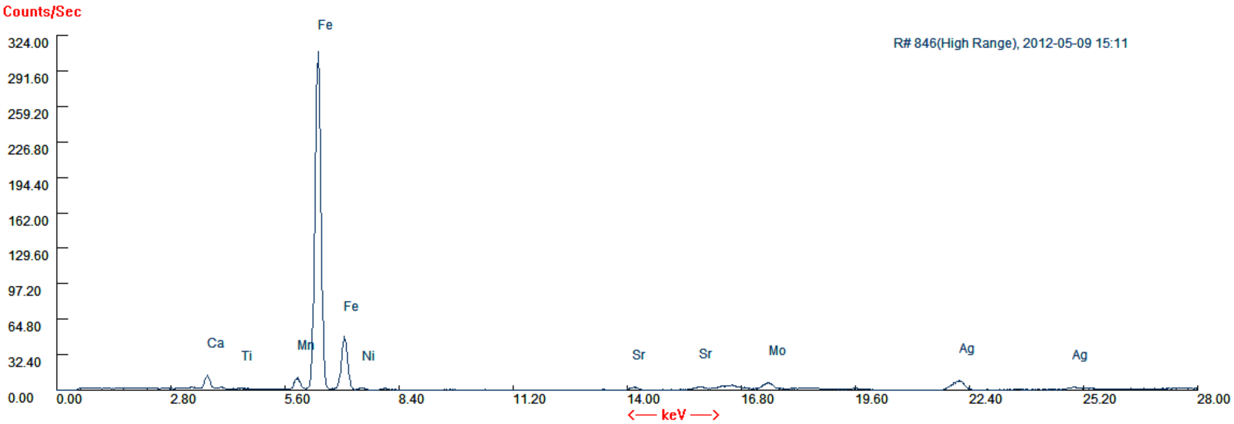

Figure I53b. pXRF spectrum

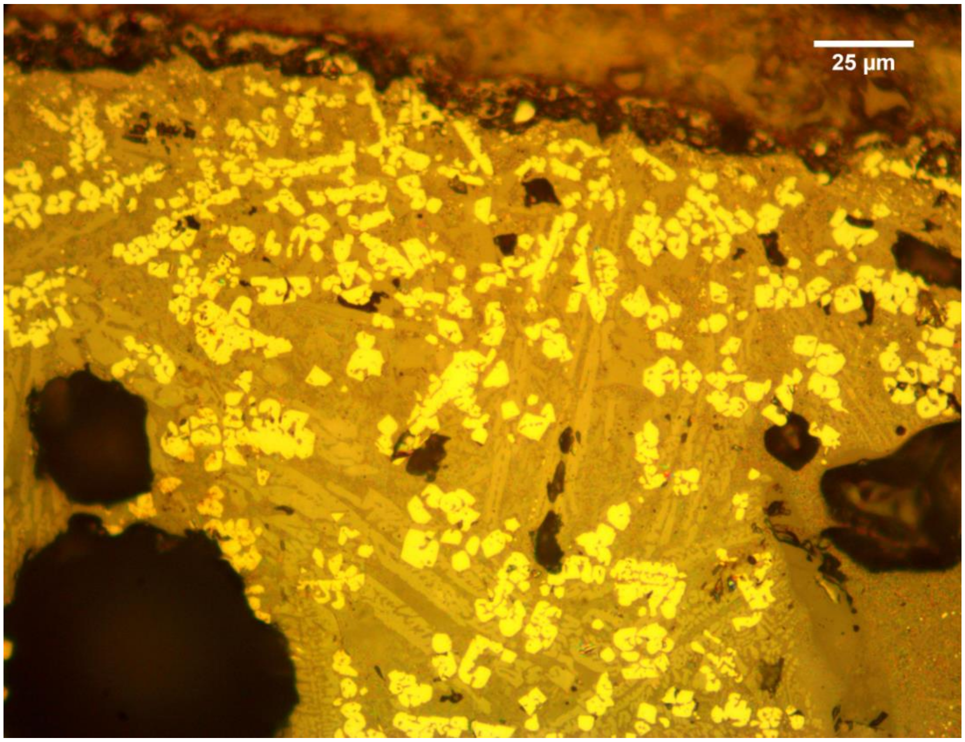

Figure I53c. Optical micrograph showing fayalite and what seems to be primary wüstite

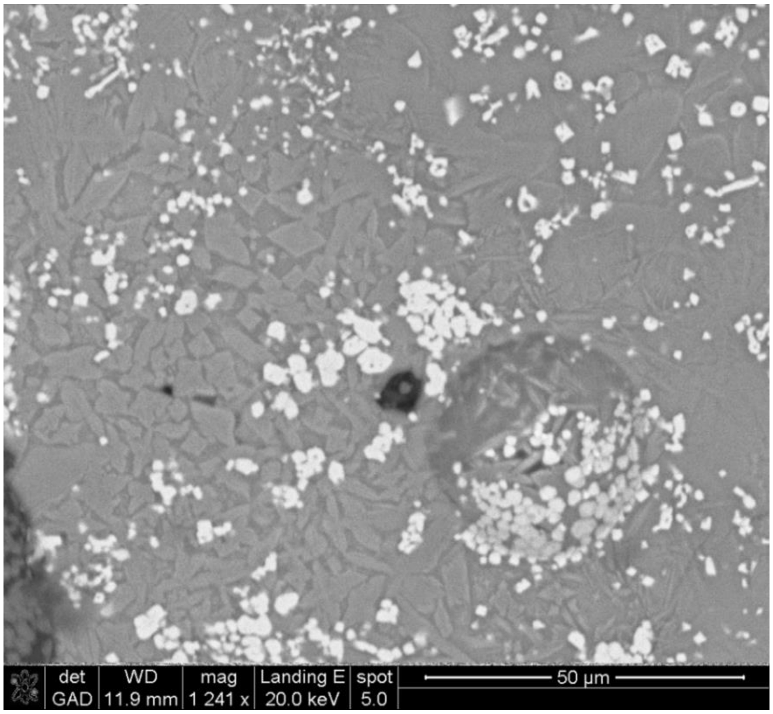

Figure I53d. Backscattered micrograph of iron silicate phases

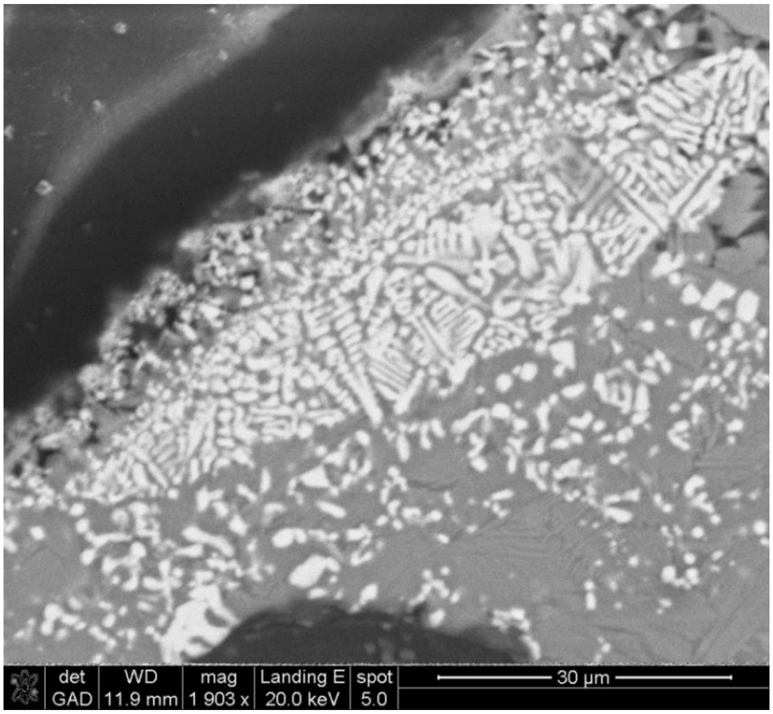

Figure I53e. Backscattered micrograph of iron silicate phases

Figure I53f. EDS in wt% (excluding 0.04Sc) 47.06Fe 0.23Ti 2.14Ca 1.57K 10.80Si 1.44Al 0.73Mg 35.99O

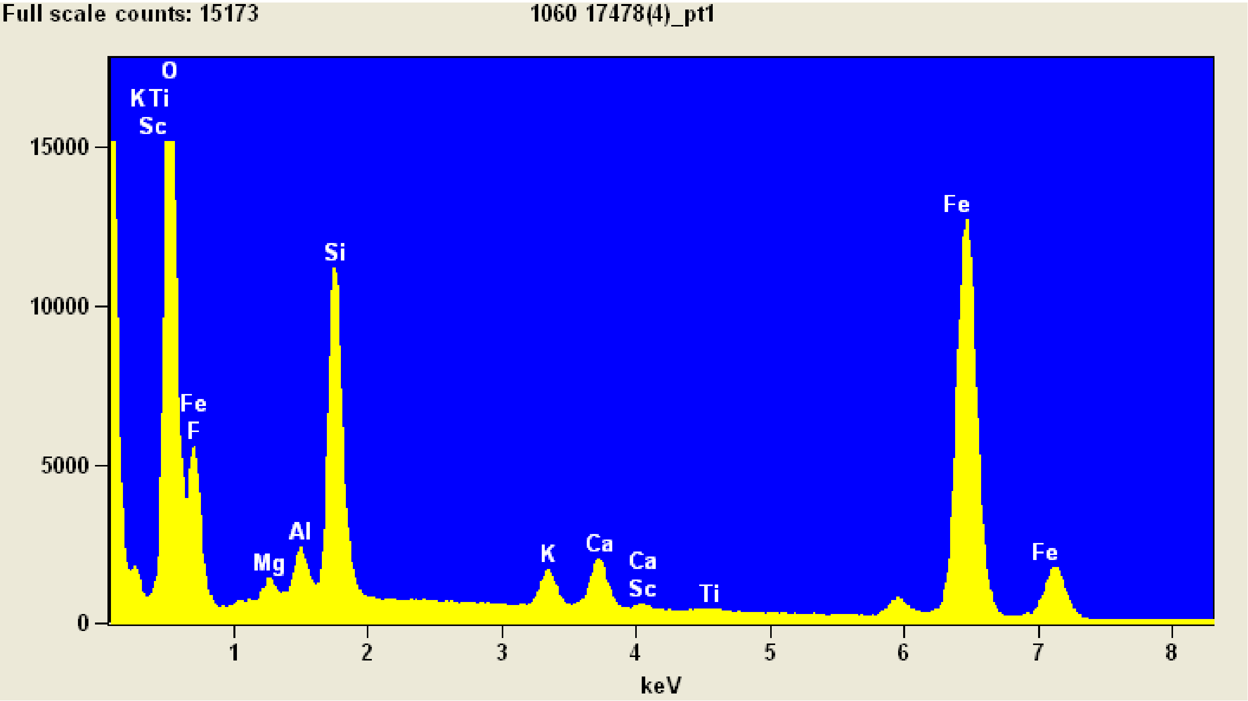

Figure I53g. EDS spectrum of above Figure I53f

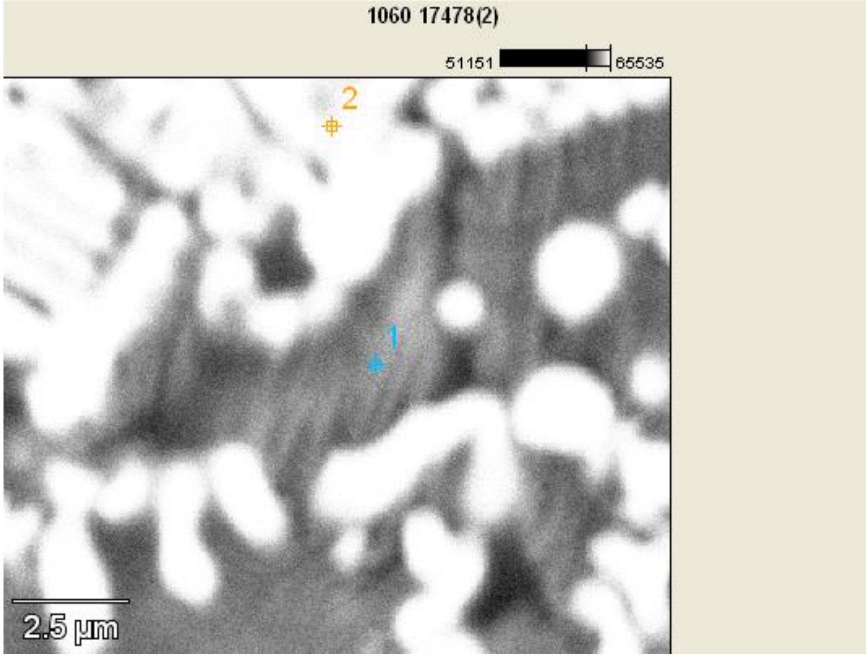

Figure I53h. EDS in wt%, spot 1: 8.50Fe 9.85Ca 2.29K 23.22Si 2.51Al 1.76Mg 1.61Na 2.60F 47.66O; spot 2: 32.10Fe 4.08Ca 1.22K 11.61Si 2.00Al 1.46Mg 0.53Na 47.00O

I54. Locus 1078, Artifact 38051

Context: 200-146 BC – “= 1076 [One fragm. of R1. = 1078: Probably original destruction layer of 146 BC; below 1072 and on top of floor 1077; next to 1078]: Original destruction layer of 146 BC; grey soil on top of floor 1077, next to 1076 and below 1072.”

Overview: Iron slag with ceramic attached. Optical micrographs verify presence of secondary wüstite.

Figure I54a. L. 1078 38051

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.1078 38051	200-146	2	7.363±0.072	6.813±0.109	23.567±0.216	1.069±0.034	0.428±0.037

S	Al	Mn	Zr	Cu
0.061±0.014	3.322±0.198	0.907±0.116	0.019±0.001	0.007±0.002

Sn	Zn	Pb	Ni	As
—	0.007±0.001	0.046±0.002	—	0.01±0.001

Table I54. pXRF slag composition

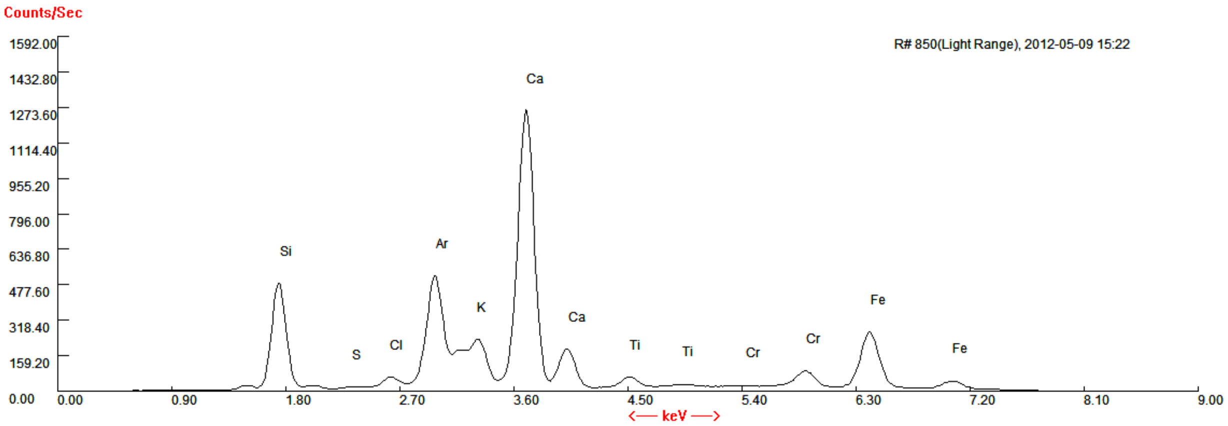

Figure I54b. pXRF spectrum

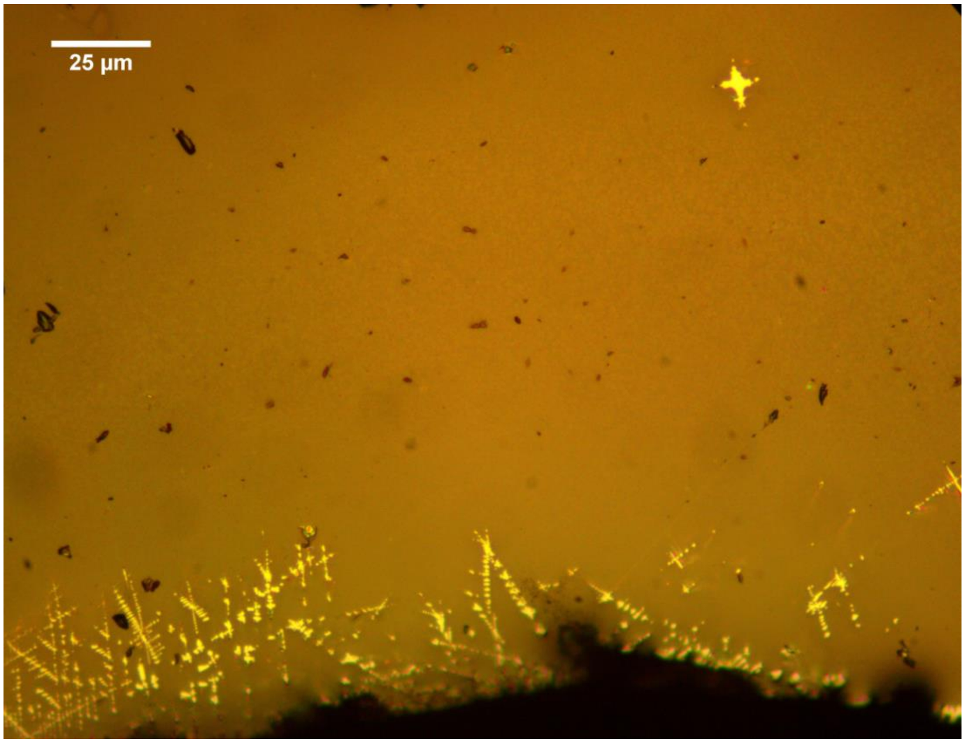

Figure I54c. Optical micrograph showing presence of secondary wüstite

I55. Locus 1096, Artifact 38001

Context: 200-146 BC – “Layer below 1060; (partly) on top of the continuation of floor 1077; on top of the foundation layer of wall 1101.”

Overview: Iron slag, one tunnel of tuyère preserved.

Figure I55a. L. 1096 38001. Preserved tunnel on bottom with slag on top

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
L.1096 38001	200-146	2	9.978±0.079	7.014±0.12	14.541±0.162	1.299±0.04	0.618±0.031

S	Al	Mn	Zr	Cu
0.102±0.012	3.175±0.178	0.967±0.099	0.019±0.001	0.007±0.002

Sn	Zn	Pb	Ni	As
—	0.005±0.001	0.009±0.001	.01±0.004	0.01±0.001

Table I55. pXRF slag composition

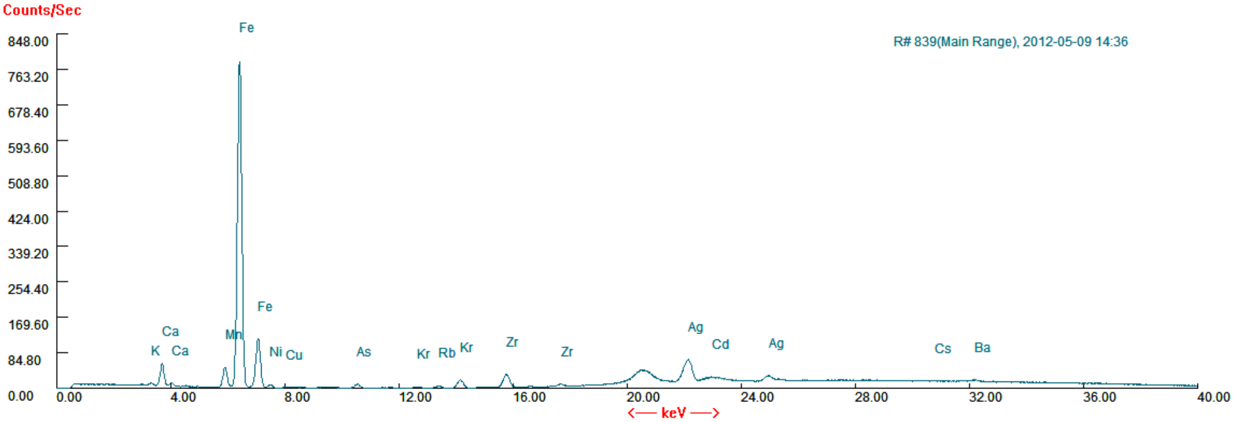

Figure I55b. pXRF spectrum

Appendix II. Loose Slag

A. *Household Contexts under Decumanus Maximus*

i. *700-550 BC*

II1. KA86/113-61

Context: 700-675 BC – "Layer III-2a1 in Room K of House 2: pp. 88, 100-102, Figs. 30 BN5, 31, BN 5, 32 BN 5, Beilage 14 BN 22: a multi-layered black-brownish leveling layer with limestones and, containing many pottery fragments and charcoal in its upper part. It is covered by Torba Floor layer III-2a2 (p. 101, fig. 31 BN 6), which had been partly removed in the following period (cf. p. 102, fig. 32 BN 6, which seems to be the remainder of a floor underlayer. The layer is dated to about 700-675 BCE."

Overview: Iron slag, high silicon content. Olivine laths are seen throughout.

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
KA86/113-61	700-675	2	8.561±0.077	4.272±0.093	24.872±0.22	2.012±0.047	2.435±0.05

S	Al	Mn	Zr	Cu
—	3.197±0.176	—	0.021±0.001	0.005±0.002

Sn	Zn	Pb	Ni	As
—	0.01±0.002	—	—	0.011±0.001

Table II1. pXRF slag composition

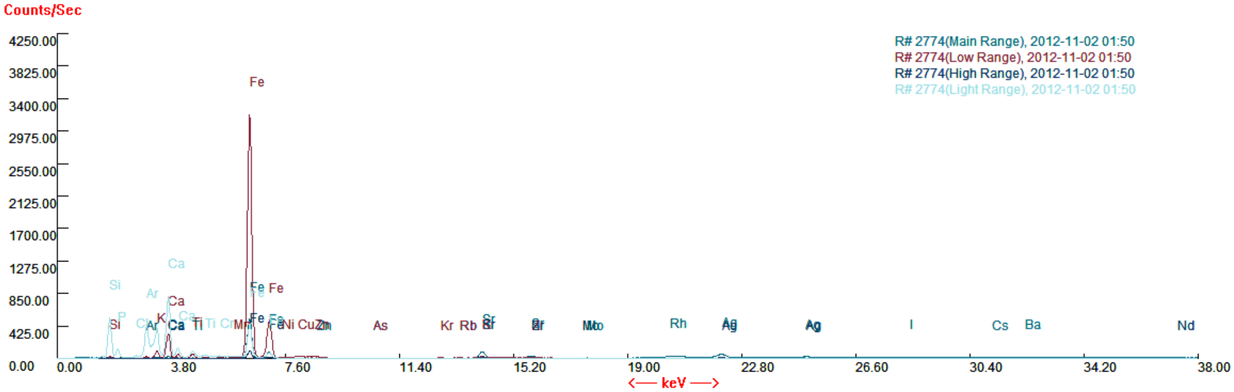

Figure II1a. pXRF spectrum of one of the iron-rich averages

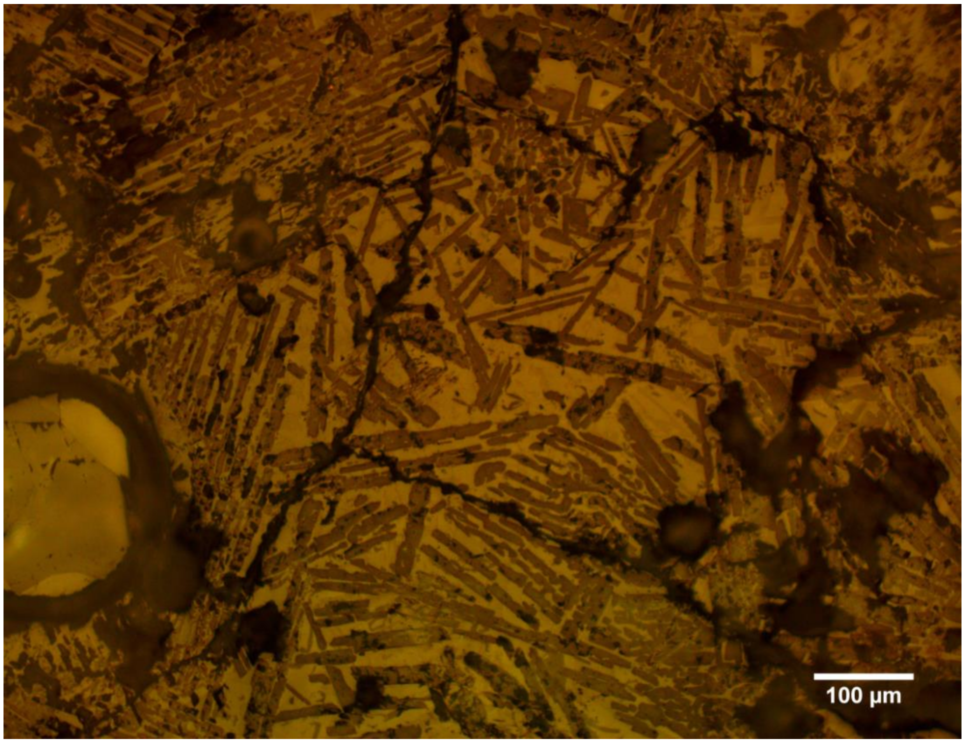

Figure II1b. Optical micrograph of lath microstructure

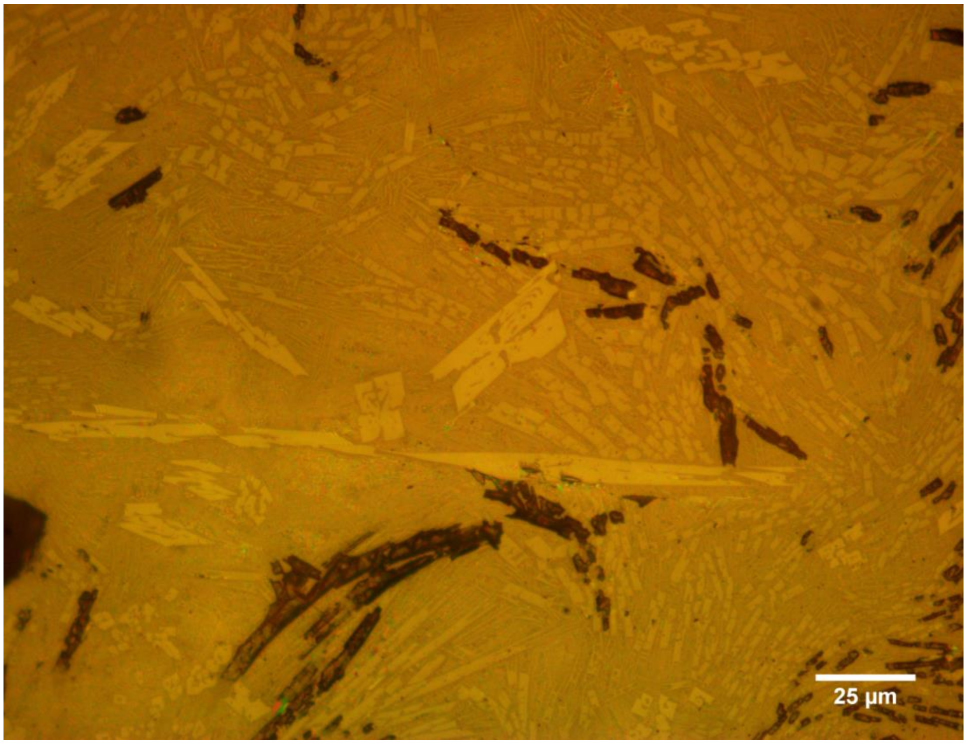

Figure II1c. Olivine laths

II2. KA88/41-1

Context: 600-550 BC – "Layer IV-2c1 in Room K of House 2: p. 114, Beilage 14 BN 50: fill of a large and wide construction trench for the communal wall of Houses 1 and 2 on the y8.3 coordinate. The foundation trench itself has been cut to older layers so also through the one to which KA 86/113 belongs and has afterwards been filled in with the backfill of this action. It contains therefore material from the whole timespan of phase I to IV. The layer is dated to around 600-550, with construction phase IV-2c2 dated to around 550 BCE. Material included in the layer may be older, though."

Overview: Iron slag, high iron content. The slag contains mostly primary wüstite with some secondary formations, and olivine, likely fayalite. The heterogeneous mixture of fayalite-rich and wüstite-rich phases indicates a product of ferritic and pearlitic nature.

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
KA88/41-1	600-550	2	33.825±0.305	7.482±0.166	7.154±0.126	0.791±0.047	2.664±0.053

S	Al	Mn	Zr	Cu
0.142±0.015	1.278±0.216	—	0.011±0.001	0.056±0.004

Sn	Zn	Pb	Ni	As
—	0.007±0.002	—	0.013±0.006	0.014±0.001

Table II2. pXRF slag composition

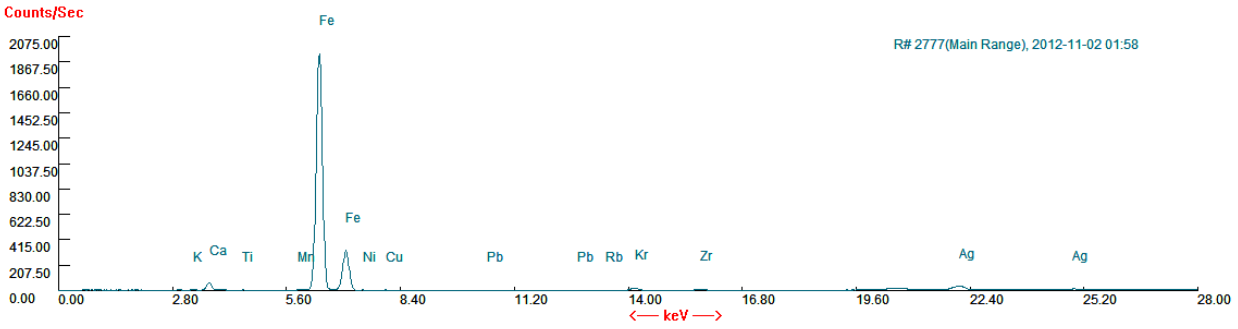

Figure II2a. pXRF spectrum

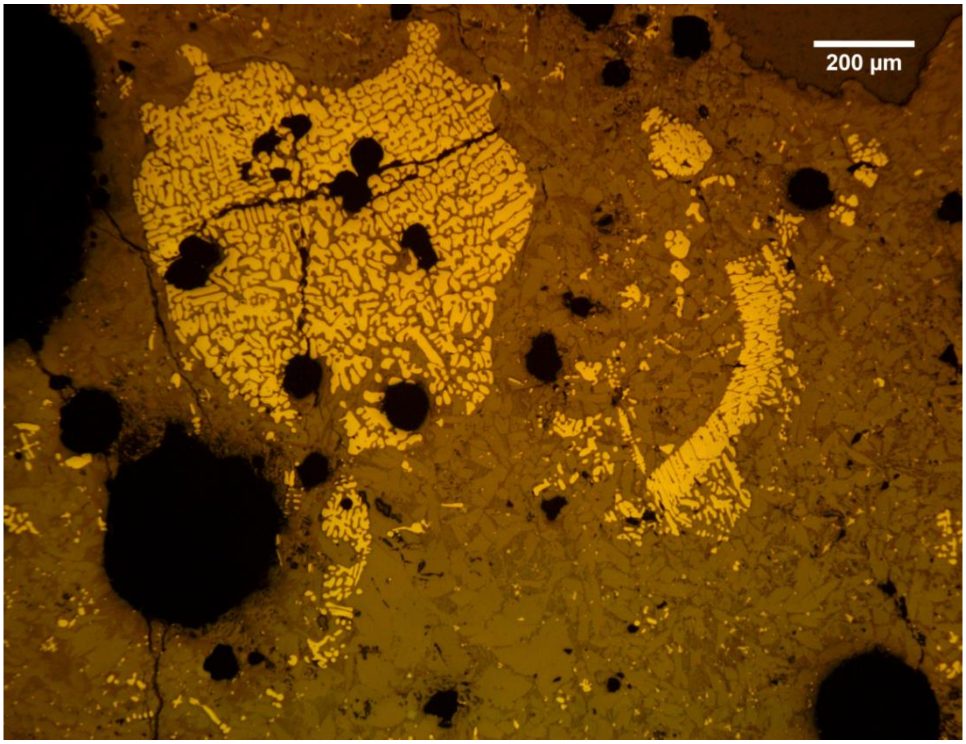

Figure II2b. Optical micrograph of olivine and primary wüstite

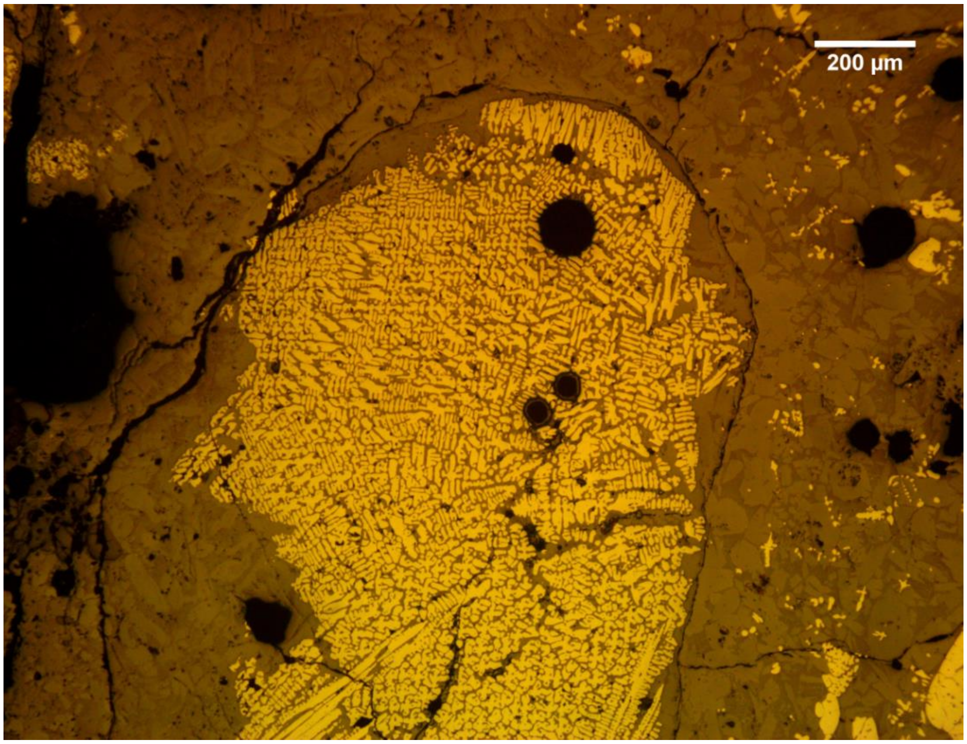

Figure II2c. Olivine and primary wüstite

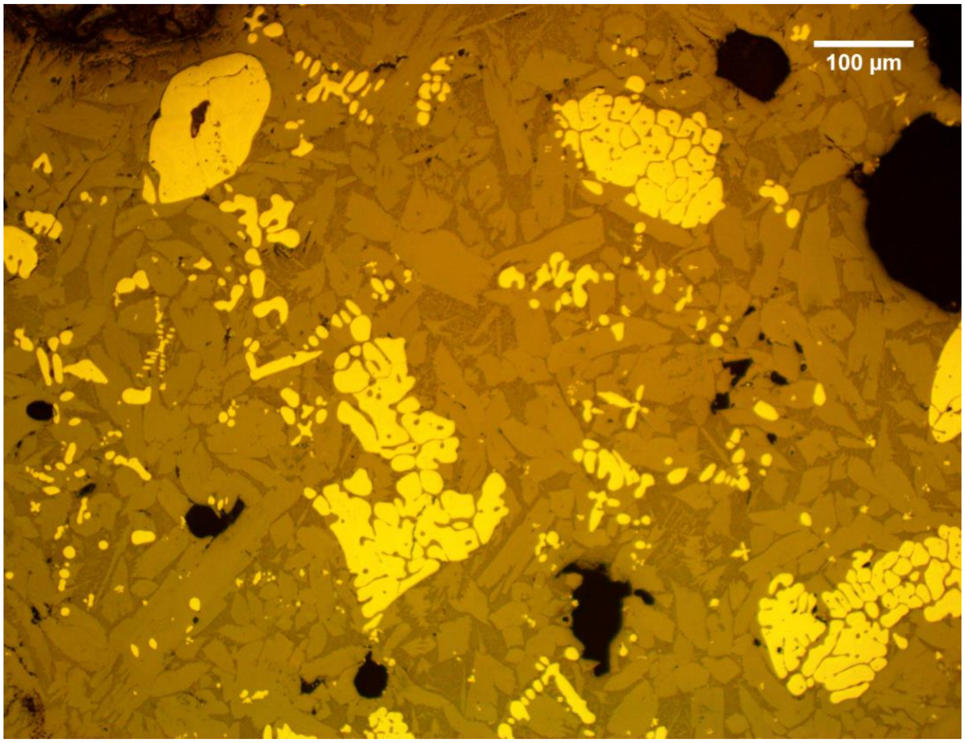

Figure II2d. Primary and secondary wüstite, with olivine/fayalite laths in glassy matrix

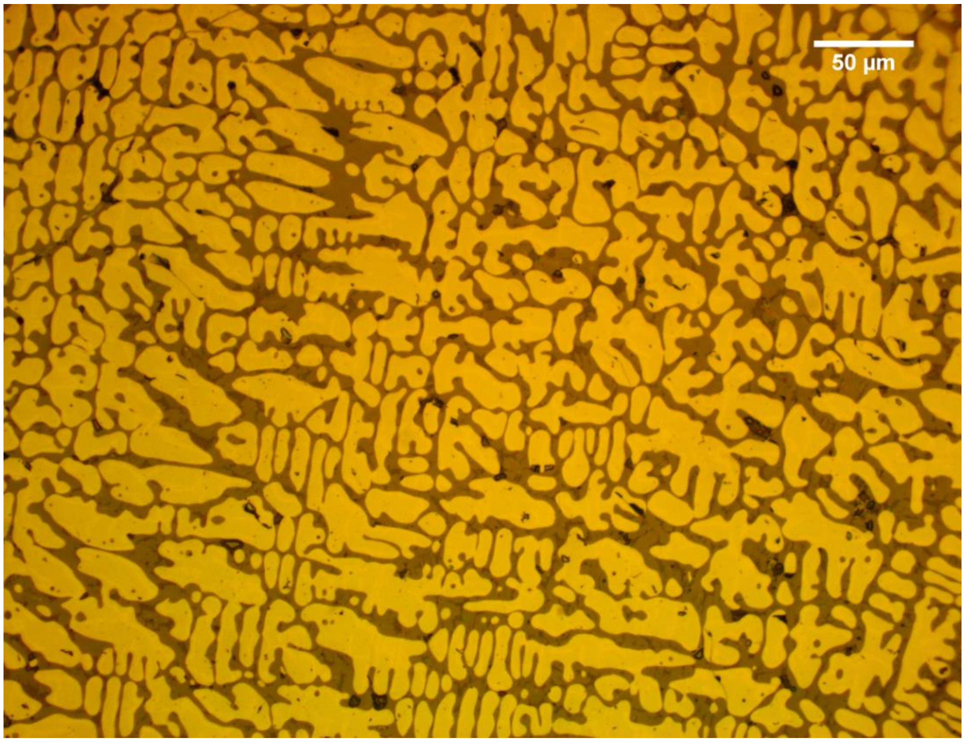

Figure II2e. Primary wüstite

II3. KA91/496-17

Context: ~675 BC – "Layer III-1b1 in Room C/D of House 1 (typical Levantine four-room house): pp. 69-70, 77, 92-93, 118, figs. 15 BN 6, 16 BN 14, 18 BN 7, 37 BN 10, Pl. 11h. This is a compact pottery and finds-rich layer of primary nature. It is a destruction layer with a full room inventory left in situ. More particularly, this context was excavated in the southern part of the stratigraphy below the y10.4 Opus Africanus wall, which is visible on p. 70, fig. 16 BN 14, right. For this context, see also: R. Docter, published settlement contexts of Punic Carthage, *Carthage Studies* 1, 2007, 37-76, in particular p. 51, context no. 101. The layer is dated to around 675 BCE."

Overview: This iron slag demonstrated a spinifex crystalline microstructure. The high iron content is not manifested in magnetite, wüstite, or any other iron oxide, but rather in iron and calcium rich silicates. This indicates production of pearlite. Dark field microscopy provided an example of a leafy microstructure. The dearth of any wüstite and rich fayalite structures strongly indicate that this slag was remnant from the production of steel (Buchwald and Wivel 1998).

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
KA91/496-17	~675	1	23.031±0.207	6.795±0.148	8.022±0.134	1.035±0.047	1.855±0.045

S	Al	Mn	Zr	Cu
0.057±0.014	0.355±0.16	—	0.011±0.001	0.013±0.003

Sn	Zn	Pb	Ni	As
—	0.005±0.002	—	0.017±0.006	0.007±0.001

Table II3. pXRF slag composition

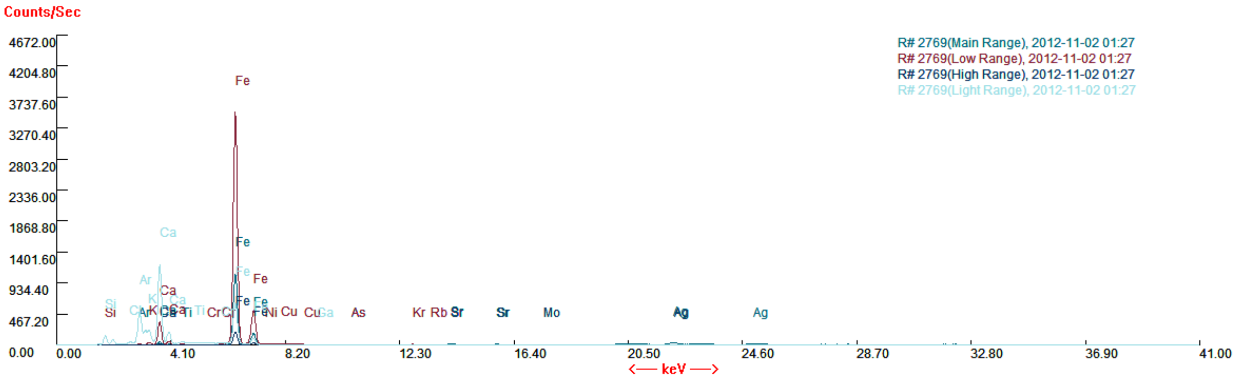

Figure II3a. pXRF spectrum

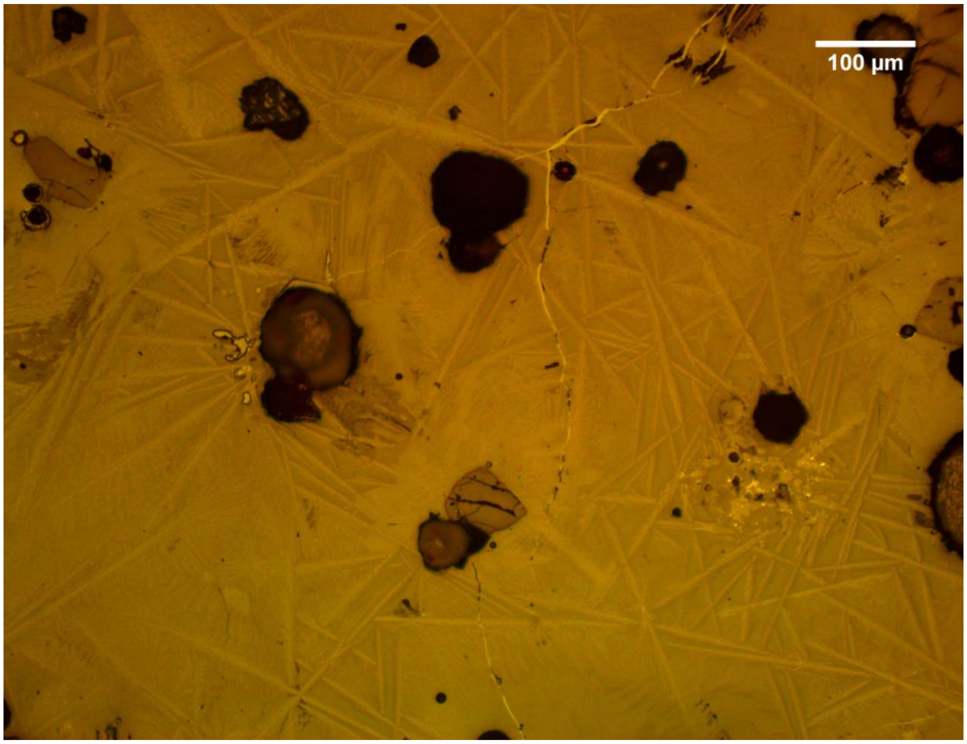

Figure II3b. Optical micrograph of spinifex microstructure

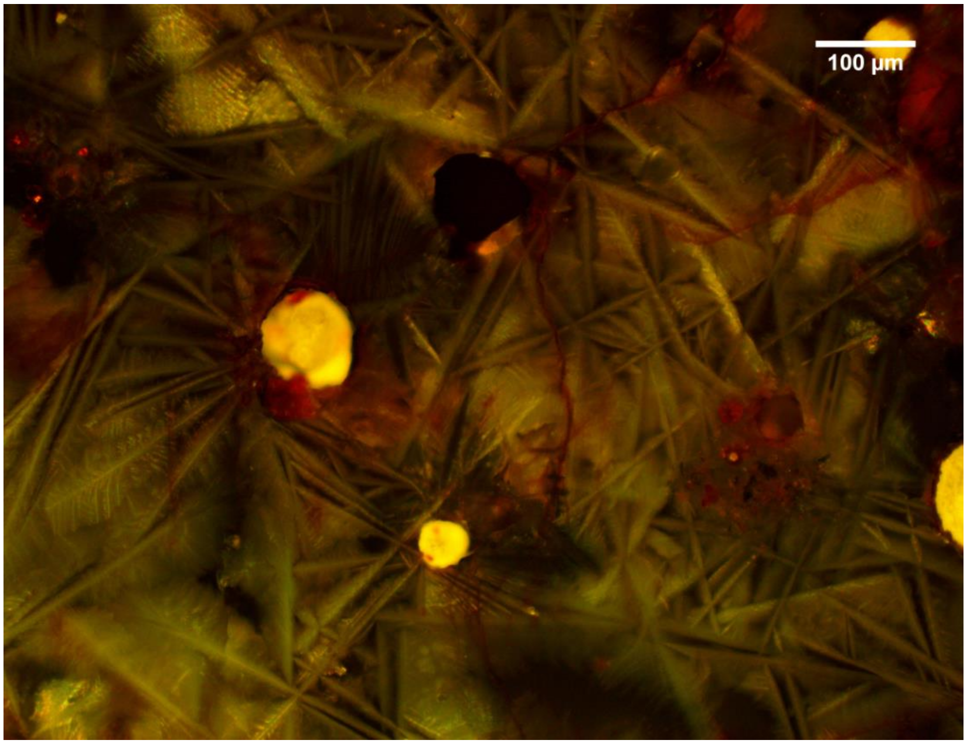

Figure II3c. Dark field micrograph of above Figure II3b with leafy microstructure

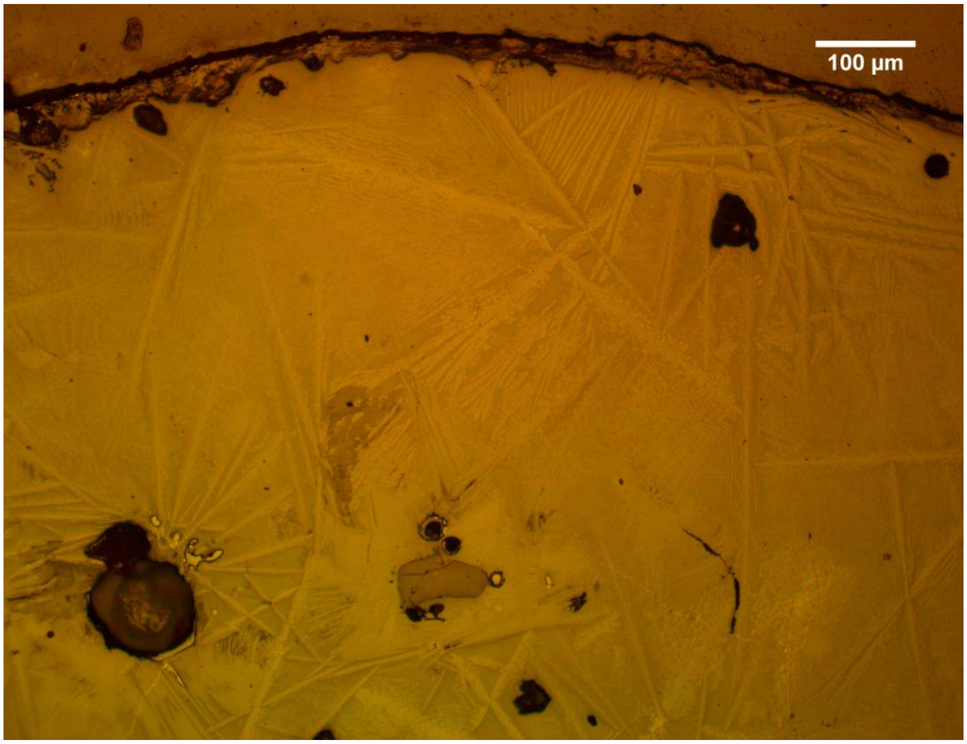

Figure II3d. Optical micrograph of spinifex microstructure

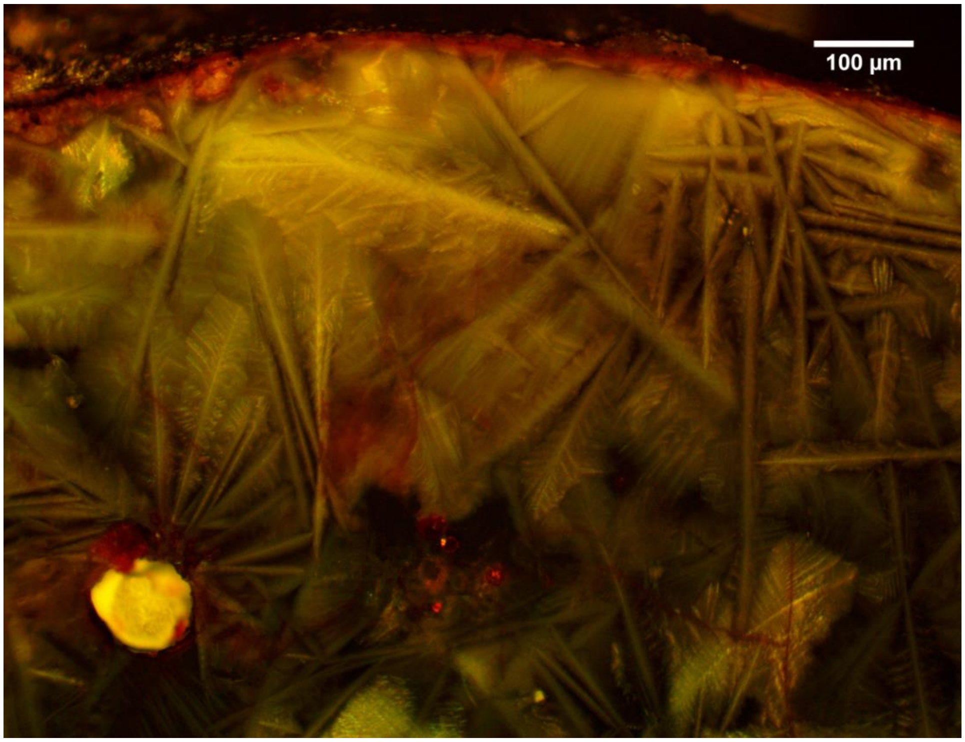

Figure II3e. Dark field micrograph of above Figure II3d with leafy microstructure

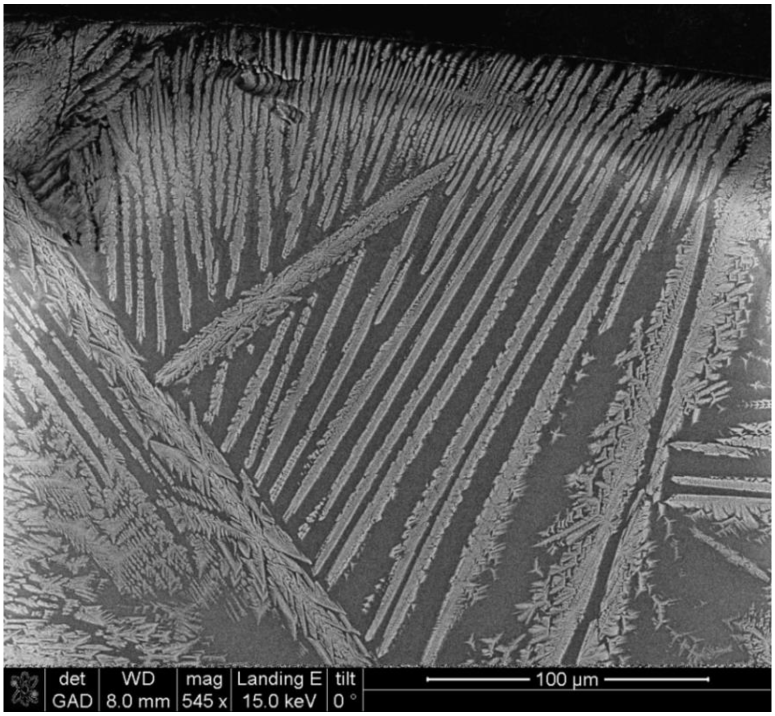

Figure II3f. Backscattered close-up of zone at the uppermost center right of Figures II3d, e

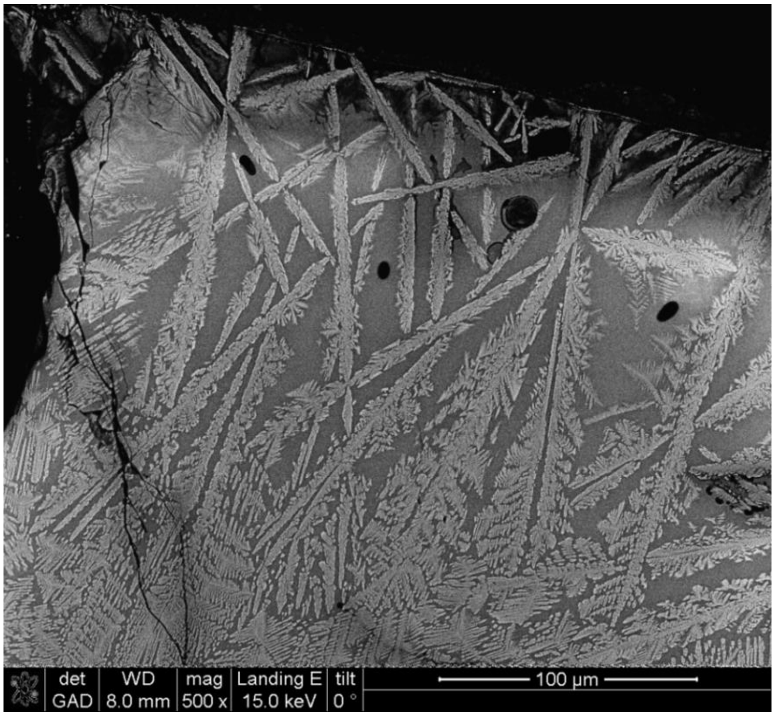

Figure II3g. Backscattered close-up of zone at the top, directly to the right of the large inclusion in Figures II3h, i

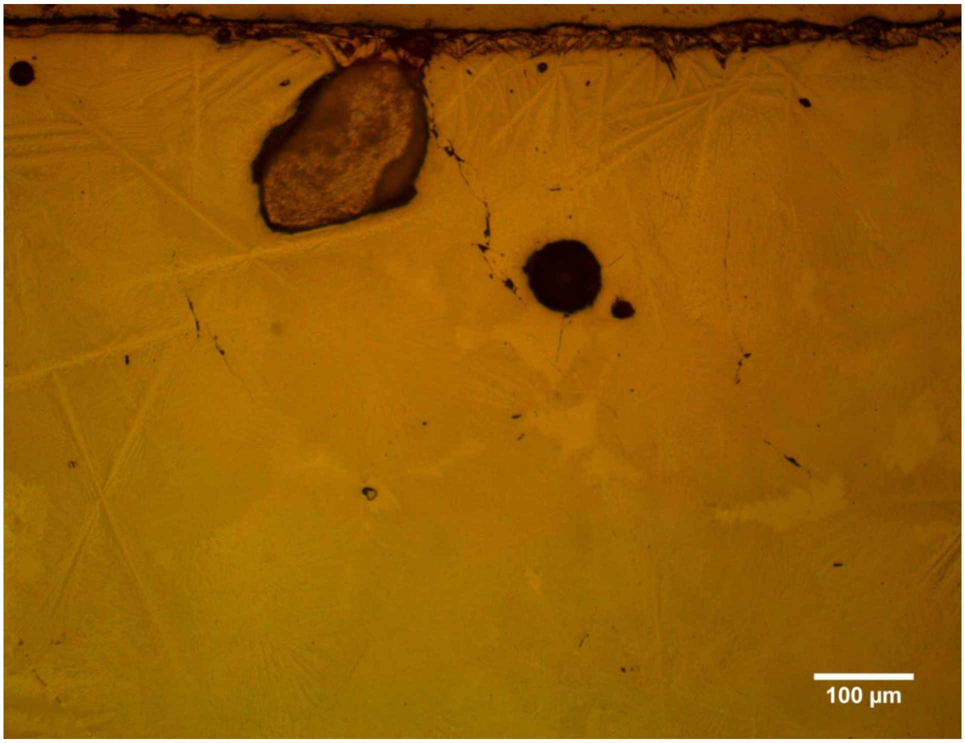

Figure II3h. Optical micrograph of spinifex microstructure

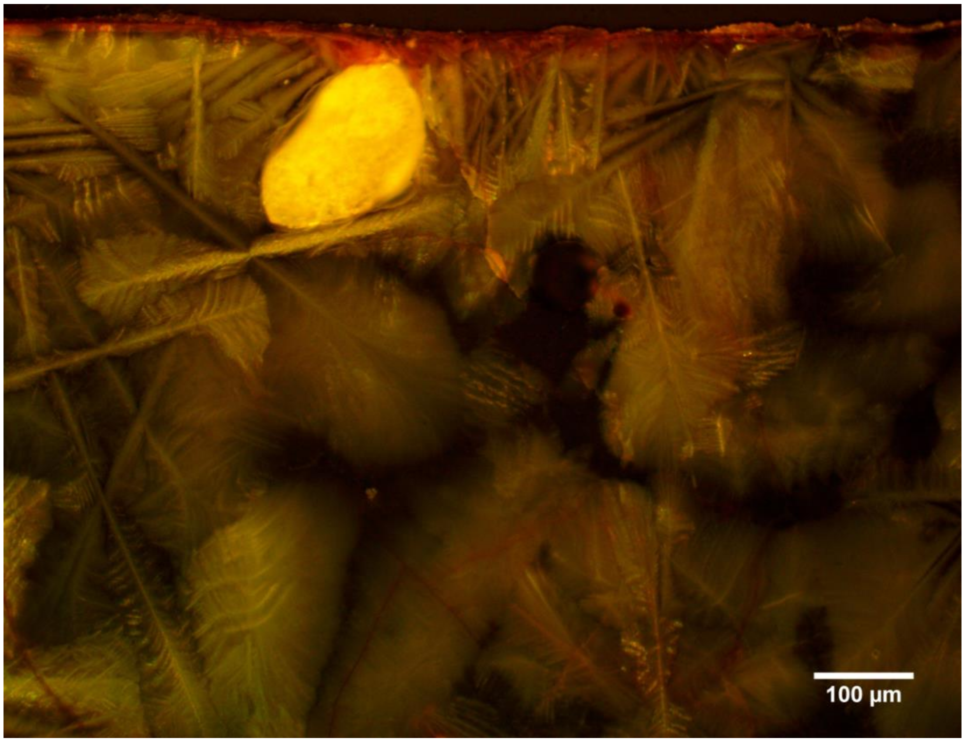

Figure II3i. Dark field micrograph of above Figure II3h with leafy microstructure

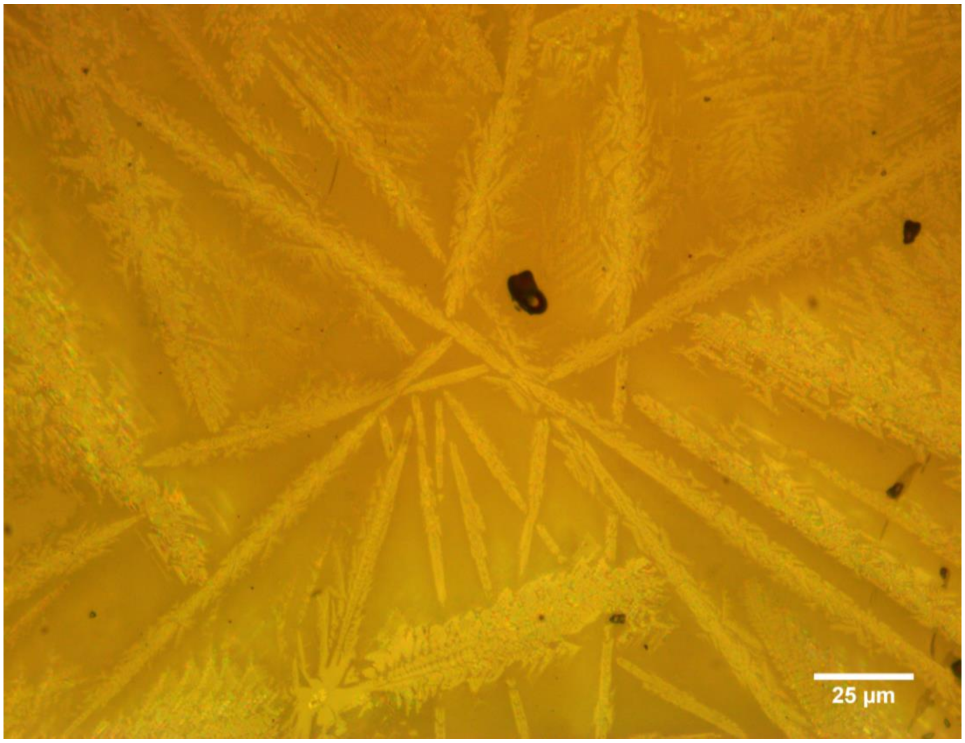

Figure II3j. Optical micrograph of spinifex microstructure

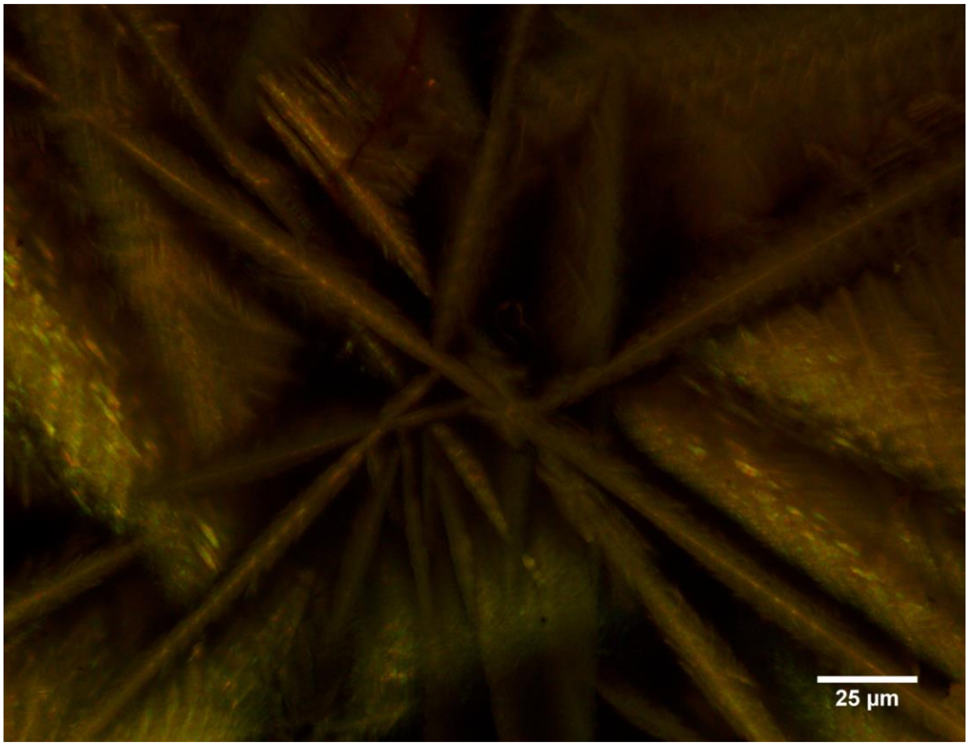

Figure II3k. Dark field micrograph of above Figure II3j with leafy microstructure

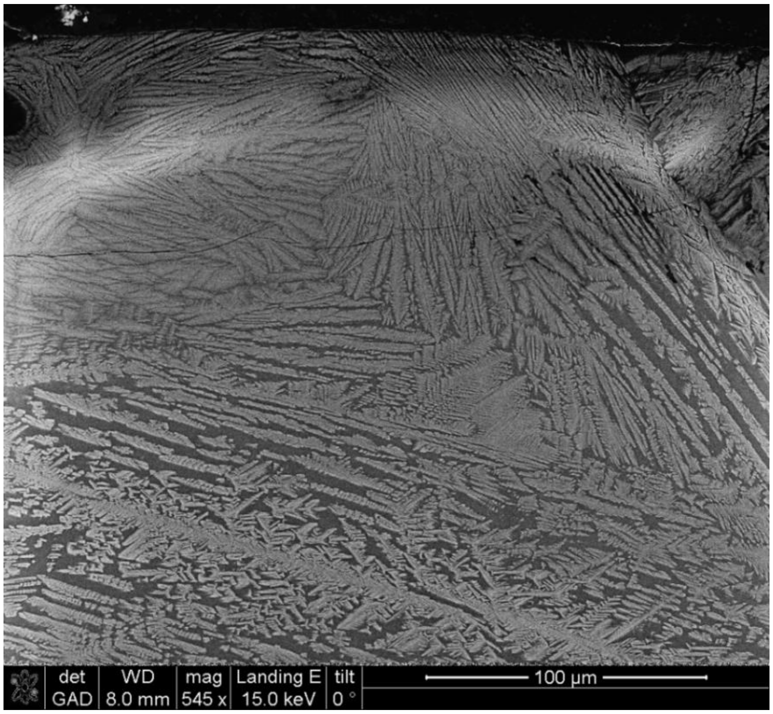

Figure II3l. Crystalline leafy regions

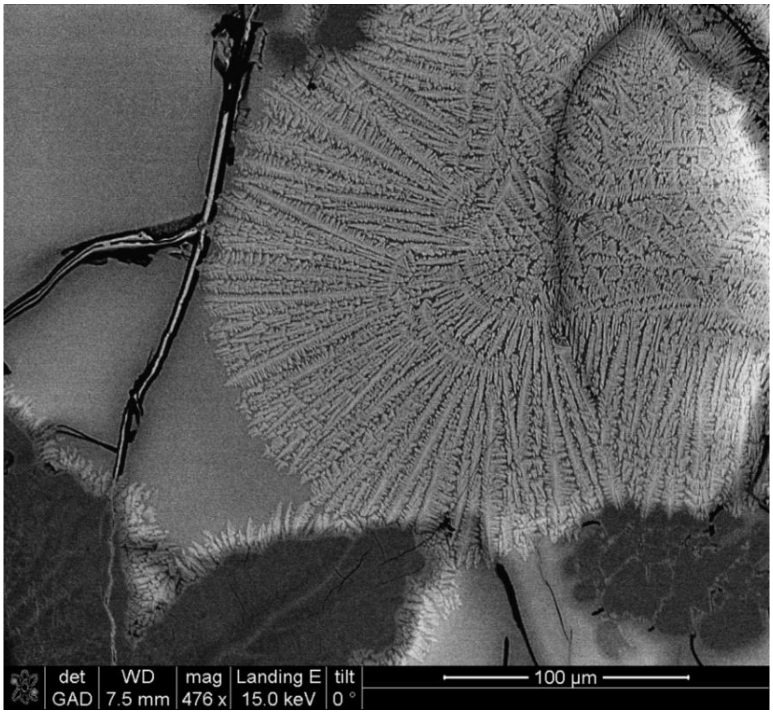

Figure II3m. Crystalline spinifex microstructure

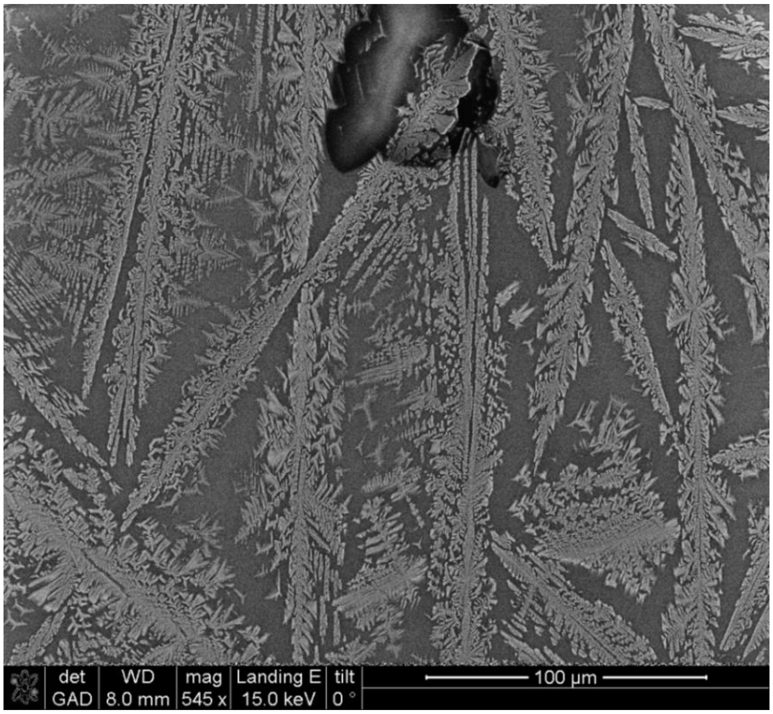

Figure II3n. Olivine phases in glassy matrix

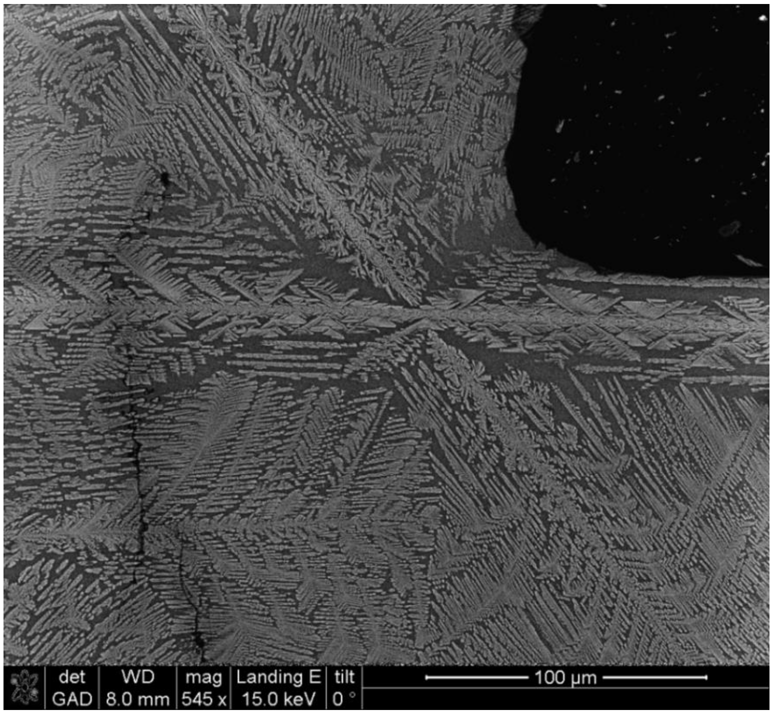

Figure II3o. Olivine phases in glassy matrix

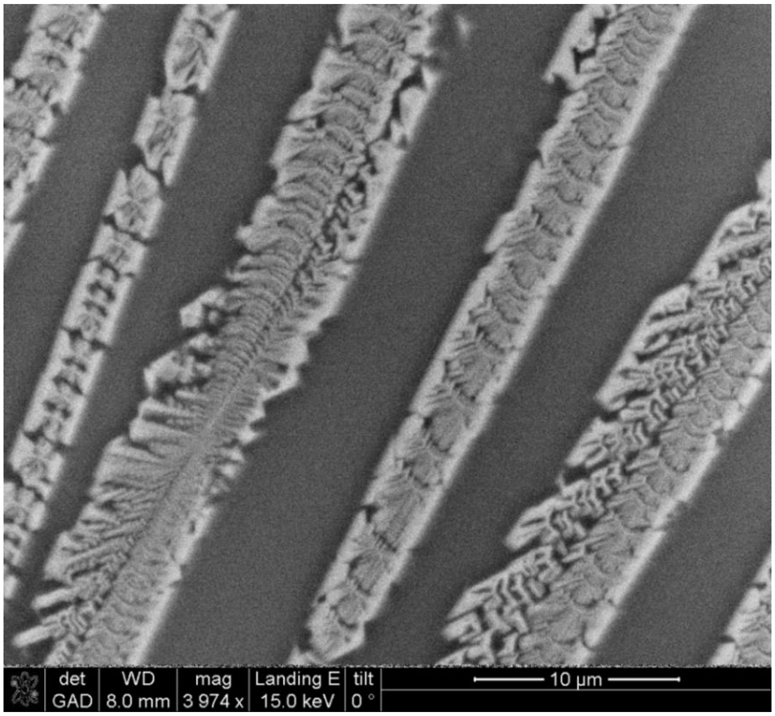

Figure II3p. EDS taken on dark and light phases. In wt%, dark phase: 16.70Fe 0.18Ti 12.72Ca 0.90K 21.59Si 2.80Al 0.17Mg 0.52Na 41.50O 2.92C; light phase: 32.53Fe 3.84Ca 1.49K 17.89Si 1.60Al 1.00Mg 39.23O 2.42C

B. *Bir Massouda Industrial Contexts*

i. *800-600 BC*

II4. Locus 3348, Artifact 34318

Context: 800-700 BC – “C14 program.”

Overview: Iron slag, mostly comprised of calcium-rich iron silicates indicative of pearlite production, with nickel-rich globes throughout.

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
3348 34318	800-700	1	7.122±0.127	2.285±0.113	11.905±0.234	1.872±0.056	0.619±0.046

S	Al	Mn	Zr	Cu
0.199±0.019	—	0.707±0.174	0.017±0.001	—

Sn	Zn	Pb	Ni	As
—	0.007±0.002	—	0.017±0.009	0.01±0.001

Table II4. pXRF slag composition

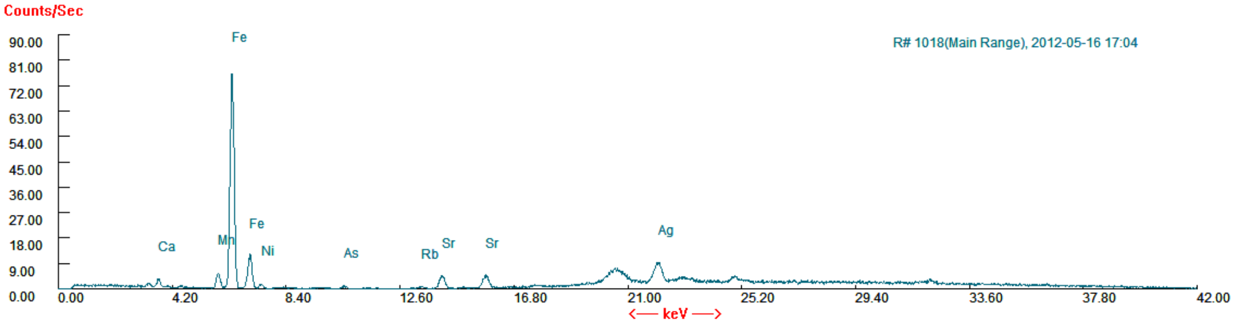

Figure II4a. pXRF spectrum

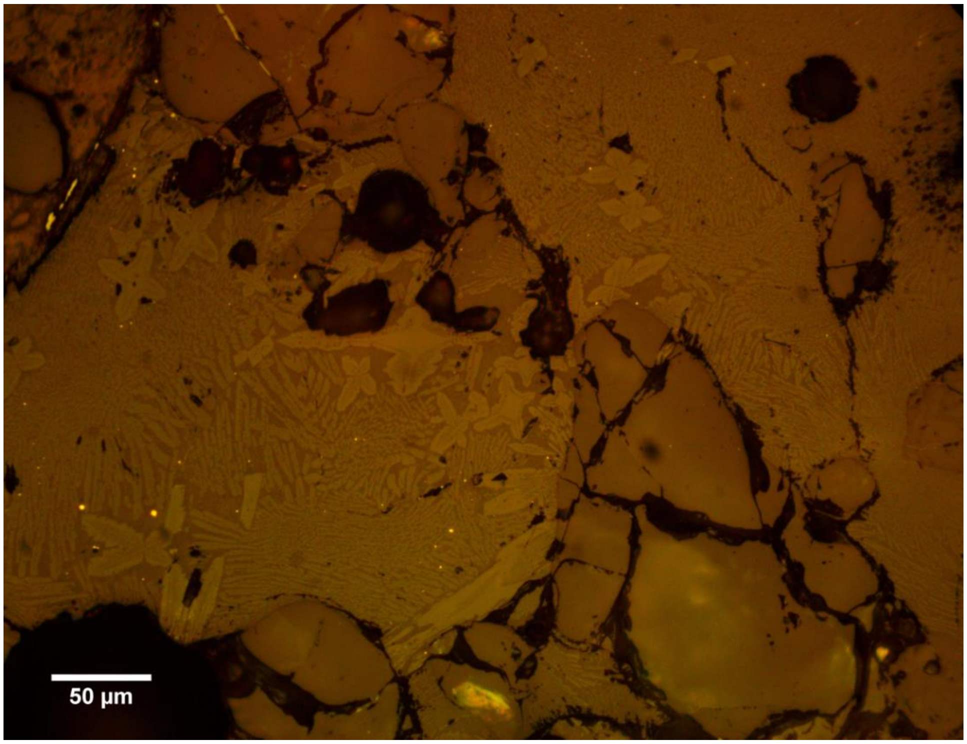

Figure II4b. Optical micrograph of iron silicates with bright nickel-rich globes

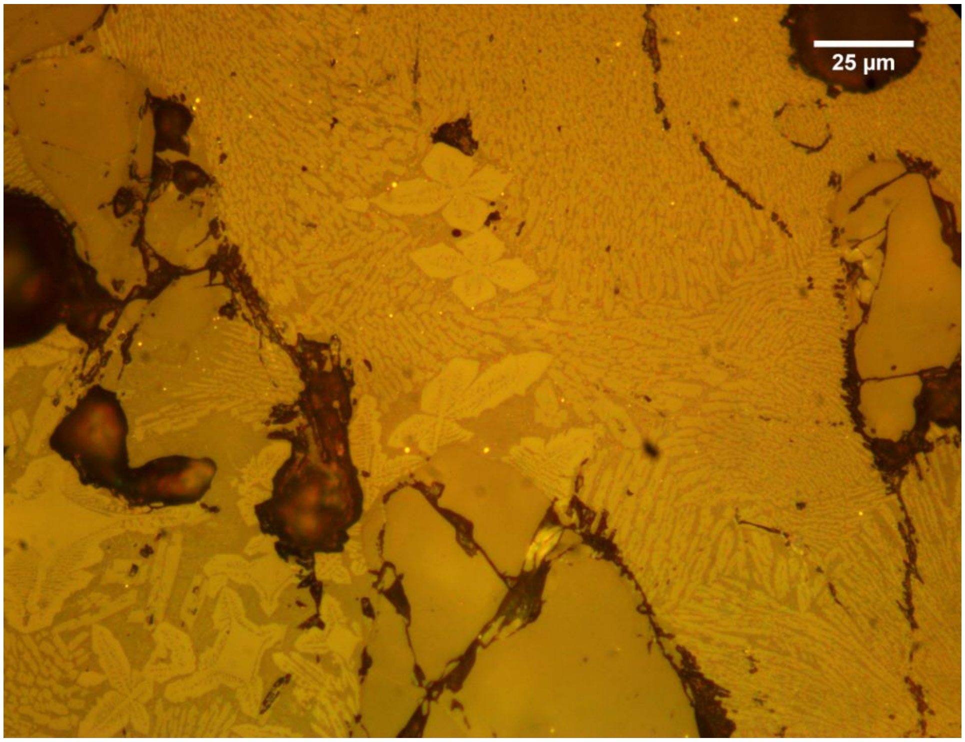

Figure II4c. Optical micrograph

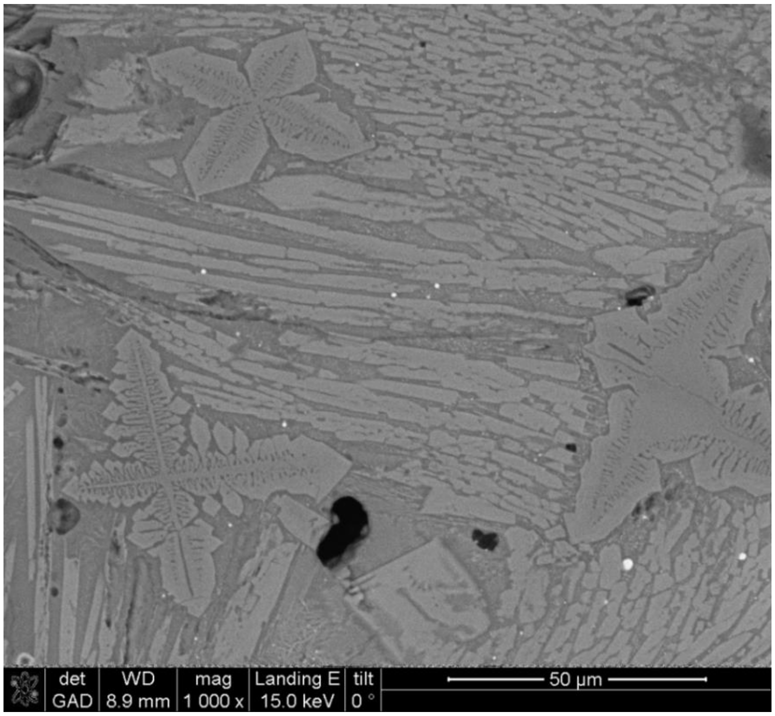

Figure II4d. Backscattered micrograph of iron silicates and nickel-rich globes

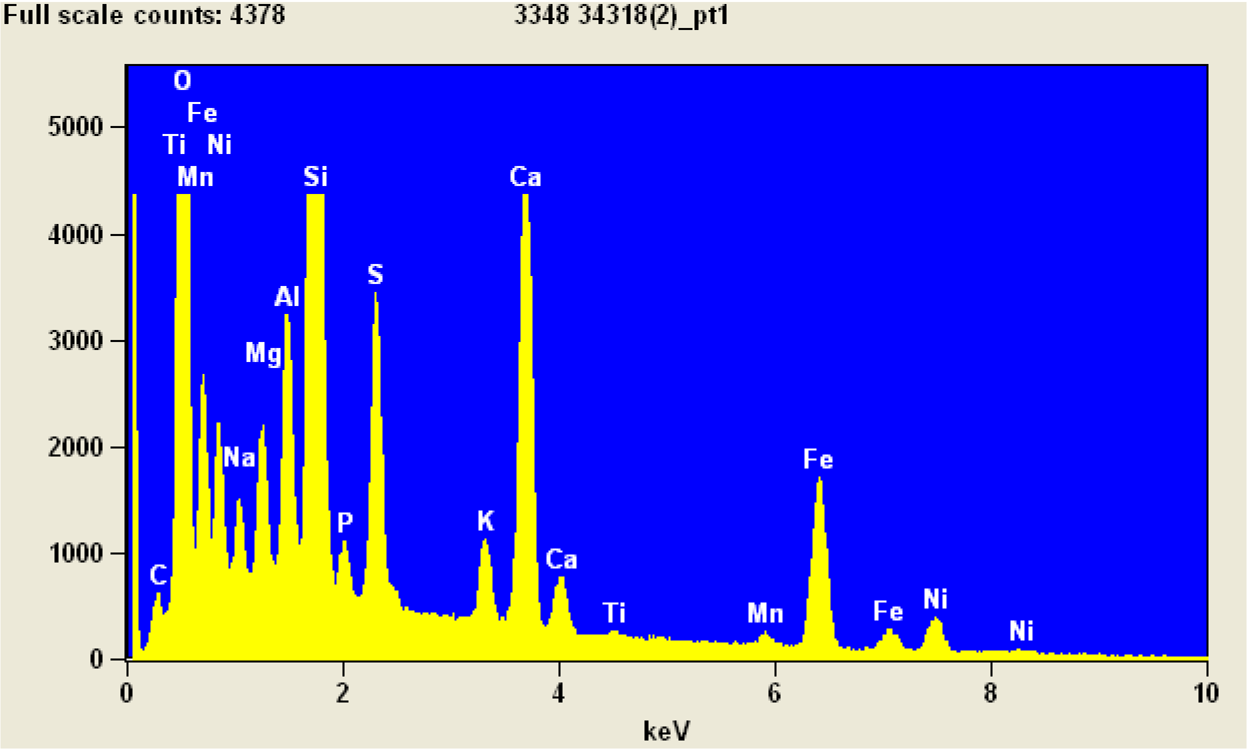

Figure II4e. EDS spectrum of nickel-rich globe

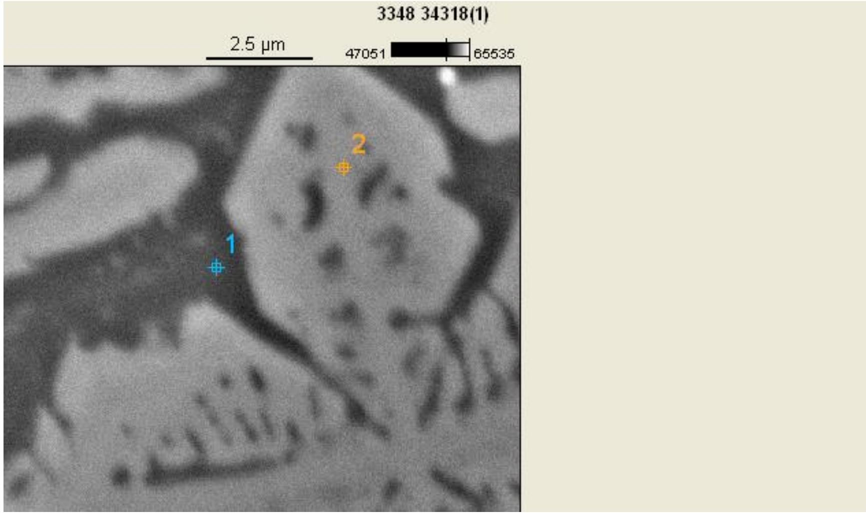

Figure II4f. EDS in wt%, spot 1: 10.19Fe 0.50Mn 0.33Ti 12.04Ca 1.16K 0.38P 25.21Si 1.80Al 3.13Mg 1.09Na 44.16O; spot 2: 10.29Fe 0.50Mn 0.16Ti 12.59Ca 1.08K 0.51P 25.08Si 1.63Al 3.41Mg 1.03Na 43.71O. The two phases are surprisingly similar in content, likely due to a beam size of about one micron

II5. Locus 8210, Artifact A

Context: 750-600 BC – "Fill (*BABesch* 2003, 48-51, cat. 1-3, fig. 6; *Carthage Studies* 2007, 48, No. 65)."

Overview: Iron slag, with metallic copper, zinc, nickel, and possible arsenic components (but arsenic could not be verified by EDS and was more likely magnesium content). Detritus component attached to slag has an embedded shell, indicating fluxing activities.

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
8210 A	750-600	1	10.877±0.09	10.981±0.162	15.396±0.176	1.379±0.043	2.171±0.05

S	Al	Mn	Zr	Cu
0.092±0.014	2.995±0.211	0.772±0.107	0.038±0.001	0.01±0.002

Sn	Zn	Pb	Ni	As
—	0.007±0.001	0.008±0.001	—	0.017±0.001

Table II5. pXRF slag composition

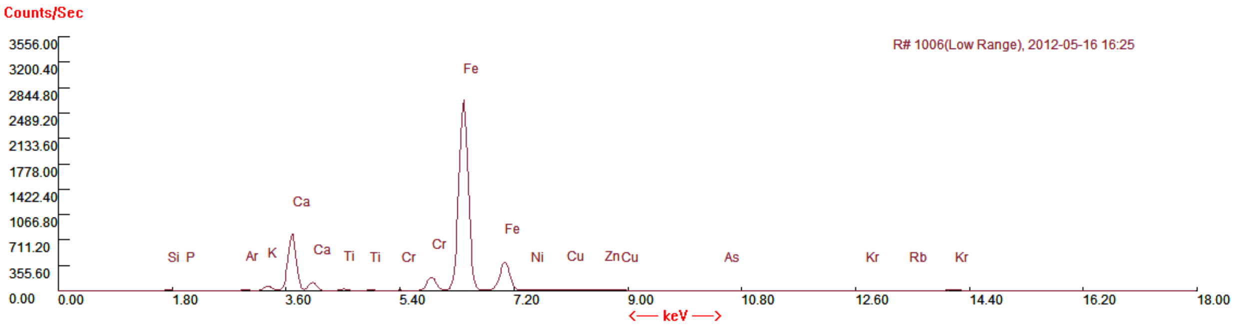

Figure II5a. pXRF spectrum

Figure II5b. Polarized optical micrograph of shell embedded in detritus

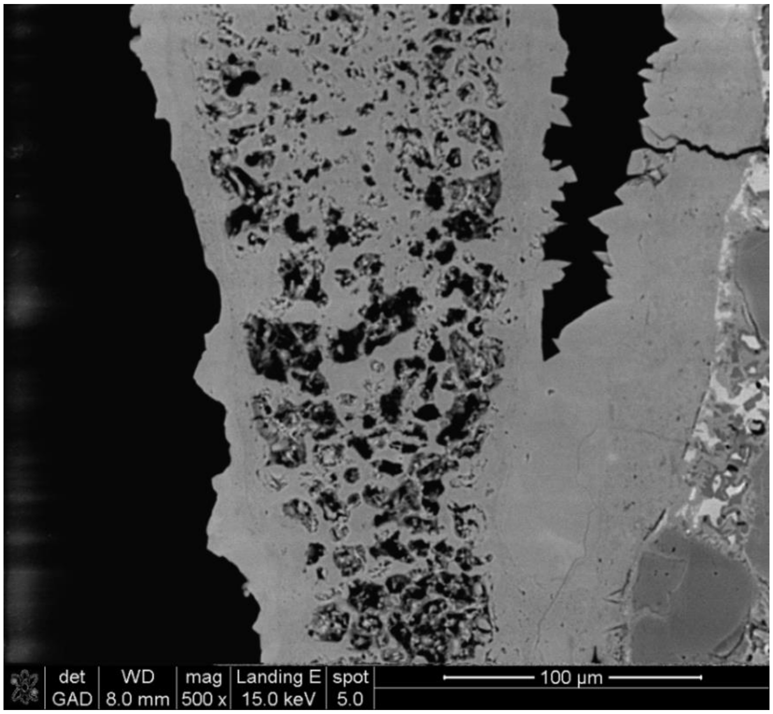

Figure II5c. Backscattered micrograph of shell. EDS of spot from the shell in wt%: 1.87Fe 37.68Ca 0.16K 0.35S 0.15P 2.45Si 0.22Al 0.29Mg 45.57O 11.26C. Surrounding zone was tested to verify a difference – about four times less calcium content was found in neighboring detritus

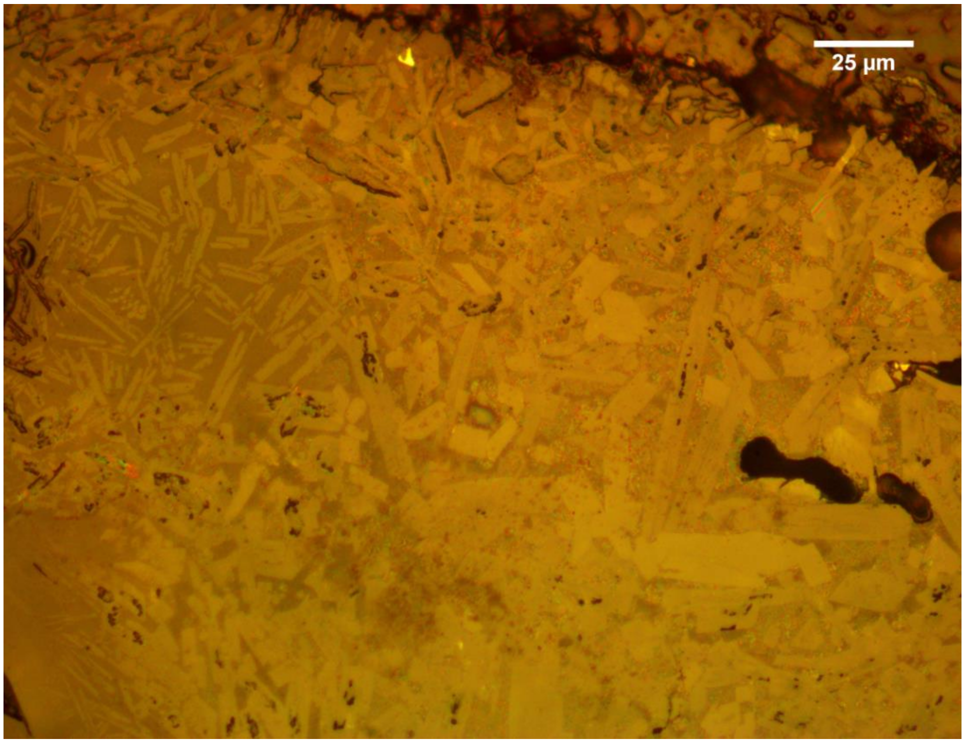

Figure II5d. Optical micrograph of iron silicates

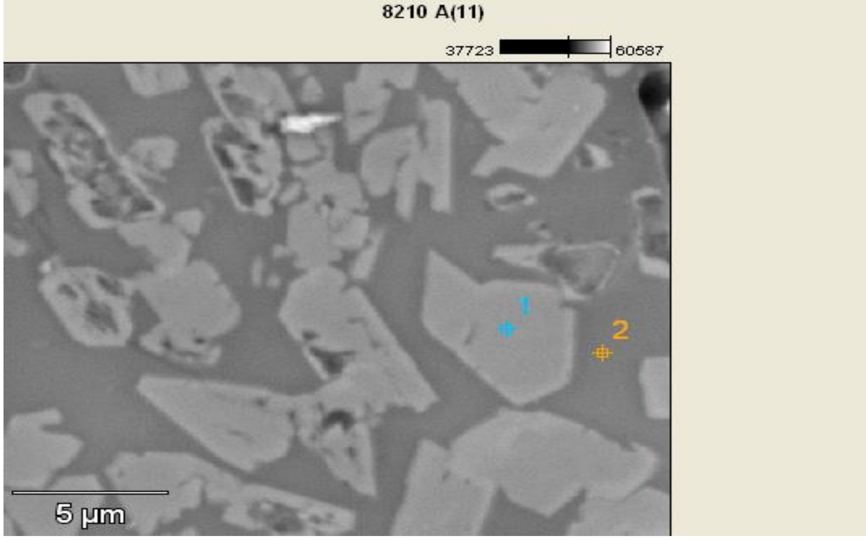

Figure II5e. EDS in wt%, spot 1: 19.62Fe 1.17Mn 15.94Ca 0.31K 21.30Si 0.37Al 1.39Mg 38.64O 1.26C; spot 2: 13.89Fe 4.92Ca 1.71K 0.10Cl 26.16Si 3.49Al 0.31Mg 46.25O 3.17C

Figure II5f. EDS in wt% of major metal constituents: 9.33Cu 3.18Ni 2.90Zn 13.55Fe

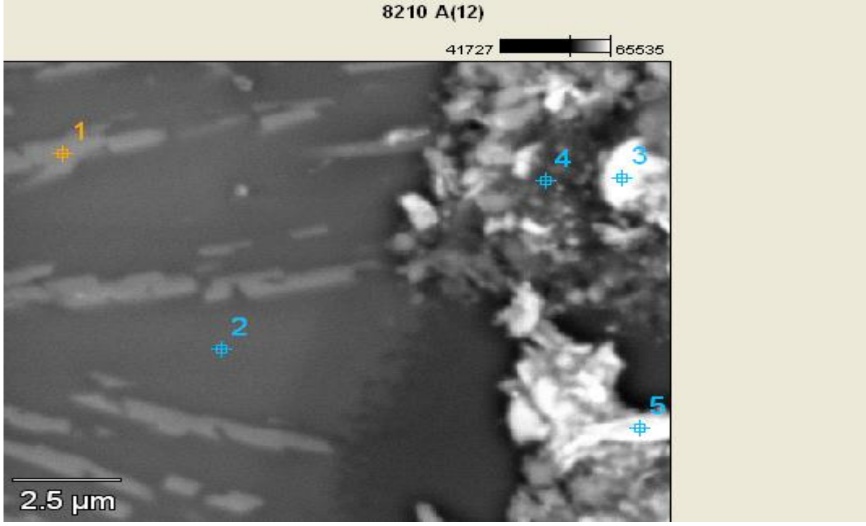

Figure II5g. EDS in wt% of point 3, major metal and metalloid constituents: 34.91Cu 2.25Ni 2.43As 1.47Mo.

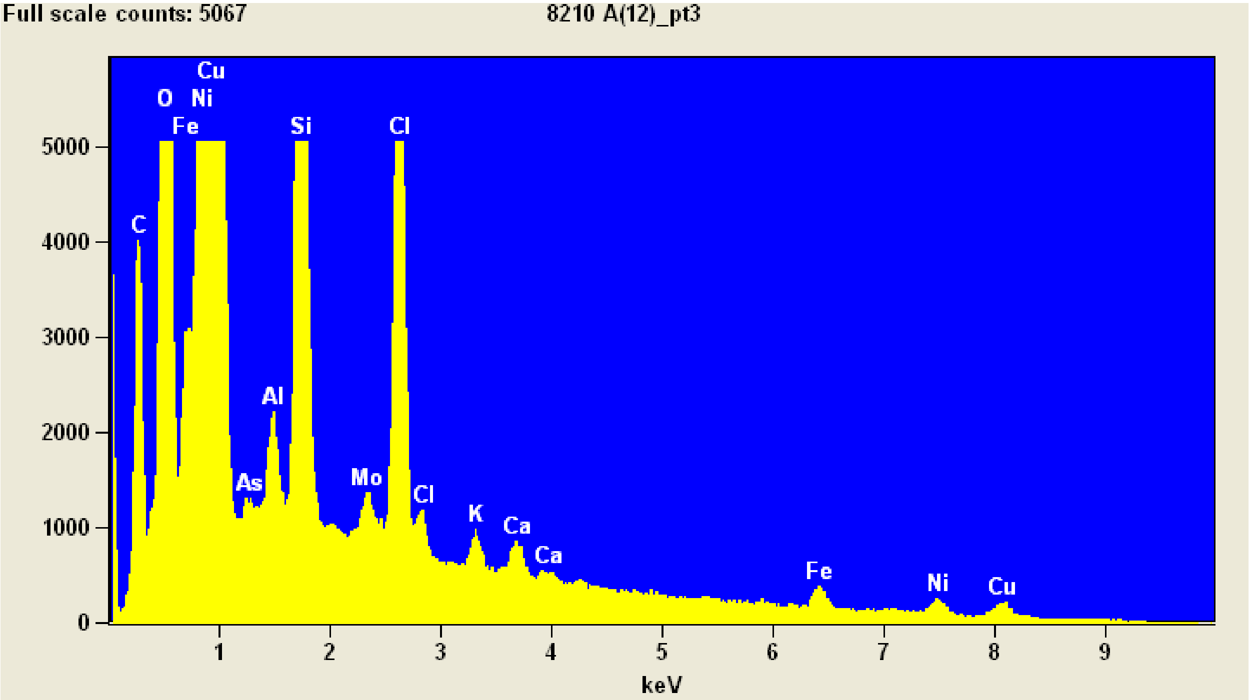

Figure II5h. EDS spectrum of above Figure II5g

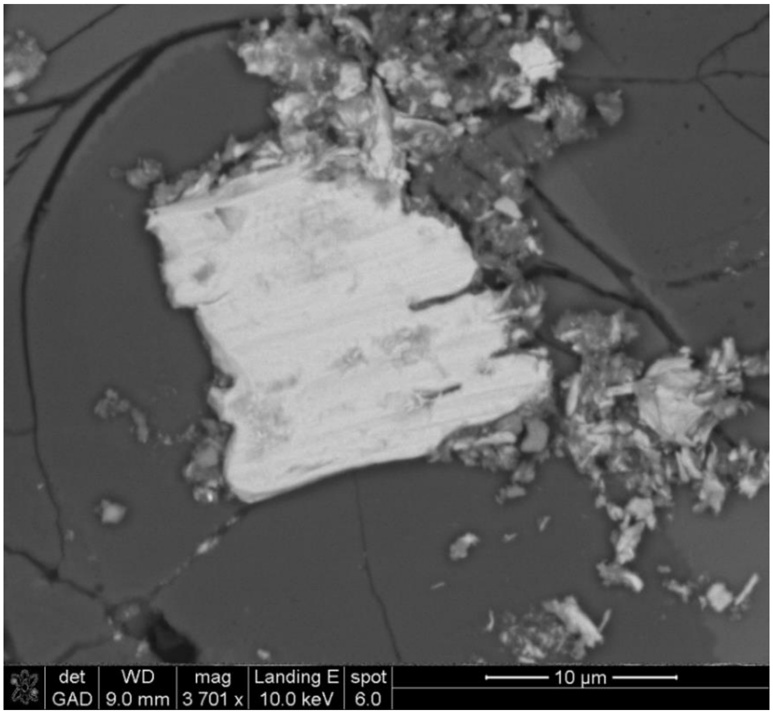

Figure II5i. Bright white zone comprised in wt%: 74.95Cu 13.91Ni 0.27Ca 0.14K 3.64Si 0.27Al 5.06O 1.77C

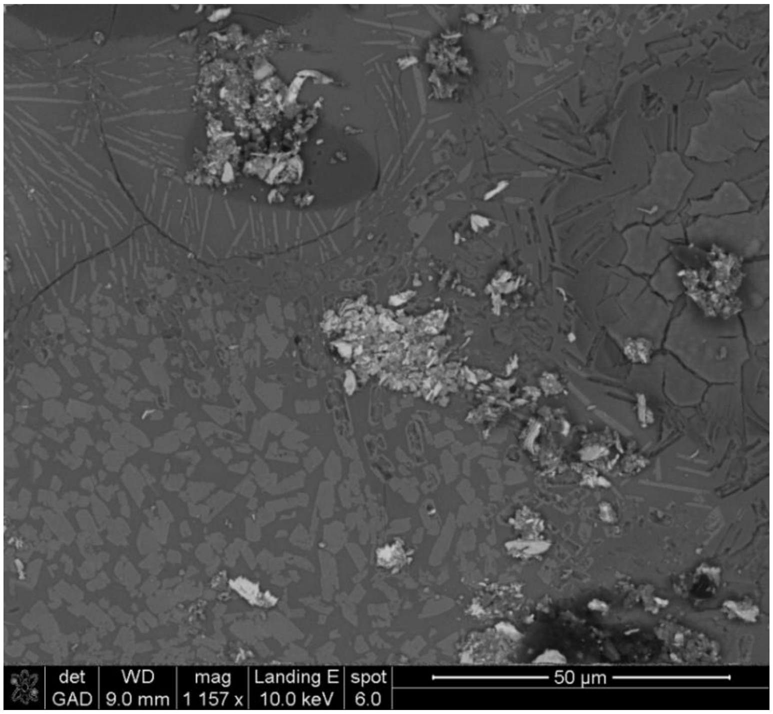

Figure II5j. Backscattered micrograph of multiple iron silicate phases, and brighter metal-rich areas with verified copper, nickel, and zinc

II6. Locus 8210, Artifact C

Context: 750-600 BC – “Fill (*BABesch* 2003, 48-51, cat. 1-3, fig. 6; *Carthage Studies* 2007, 48, No. 65).”

Overview: Iron slag with primary and secondary wüstite, multiple iron silicate phases. Differential interference contrast (DIC) and red plate applied to accentuate height of microstructural phases.

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
8210 C	750-600	2	44.75±0.449	4.867±0.132	10.622±0.157	0.85±0.051	0.538±0.03

S	Al	Mn	Zr	Cu
0.731±0.021	3.887±0.28	—	0.01±0.001	0.044±0.005

Sn	Zn	Pb	Ni	As
—	0.006±0.002	0.007±0.002	—	0.01±0.001

Table II6. pXRF slag composition

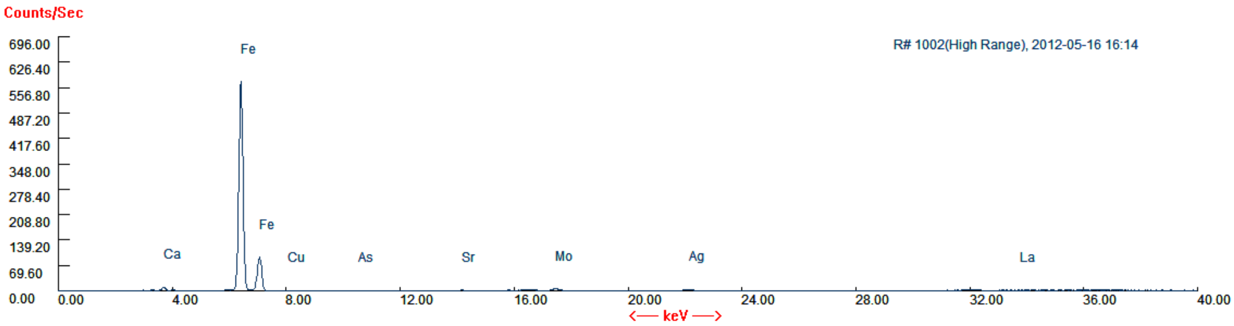

Figure II6a. pXRF spectrum

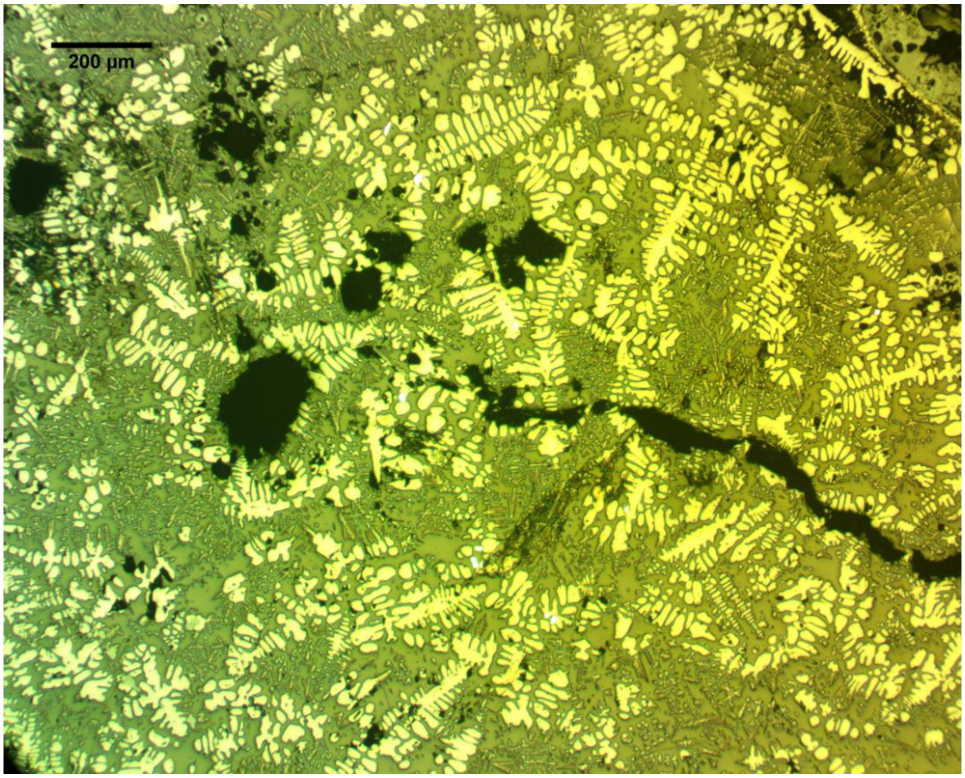

Figure II6b. Optical micrograph of primary and secondary wüstite

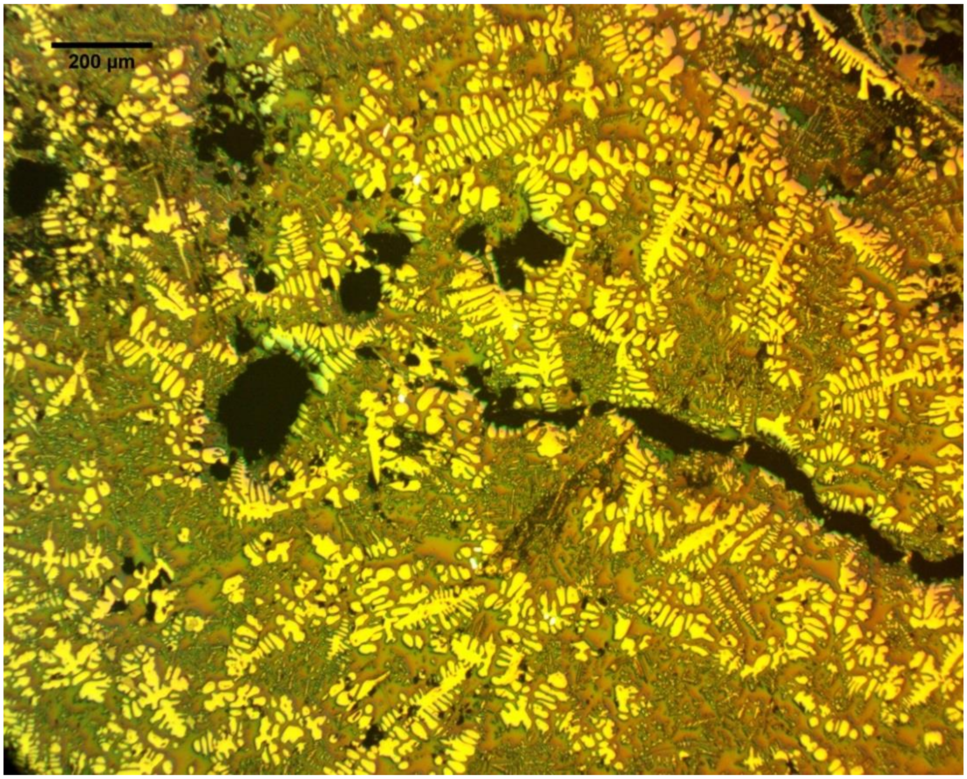

Figure II6c. Optical micrograph with red compensator plate of above Figure II6b

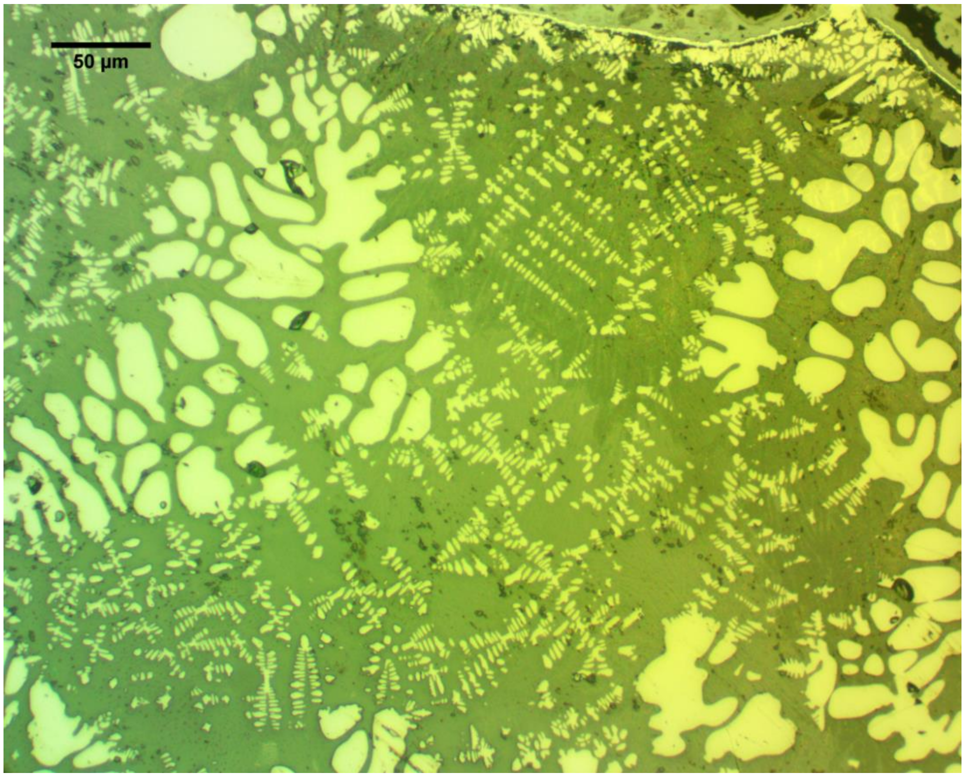

Figure II6d. Optical micrograph of primary and secondary wüstite, and iron silicate phases

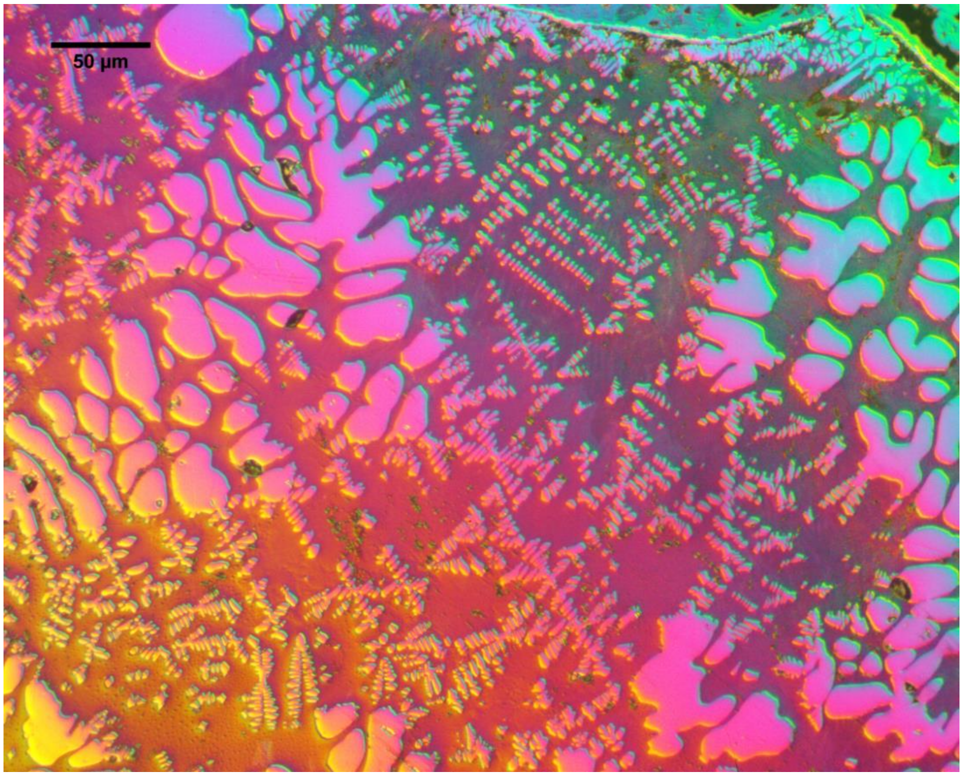

Figure II6e. DIC and red plate micrograph of above Figure II6d

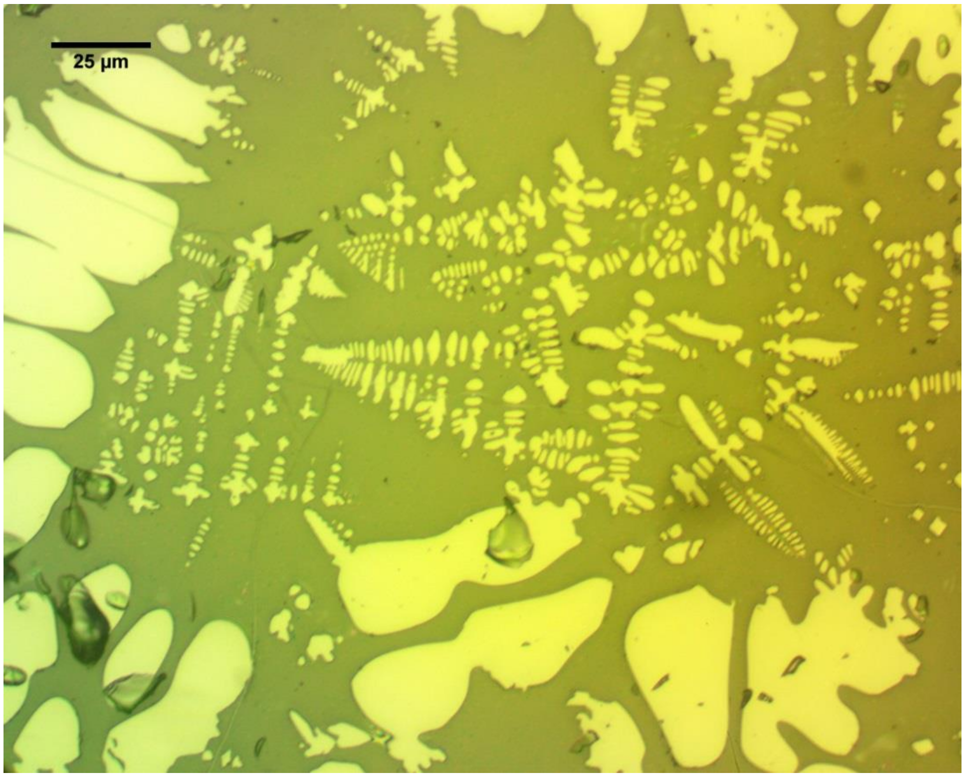

Figure II6f. Optical micrograph of primary and secondary wüstite, and glassy iron silicate phases

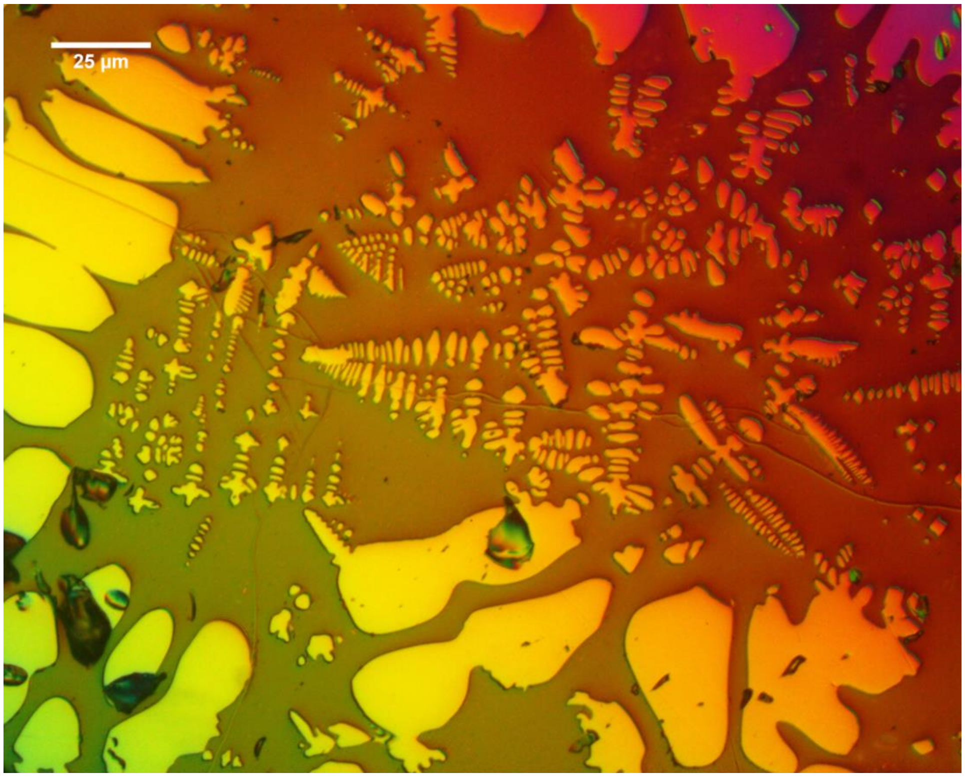

Figure II6g. DIC and red compensator plate micrograph of above Figure II6f

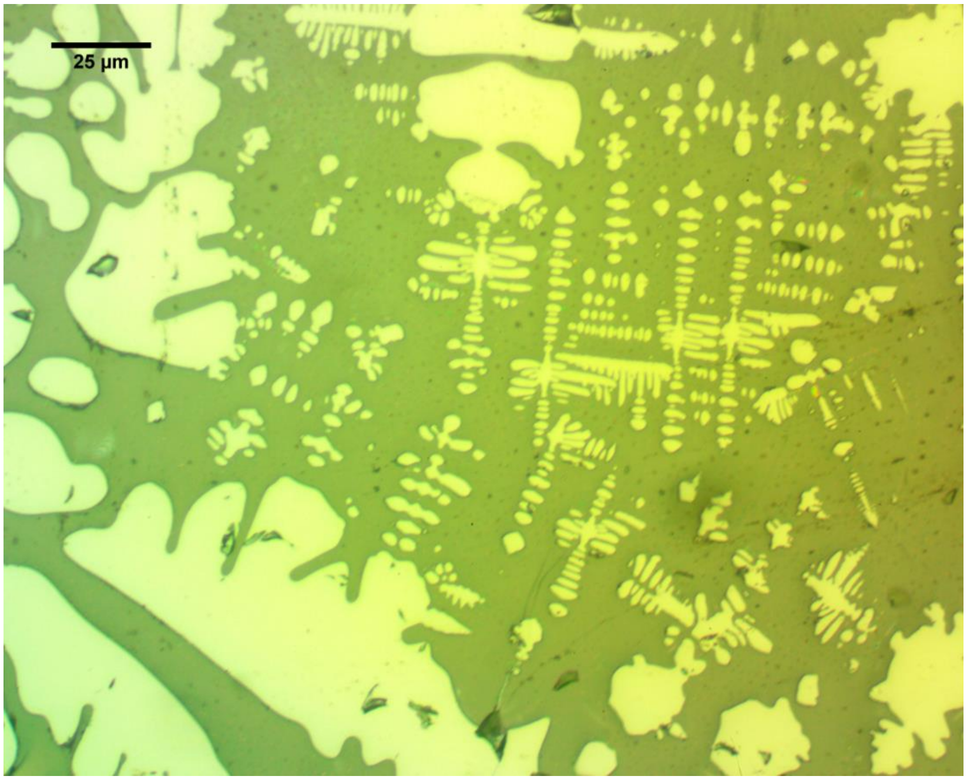

Figure II6h. Optical micrograph of primary and secondary wüstite, and glassy iron silicate phases

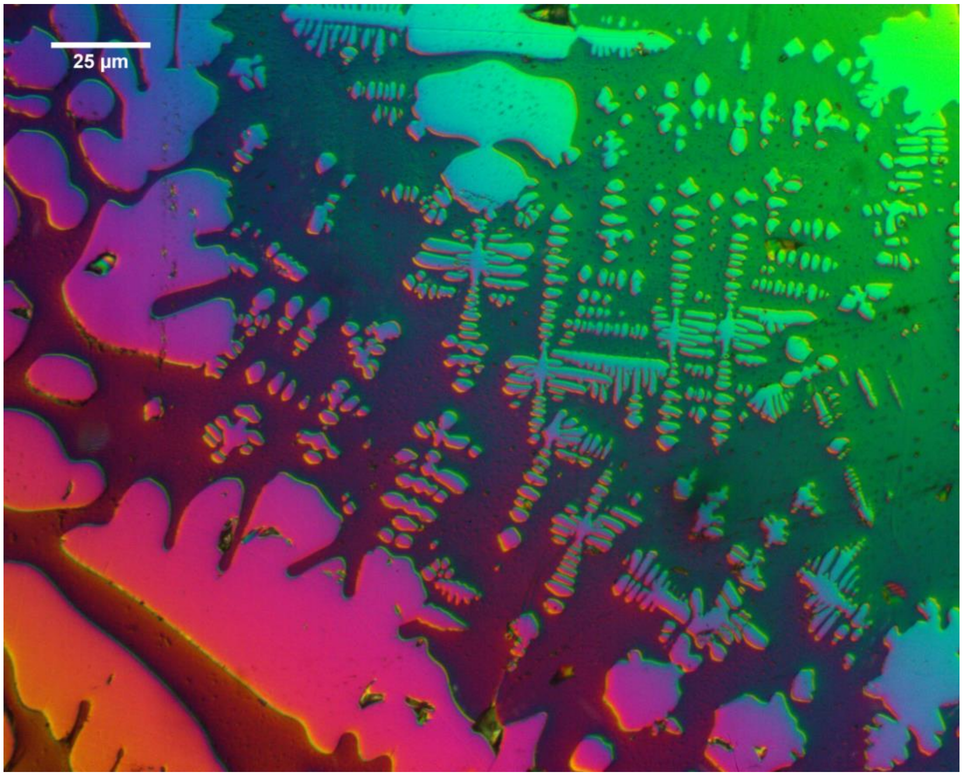

Figure II6i. DIC and red compensator plate micrograph of above Figure II6h

II7. Locus 8210, Artifact D

Context: 750-600 BC – "Fill (*BABesch* 2003, 48-51, cat. 1-3, fig. 6; *Carthage Studies* 2007, 48, No. 65)."

Overview: Iron slag, with pure iron inclusions, secondary wüstite (no primary wüstite), and iron silicates. The specimen is an excellent example of a tap slag as determined by microstructure.

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P	S	Al	Mn	Zr	Cu	Sn	Zn	Pb	Ni	As
8210 D	750-600	2	24.526±0.198	10.043±0.183	13.616±0.18	0.978±0.049	1.852±0.047	0.088±0.013	3.556±0.254	—	0.021±0.001	0.015±0.003	—	0.024±0.002	0.003±0.001	—	0.027±0.001

Table II7. pXRF slag composition

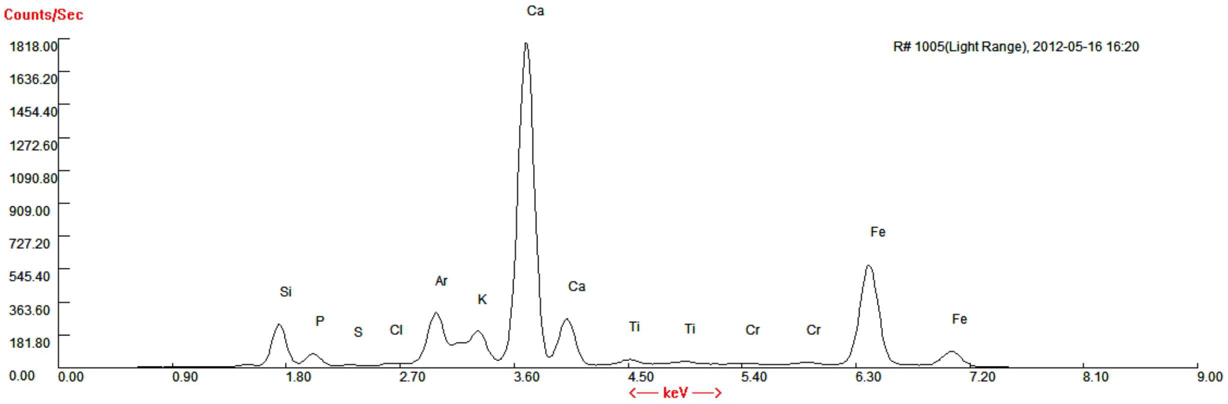

Figure II7a. pXRF spectrum

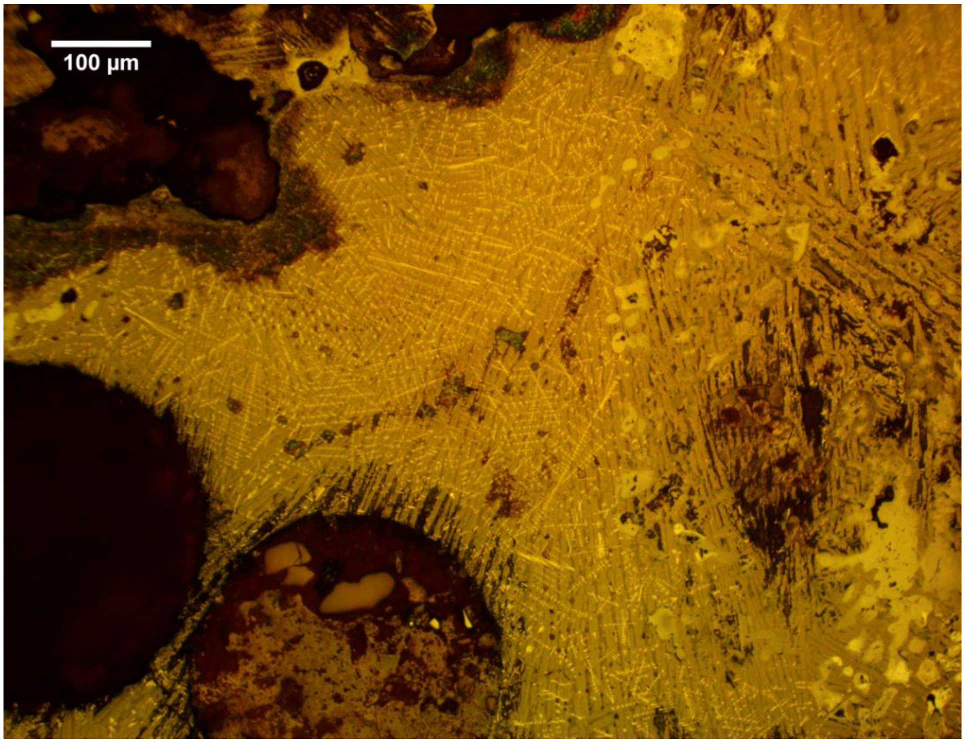

Figure II7b. Optical micrograph of secondary wüstite and iron silicate phases

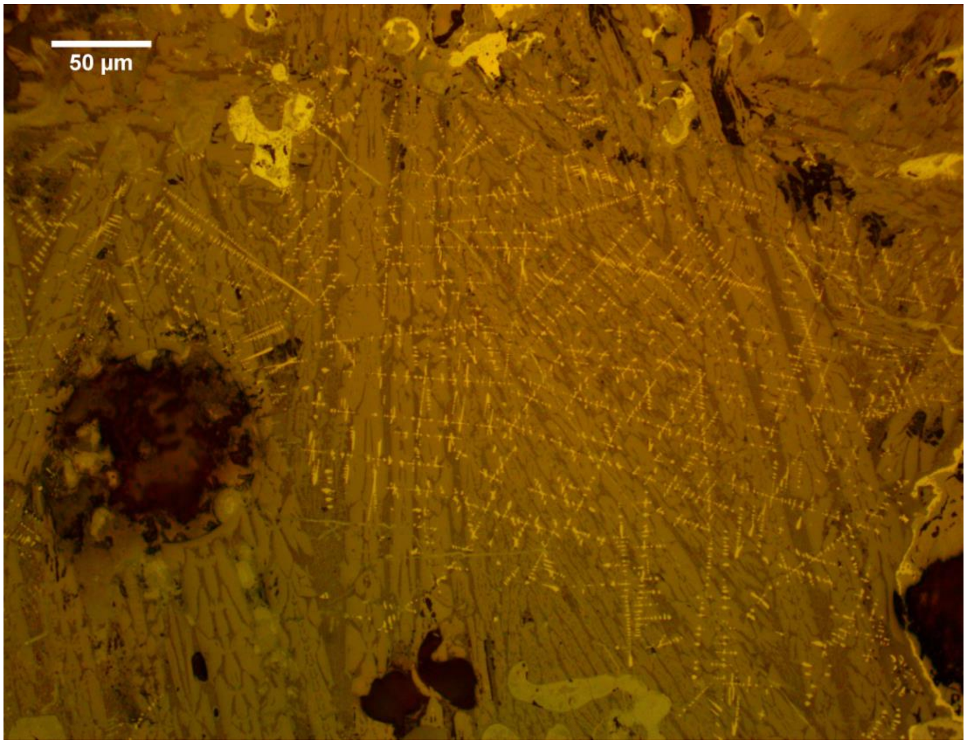

Figure II7c. Optical micrograph secondary wüstite and iron silicate phases

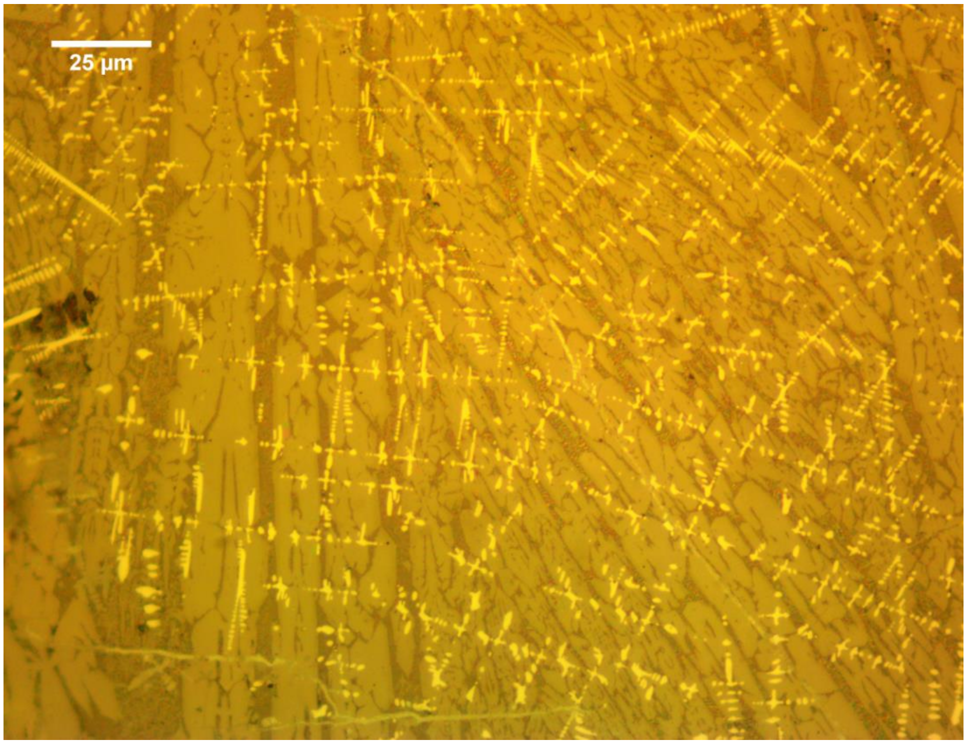

Figure II7d. Optical micrograph secondary wüstite and iron silicate phases

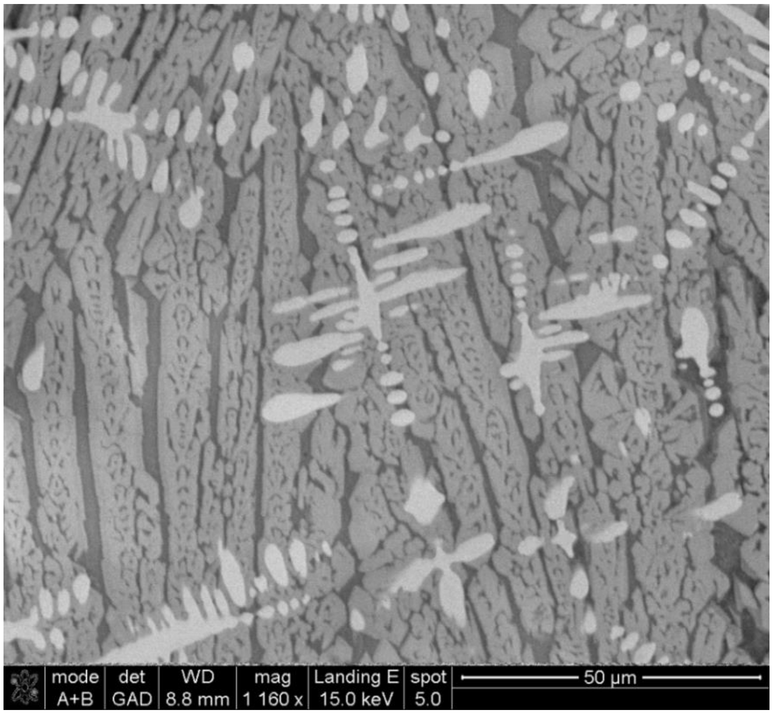

Figure II7e. Backscattered micrograph secondary wüstite with typical “dragonfly” microstructure, and iron silicate phases

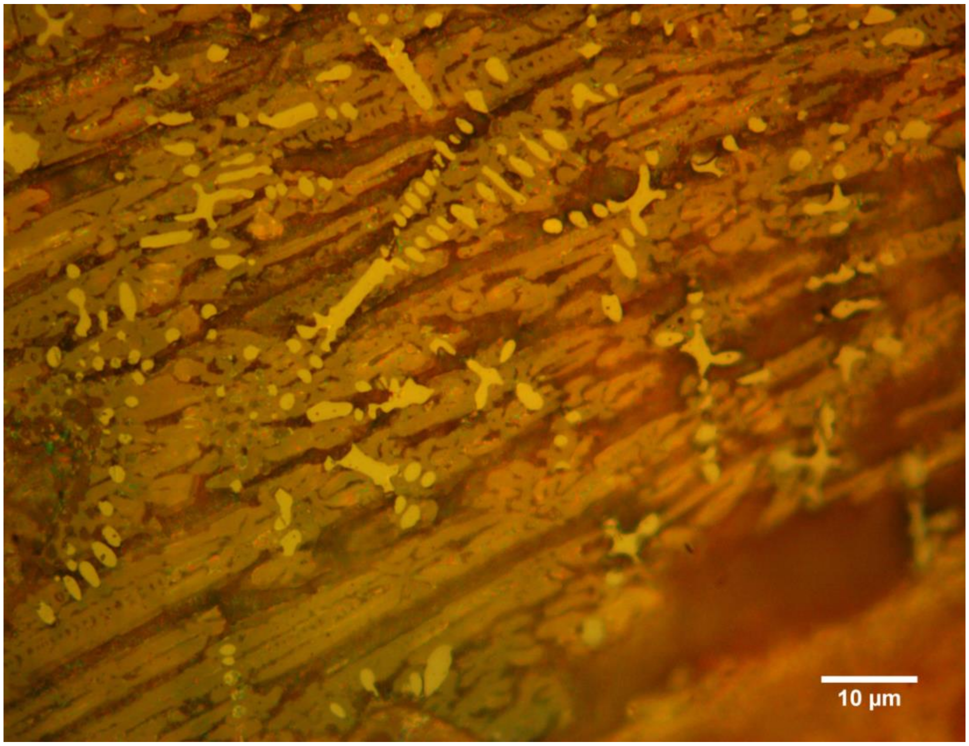

Figure II7f. Optical micrograph of secondary wüstite and iron silicate phases

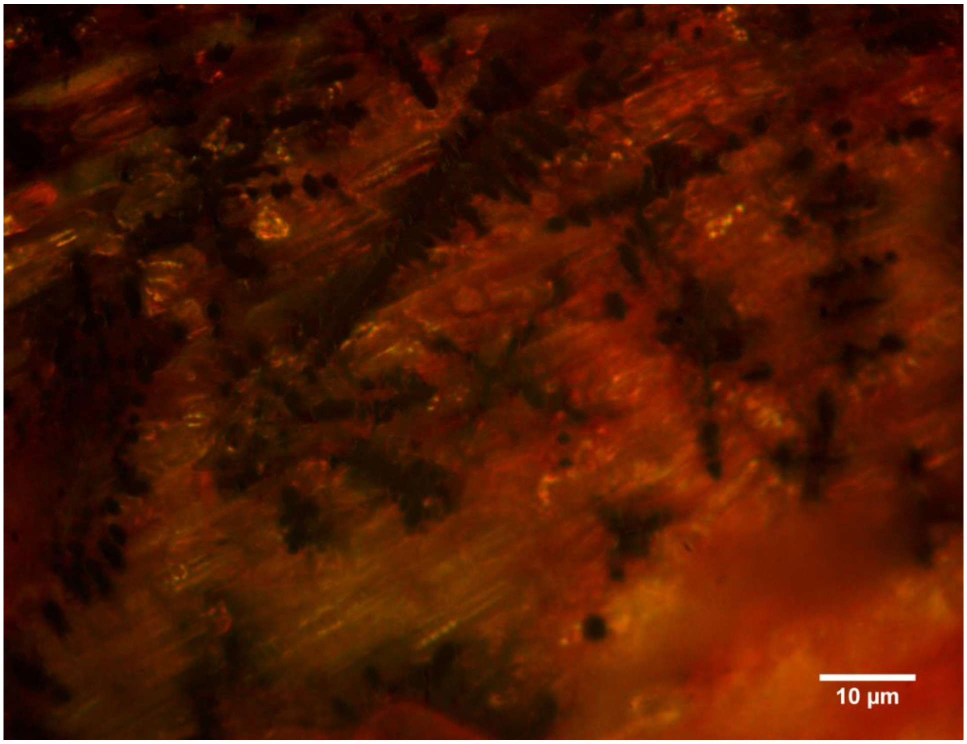

Figure II7g. Dark field micrograph of above II7f, secondary wüstite and iron silicate phases

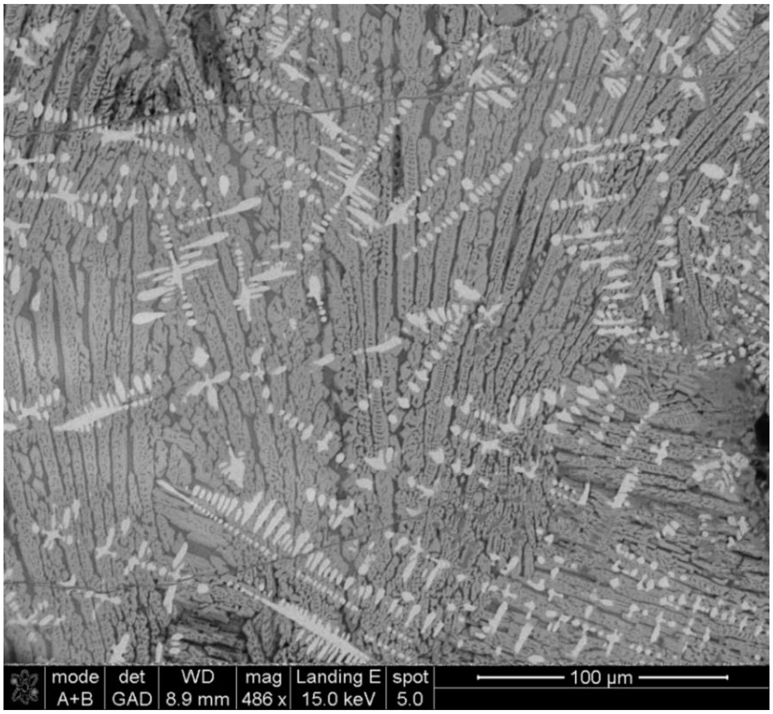

Figure II7h. Backscattered micrograph of secondary wüstite and iron silicate phases

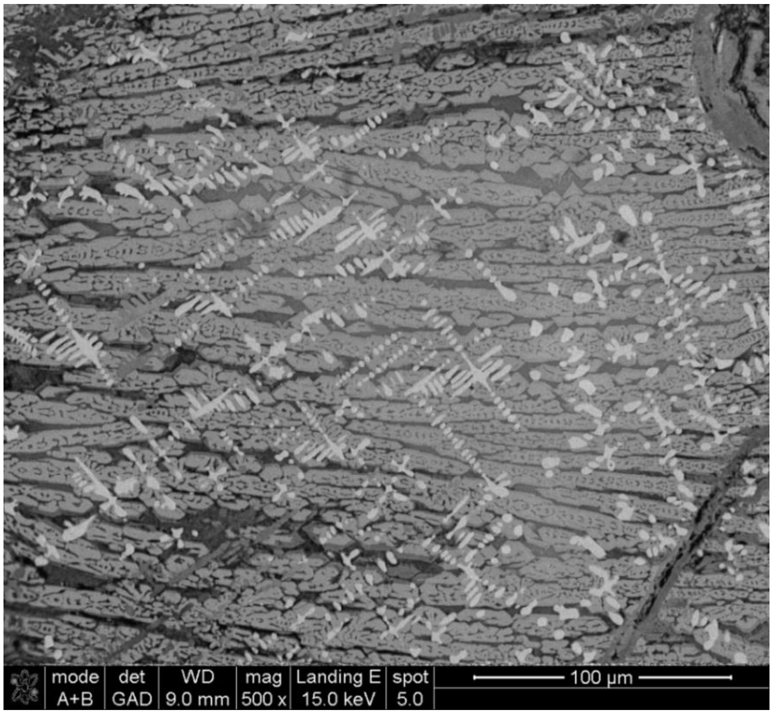

Figure II7i. Backscattered micrograph of secondary wüstite and iron silicate phases

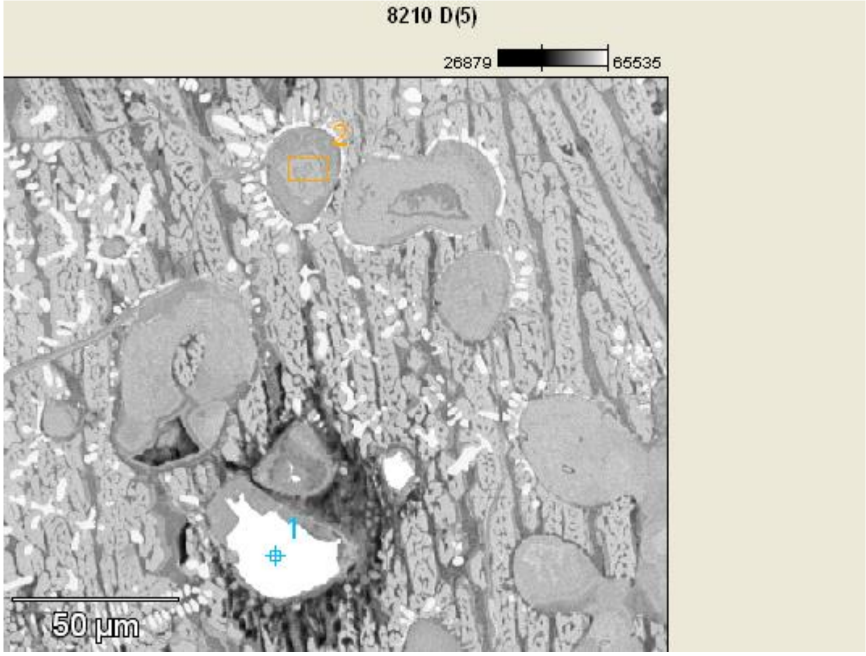

Figure II7j. EDS in wt%, spot 1 (pure iron): 97.37Fe 0.25Ca 0.10K 0.83Si 0.20Al 1.25C; Box 2: 53.05Fe 1.33Ca 0.20K 0.66P 4.46Si 0.49Al 0.21Mg 37.77O 1.84C

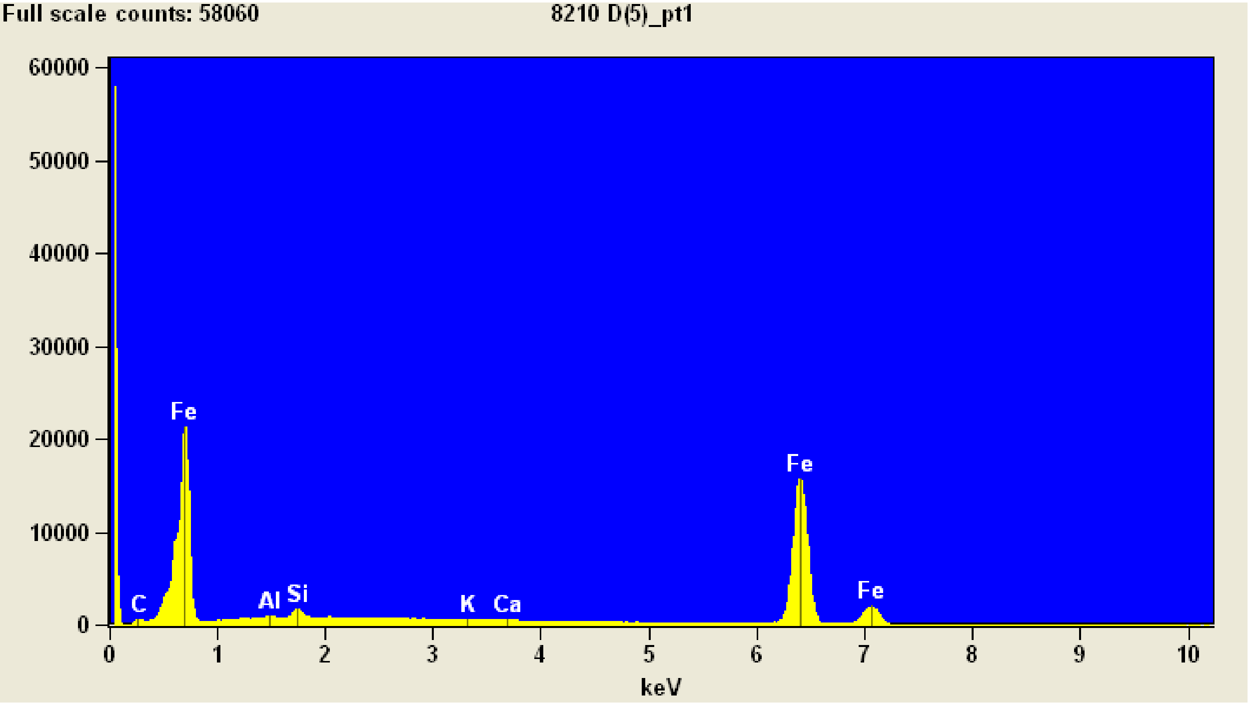

Figure II7k. EDS spectrum of pure iron, spot 1 above Figure II7j

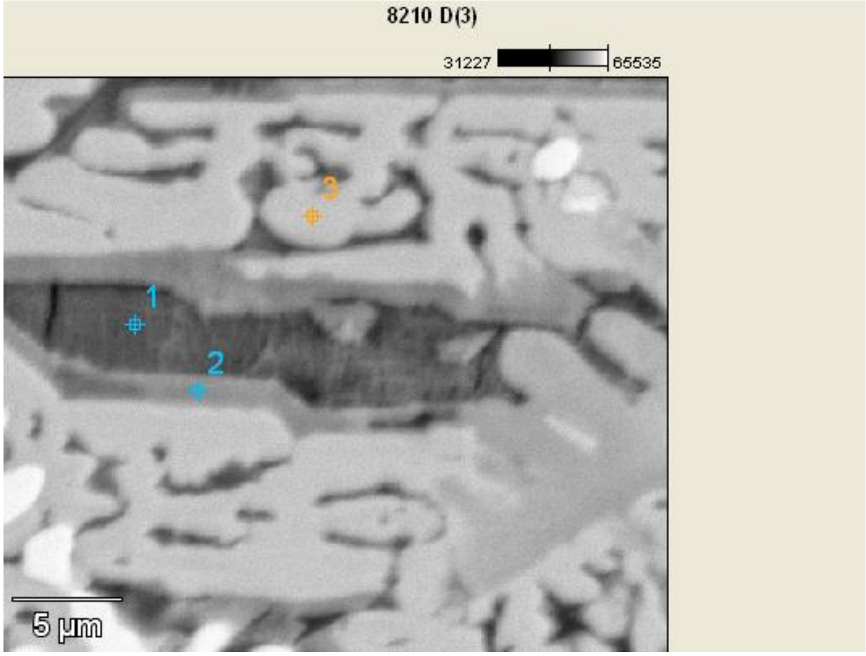

Figure II7l. EDS in wt%, spot 1: 66.35Fe 0.62Mo 0.67Ti 9.68Ca 1.50K 0.54Cl 7.81P 10.03Si 2.35Al 0.45Mg; spot 2: 42.33Fe 0.14Ti 3.59Ca 0.42K 1.71P 8.49Si 1.23Al 0.30Mg 38.47O 3.32C; spot 3: 47.87Fe 0.63Mn 4.45Ca 0.16P 13.42Si 0.25Al 0.94Mg 30.51O 1.77C

II8. Locus 8339, Artifact 34910

Context: 800-600 BC.

Overview: Low iron slag, with primary and secondary wüstite, and iron silicates. II8b indicates a pearlitic product.

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P	S	Al	Mn	Zr	Cu	Sn	Zn	Pb	Ni	As
8339 34910	800-600	2	4.232±0.047	7.084±0.102	27.897±0.212	1.242±0.031	0.338±0.034	0.075±0.011	2.391±0.145	—	0.027±0.001	—	—	0.004±0.001	—	—	—

Table II8. pXRF slag composition

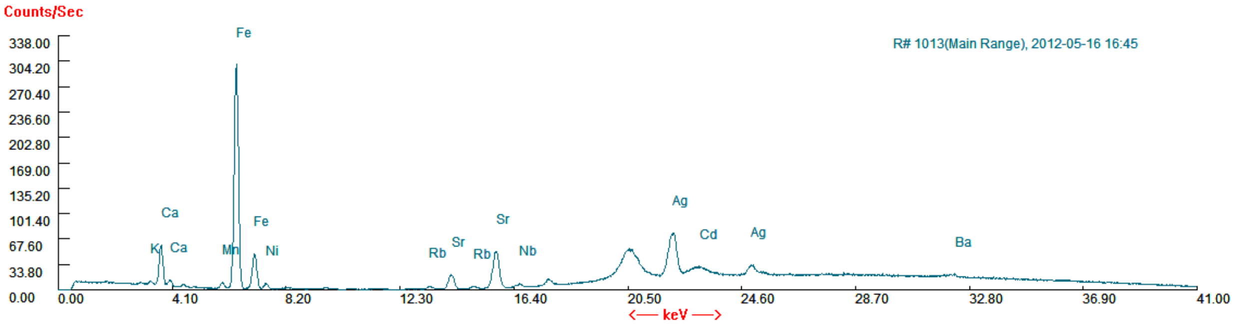

Figure II8a. pXRF spectrum

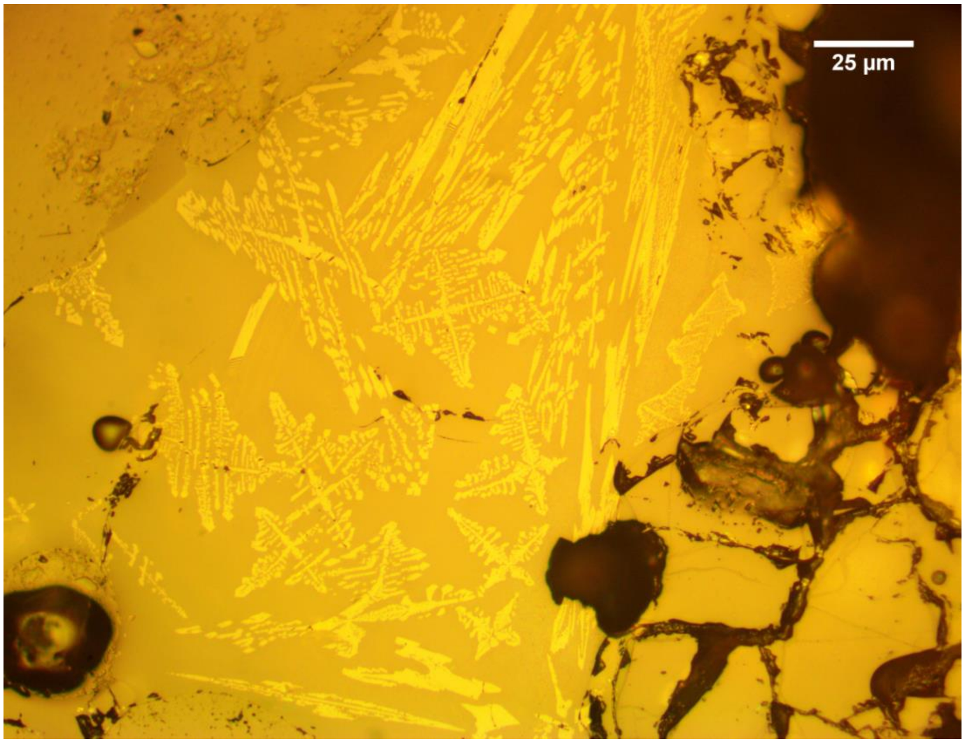

Figure II8b. Optical micrograph of iron silicates in glassy matrix

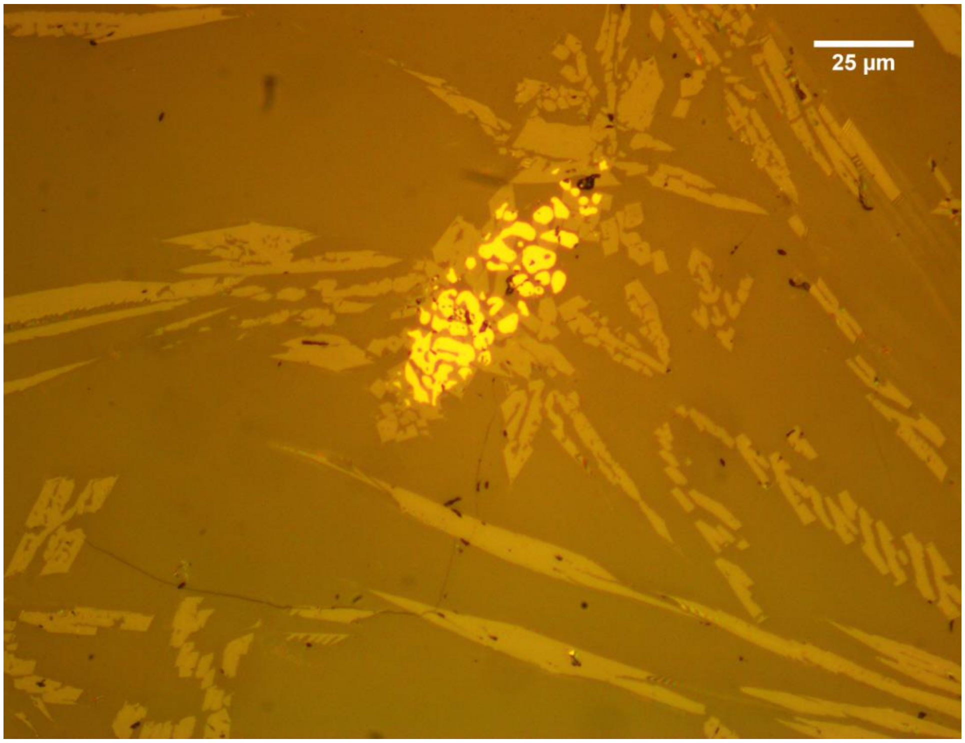

Figure II8c. Optical micrograph of iron silicates, and primary wüstite in glassy matrix

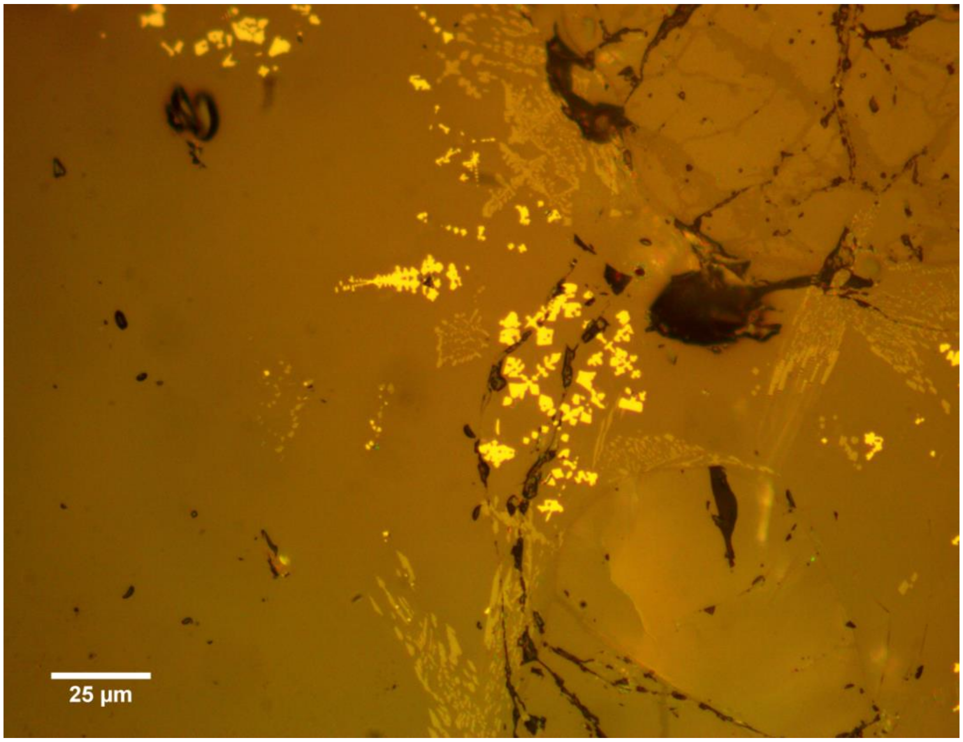

Figure II8d. Optical micrograph of iron silicates, and primary wüstite in glassy matrix

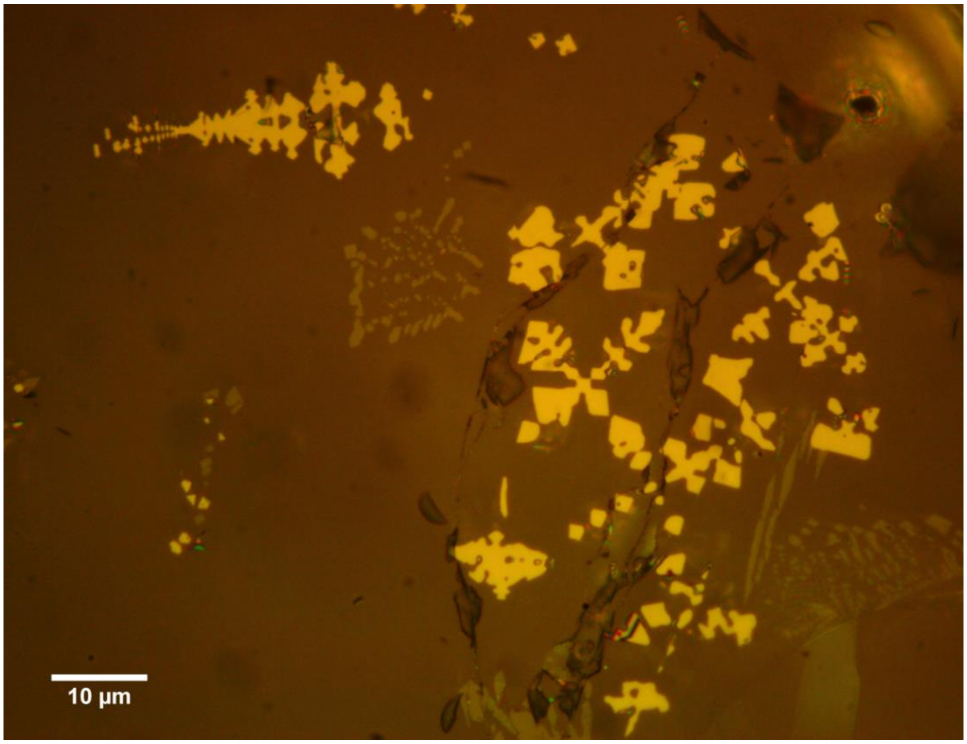

Figure II8e. Optical micrograph of iron silicates, and primary and secondary wüstite in glassy matrix

II9. Locus 8339, Artifact 34919

Context: 800-600 BC.

Overview: Iron slag, with marked heterogeneity left from the smelting or blooming process. Likely evidence for iron hammerscales caught in the detritus.

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
8339 34919	800-600	2	19.486±0.414	6.023±0.219	11.06±0.283	0.955±0.055	0.756±0.064

S	Al	Mn	Zr	Cu
0.22±0.024	—	1.344±0.291	—	—

Sn	Zn	Pb	Ni	As
—	—	—	—	0.013±0.003

Table II9. pXRF slag composition

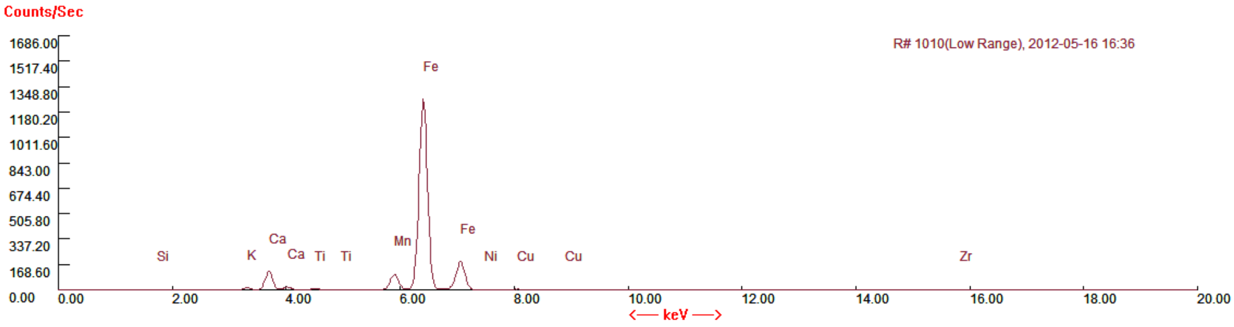

Figure II9a. pXRF spectrum

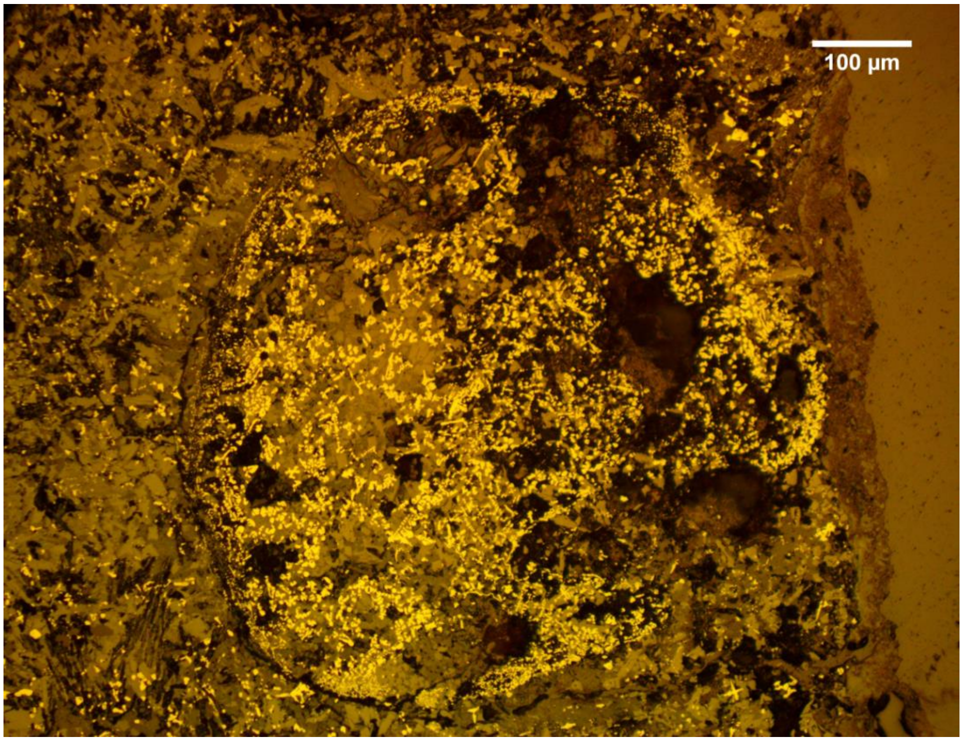

Figure II9b. Optical micrograph showing typical heterogeneity of slag phases

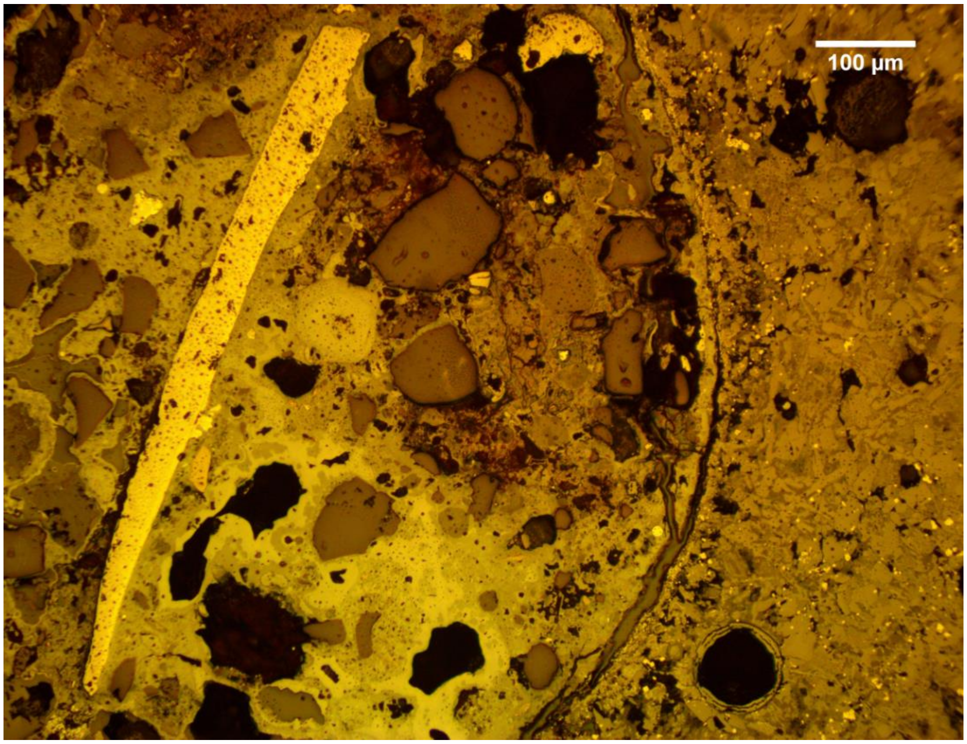

Figure II9c. Optical micrograph with what is likely an iron hammerscale on the left

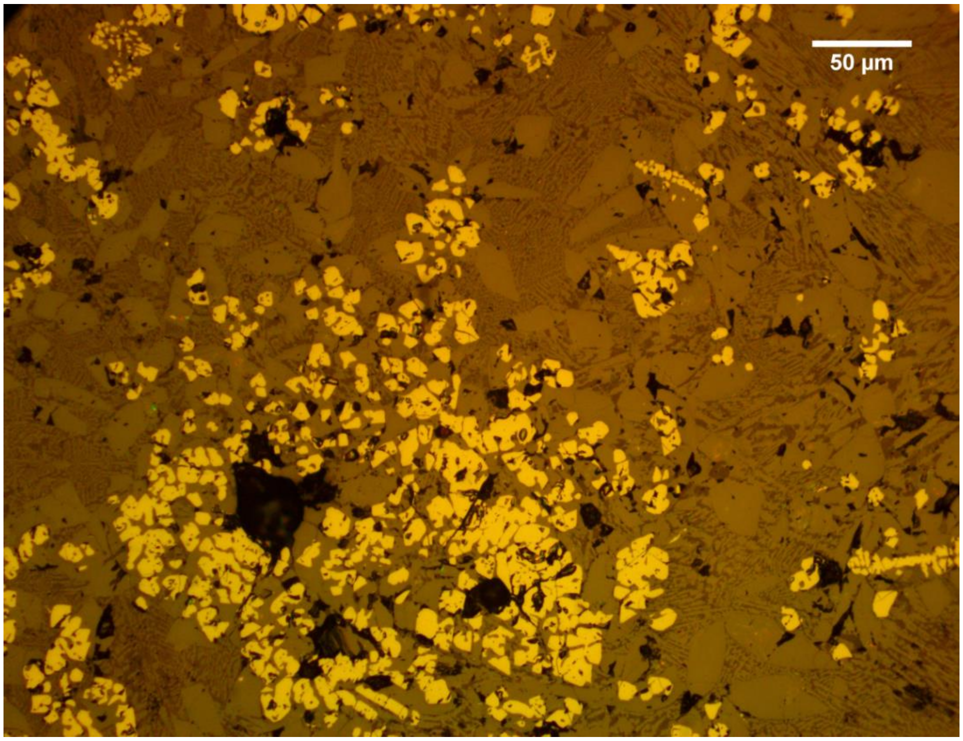

Figure II9d. Optical micrograph of primary and some secondary wüstite in matrix of iron silicates

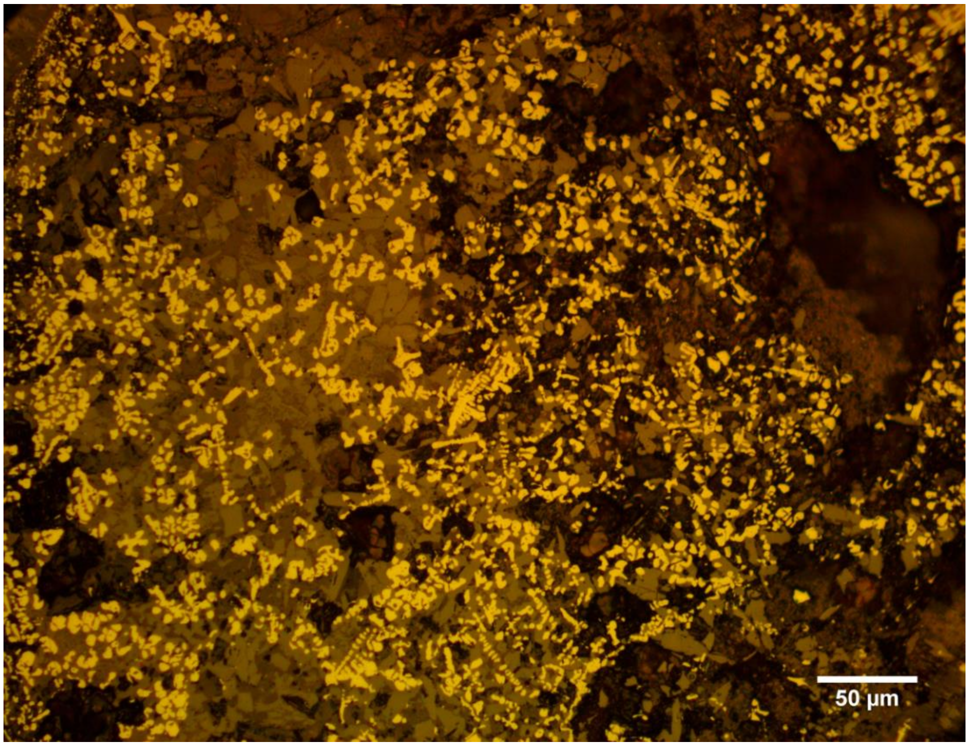

Figure II9e. Optical micrograph of primary and secondary wüstite in matrix of detritus and iron silicates

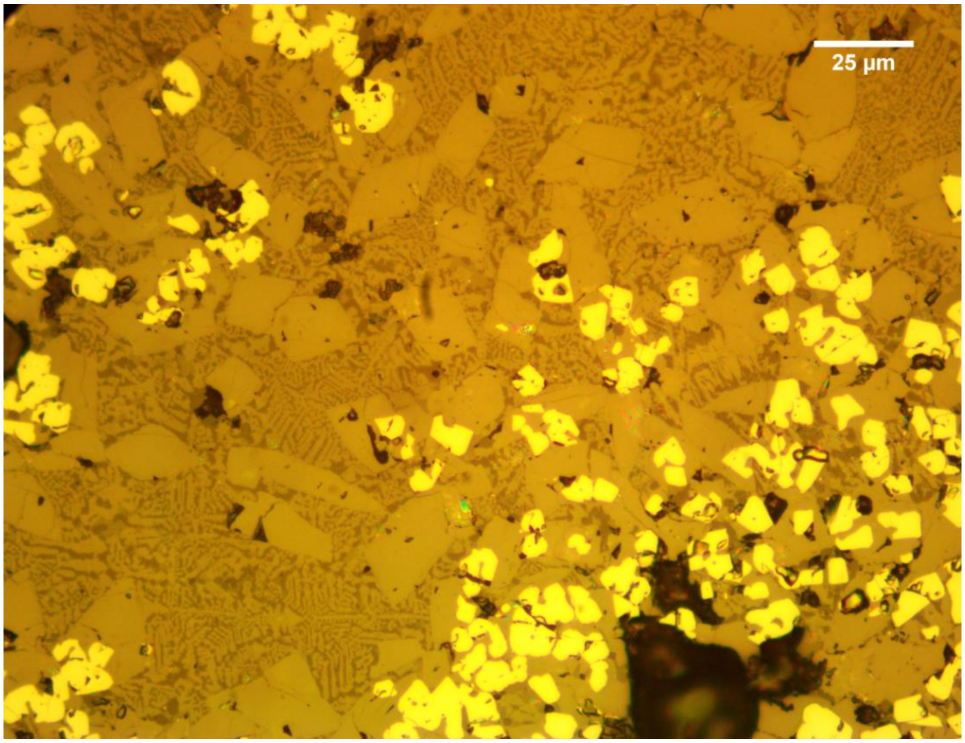

Figure II9f. Optical micrograph of primary wüstite in matrix of iron silicates

II10. Locus 8339, Artifact 34955A

Context: 800-600 BC.

Overview: Iron slag, mostly secondary but some primary wüstite, and iron silicates. This is an excellent example of a tap slag by microstructure.

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
8339 34955A	800-600	1	48.658±0.83	1.009±0.119	5.717±0.158	0.52±0.043	0.2±0.032

S	Al	Mn	Zr	Cu
0.302±0.021	—	—	0.007±0.001	—

Sn	Zn	Pb	Ni	As
—	0.014±0.004	—	—	

Table II10. pXRF slag composition

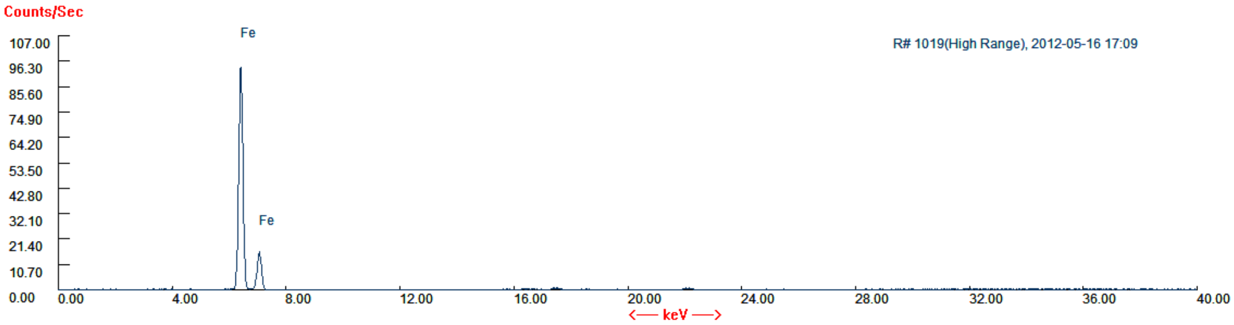

Figure II10a. pXRF spectrum

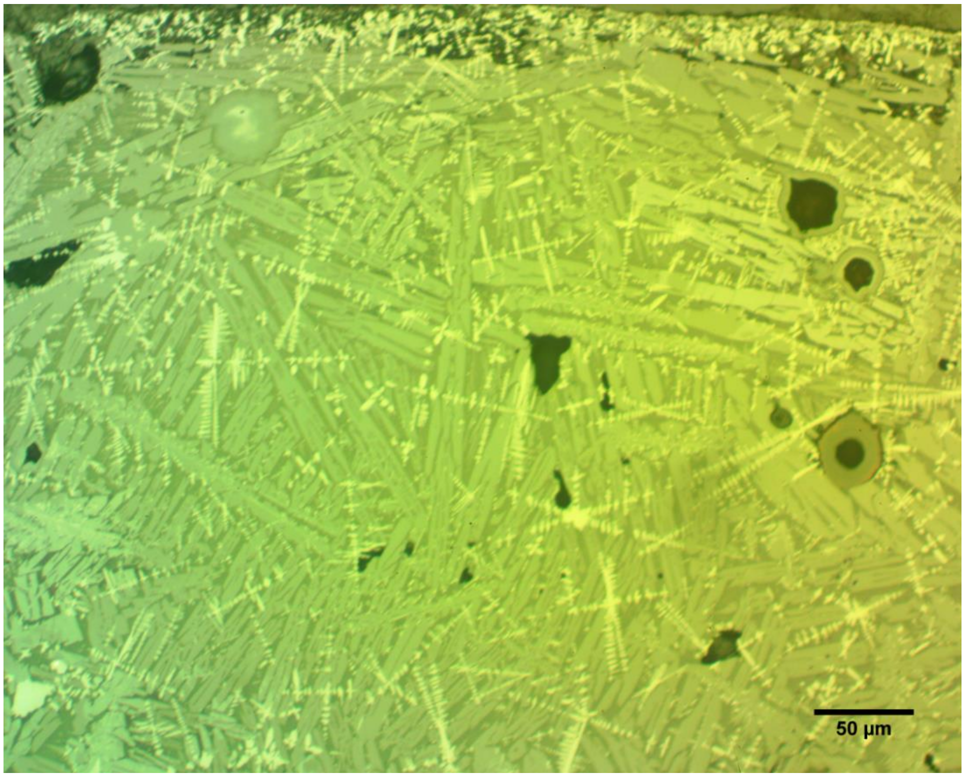

Figure II10b. Optical micrograph of primary and secondary wüstite, and iron silicates

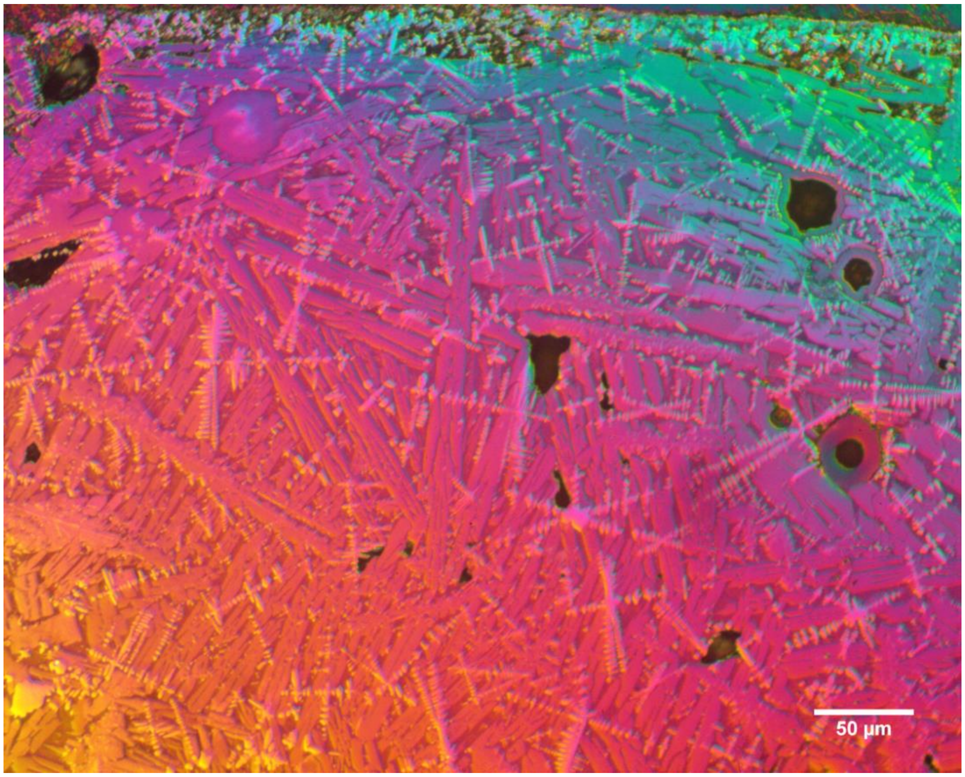

Figure II10c. DIC and red compensator plate applied to above Figure II10b, with primary and secondary wüstite, and iron silicates

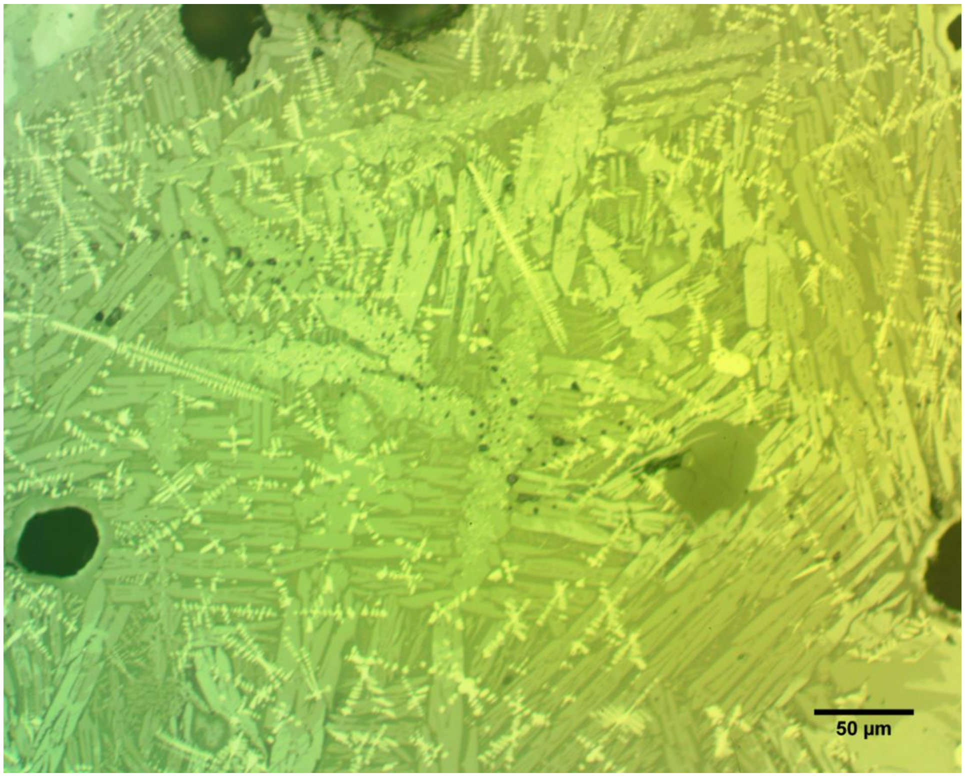

Figure II10d. Optical micrograph of primary and secondary wüstite, and iron silicates

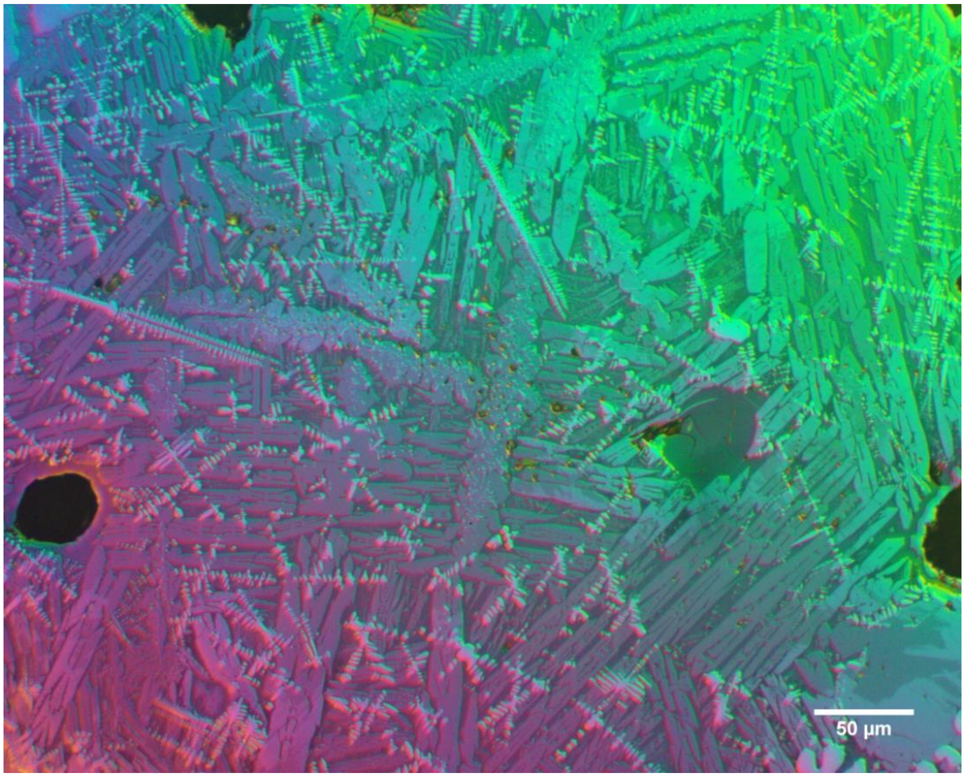

Figure II10e. DIC and red compensator plate applied to above Figure II10d, with primary and secondary wüstite, and iron silicates

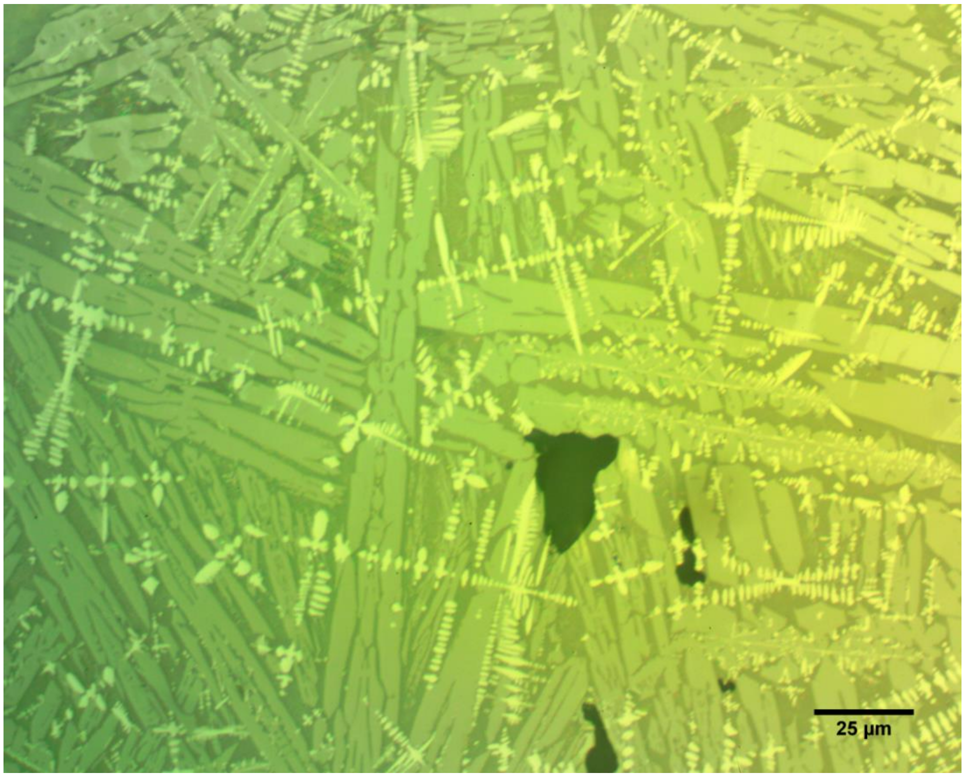

Figure II10f. Optical micrograph of primary and secondary wüstite, and iron silicates

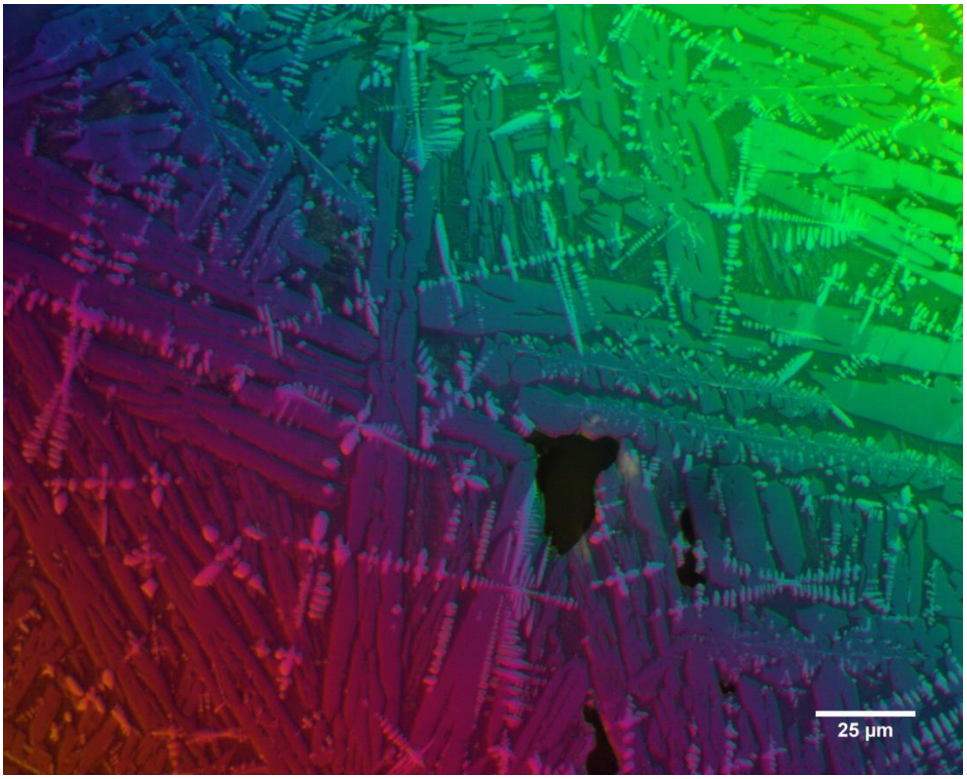

Figure II10g. DIC and red plate applied to above Figure II10f, with primary and secondary wüstite, and iron silicates

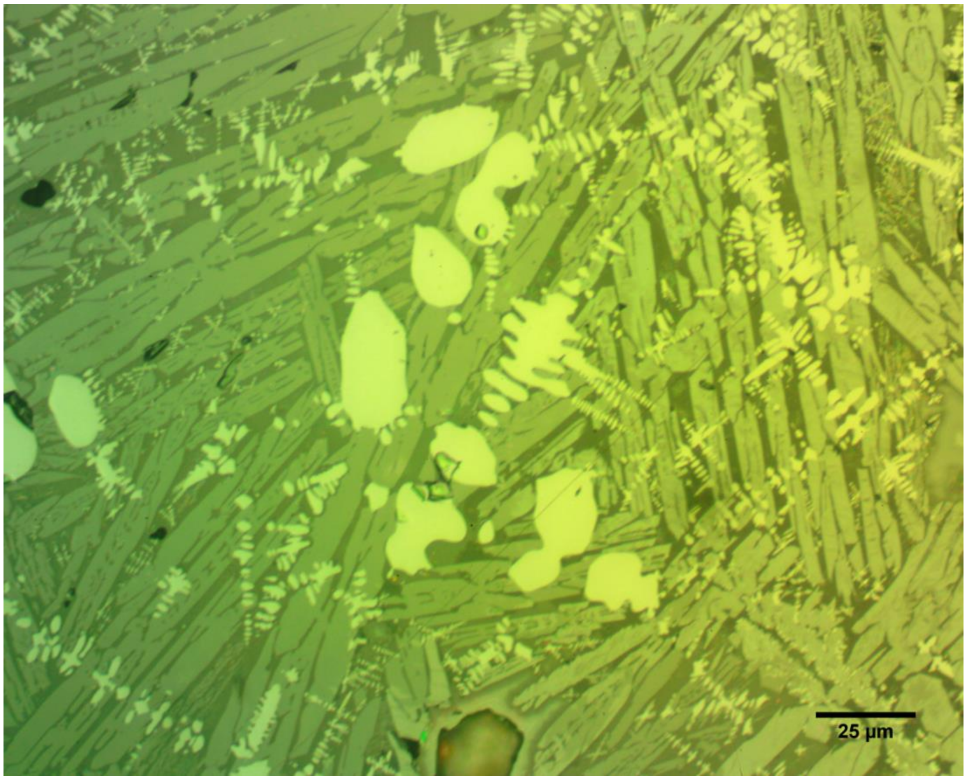

Figure II10h. Optical micrograph of primary and secondary wüstite, and iron silicates

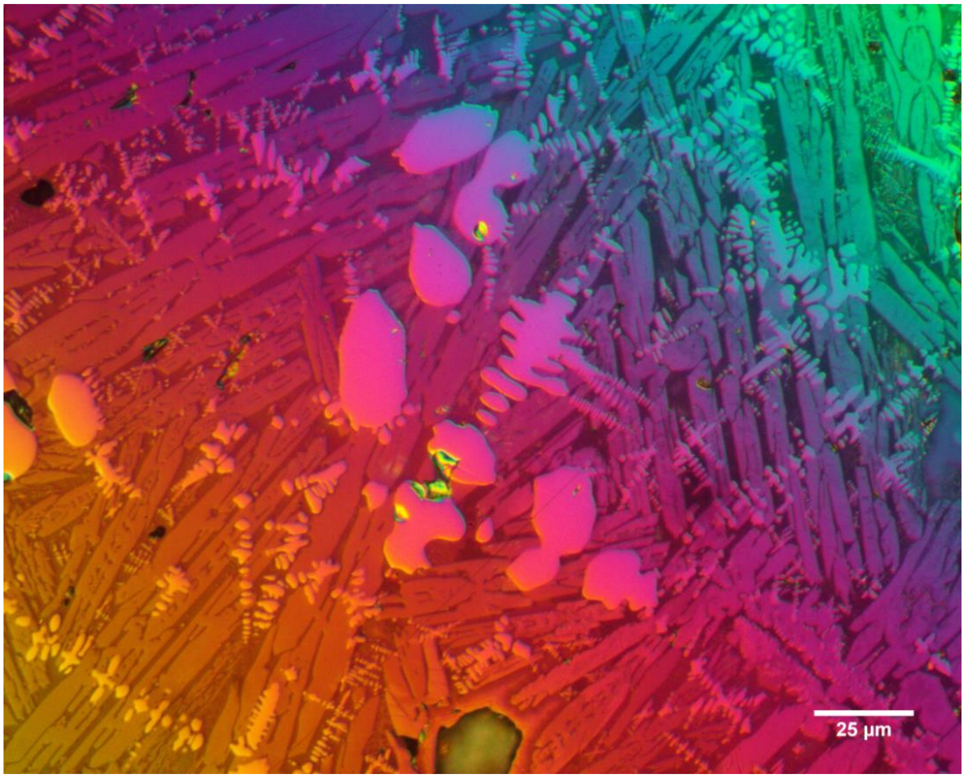

Figure II10i. DIC and red compensator plate applied to above Figure II10h, with primary and secondary wüstite, and iron silicates

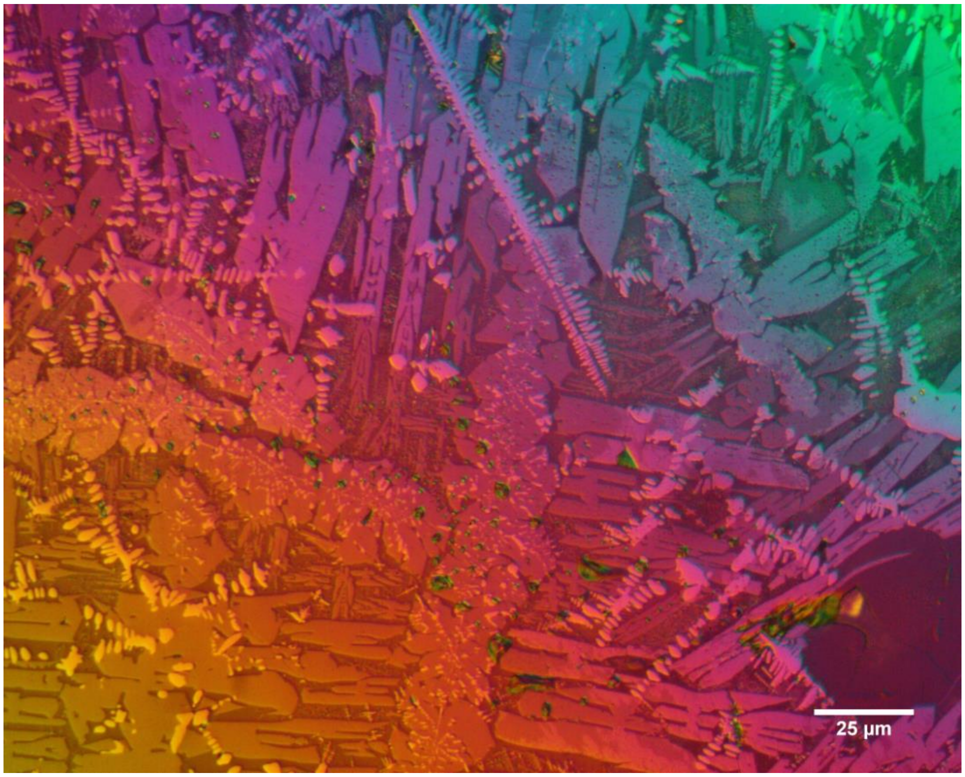

Figure II10j. DIC and red compensator plate optical micrograph with primary and secondary wüstite, and iron silicates

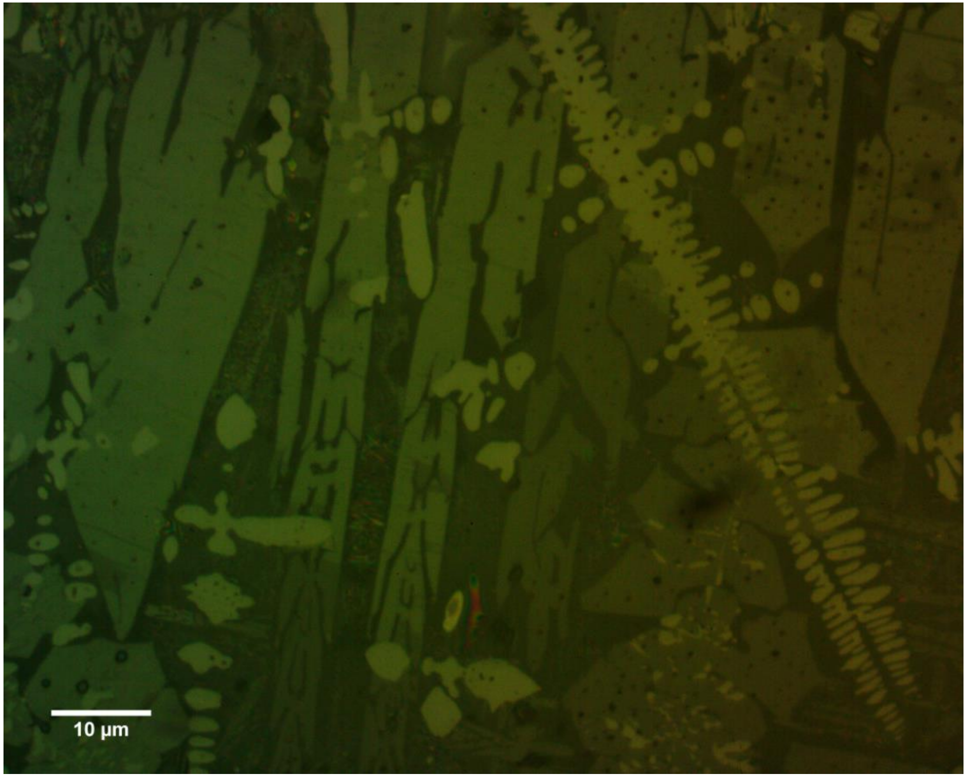

Figure II10k. DIC and red compensator plate optical micrograph with primary and secondary wüstite, and iron silicates

II11. Locus 8339, Artifact 34955B

Context: 800-600 BC.

Overview: Iron slag, with highest iron content in the corpus. Primary and secondary wüstite zones are generally divided into distinct zones, with likely evidence of a hammerscale, and iron silicates flowing directionally. Verification of wüstite in Figure II11k. Evidence of fayalite in Figure II11n, spot 2. The portions of the slag with secondary wüstite, fayalite, and glassy phases are representative of a tap slag. Some of the EDS spectra are mislabeled "1093 10191".

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
8339 34955B	800-600	1	61.236±1.164	1.455±0.14	3.914±0.133	0.199±0.04	0.242±0.032

S	Al	Mn	Zr	Cu
0.237±0.02	—	—	0.003±0.001	—

Sn	Zn	Pb	Ni	As
—	0.021±0.005	—	—	0.054±0.006

Table II11. pXRF slag composition

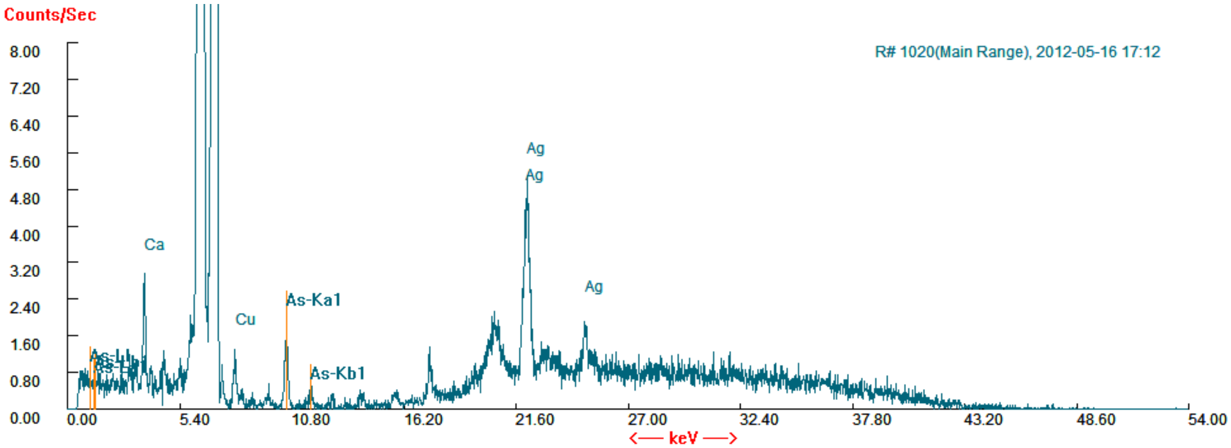

Figure II11a. pXRF spectrum with arsenic peaks

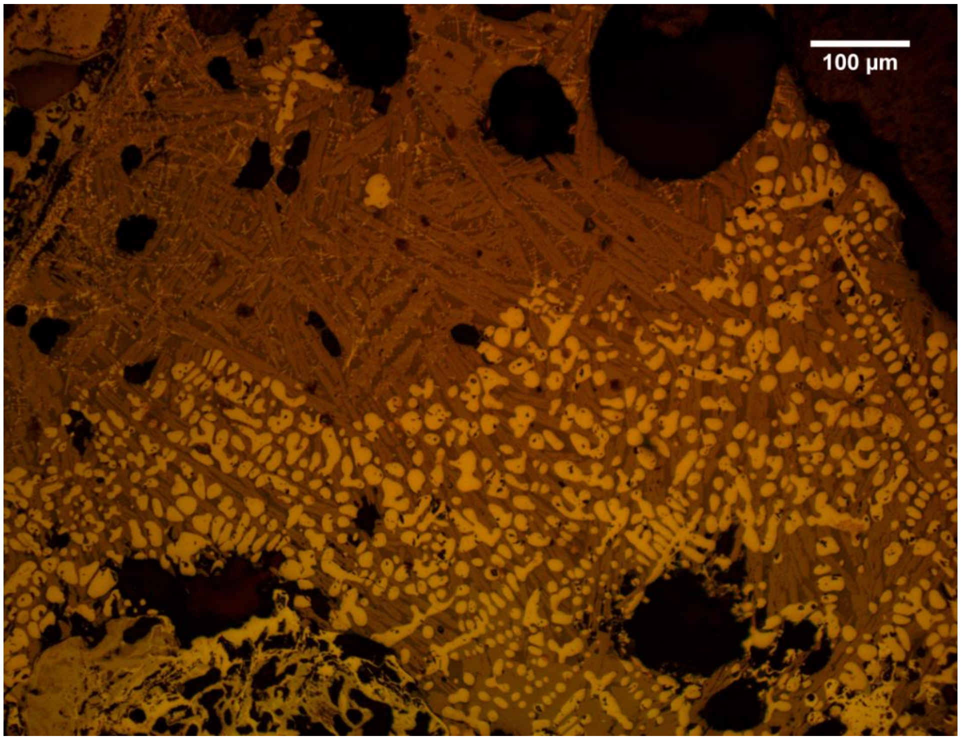

Figure II11b. Optical micrograph of distinct primary and secondary wüstite zones

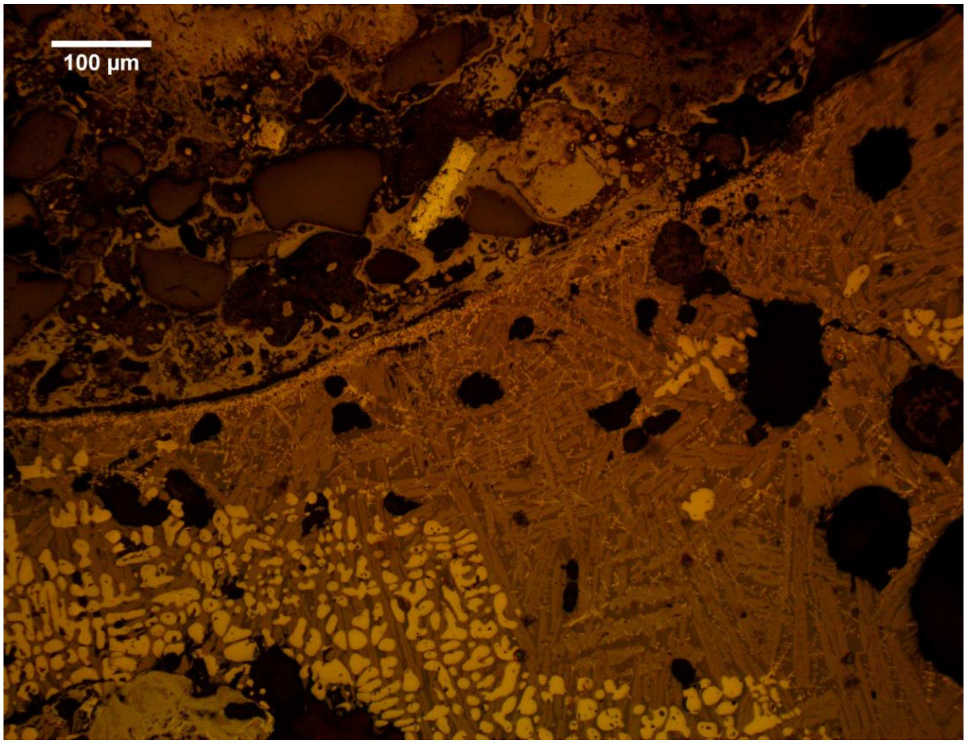

Figure II11c. Optical micrograph of distinct primary and secondary wüstite zones, with likely evidence of a hammerscale trapped in the detritus

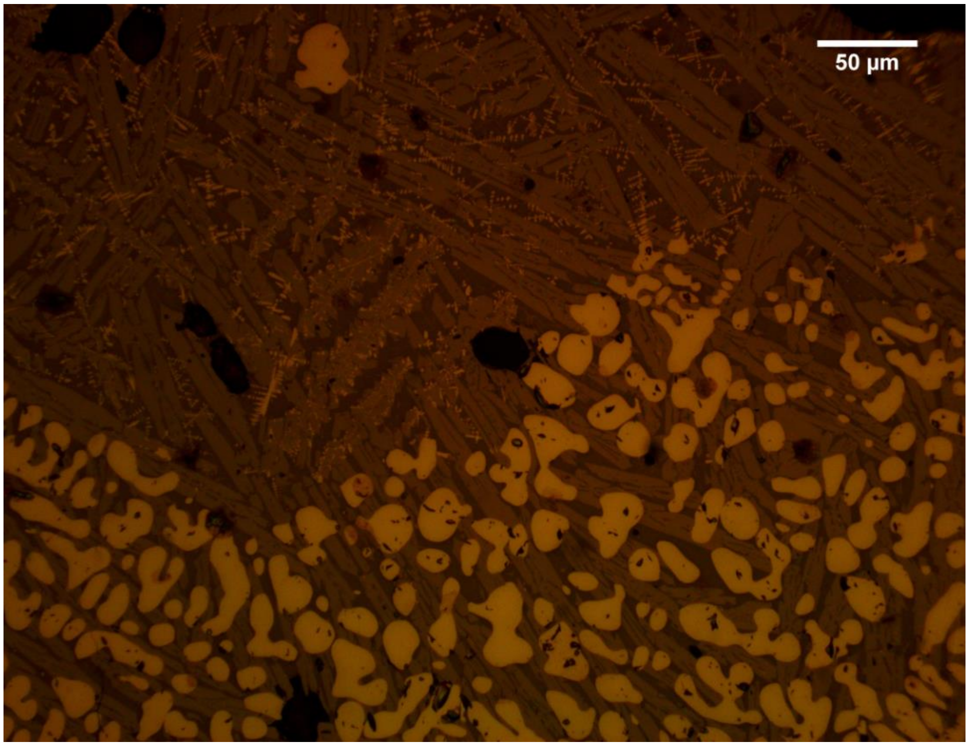

Figure II11d. Optical micrograph of distinct primary and secondary wüstite zones

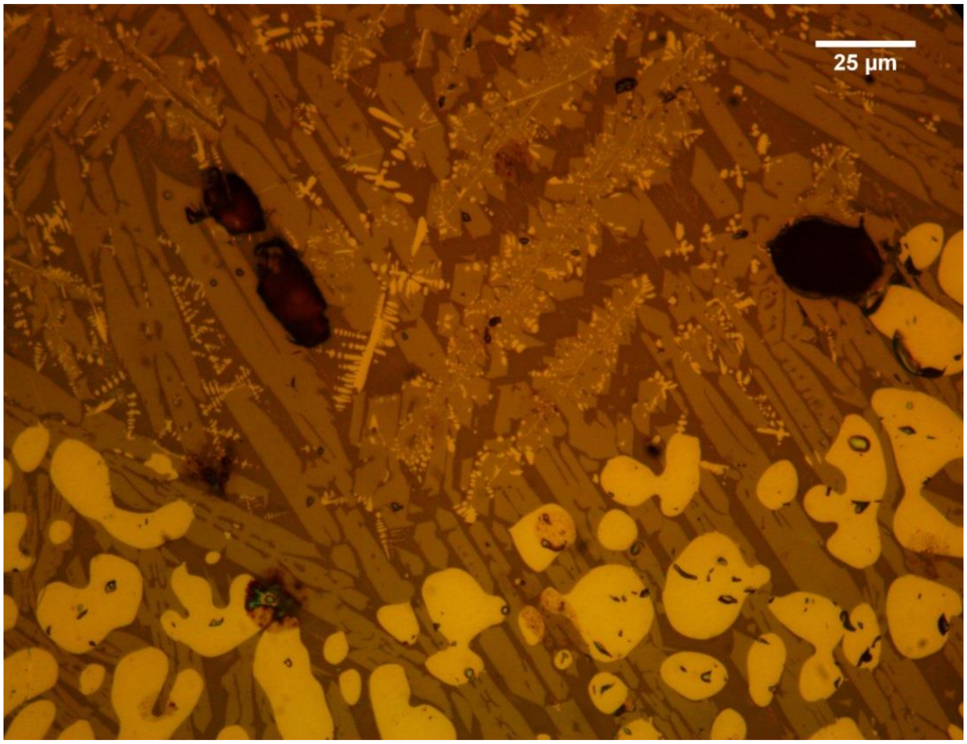

Figure II11e. Optical micrograph of distinct primary and secondary wüstite zones

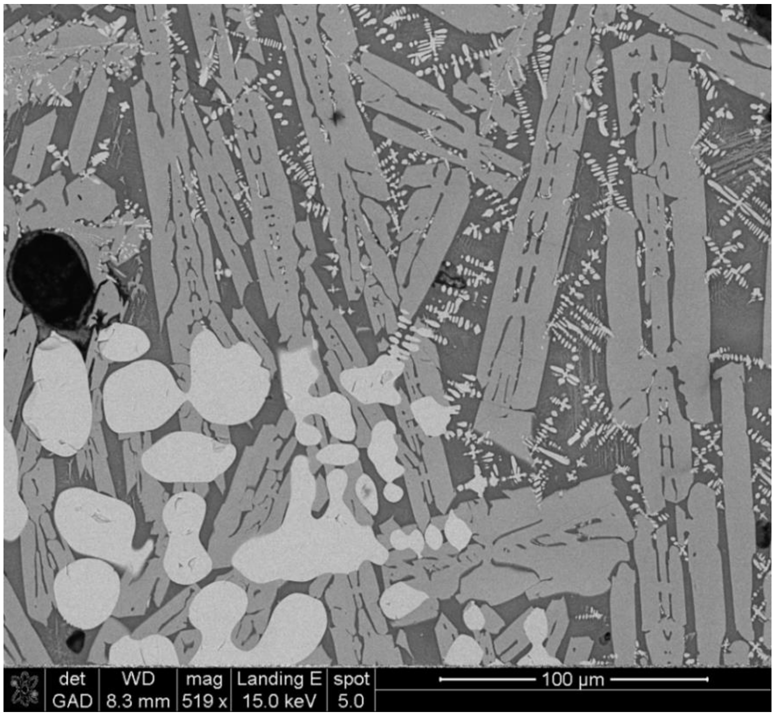

Figure II11f. Backscattered micrograph of distinct primary and secondary wüstite zones

Figure II11g. Backscattered micrograph of phases and external prilly slag surface

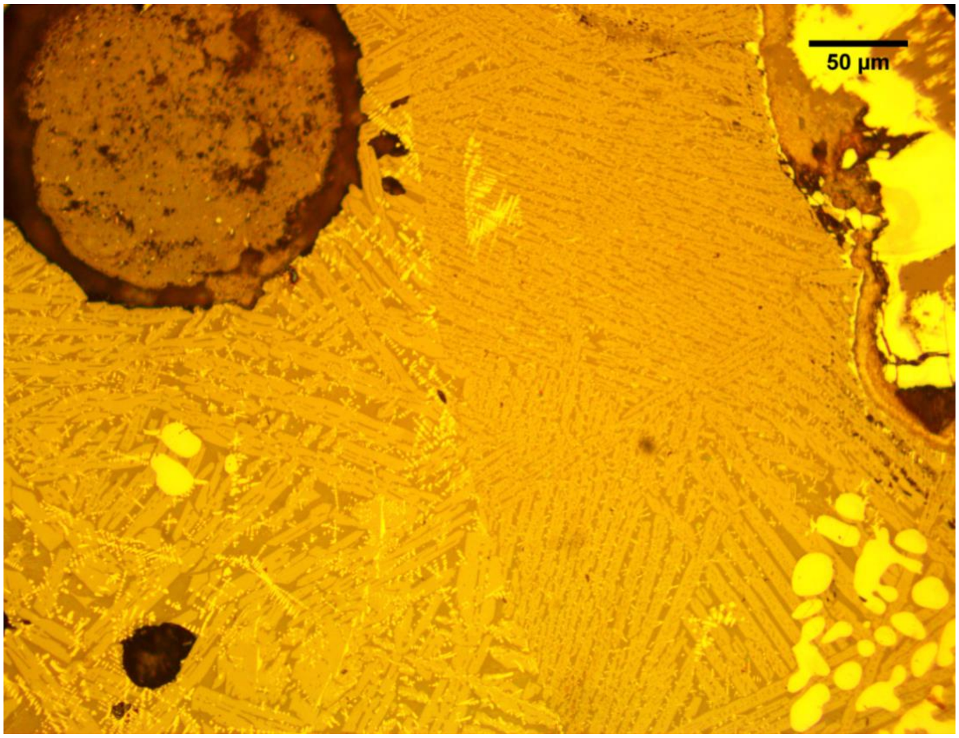

Figure II11h. Optical micrograph showing heterogeneity of various wüstite and silicate phases

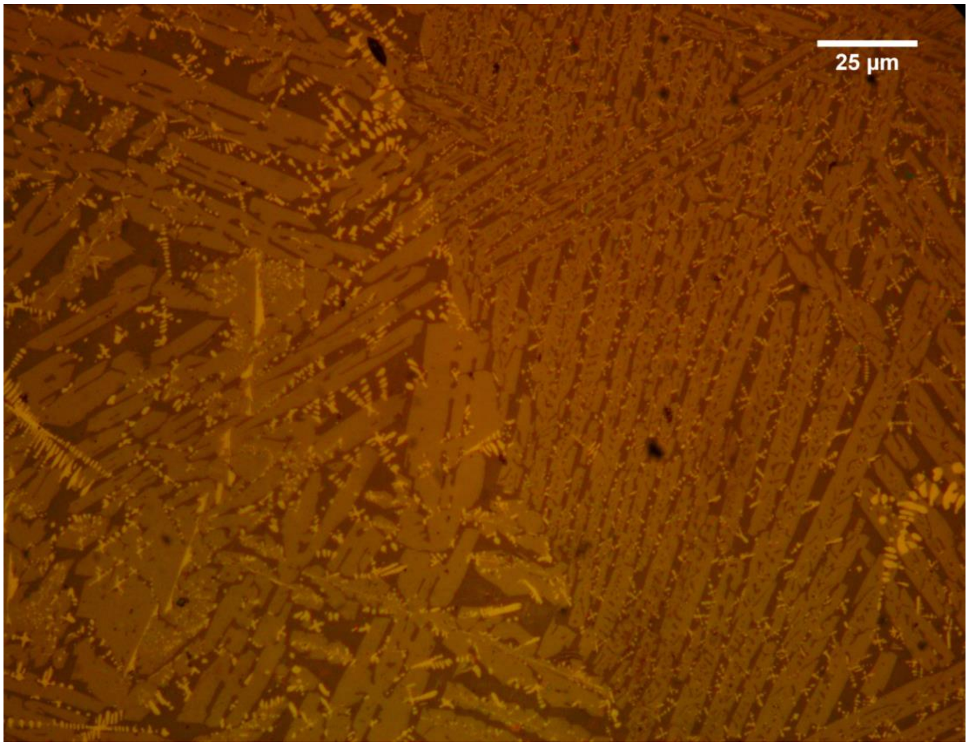

Figure II11i. Optical micrograph showing heterogeneity of various wüstite and silicate phases

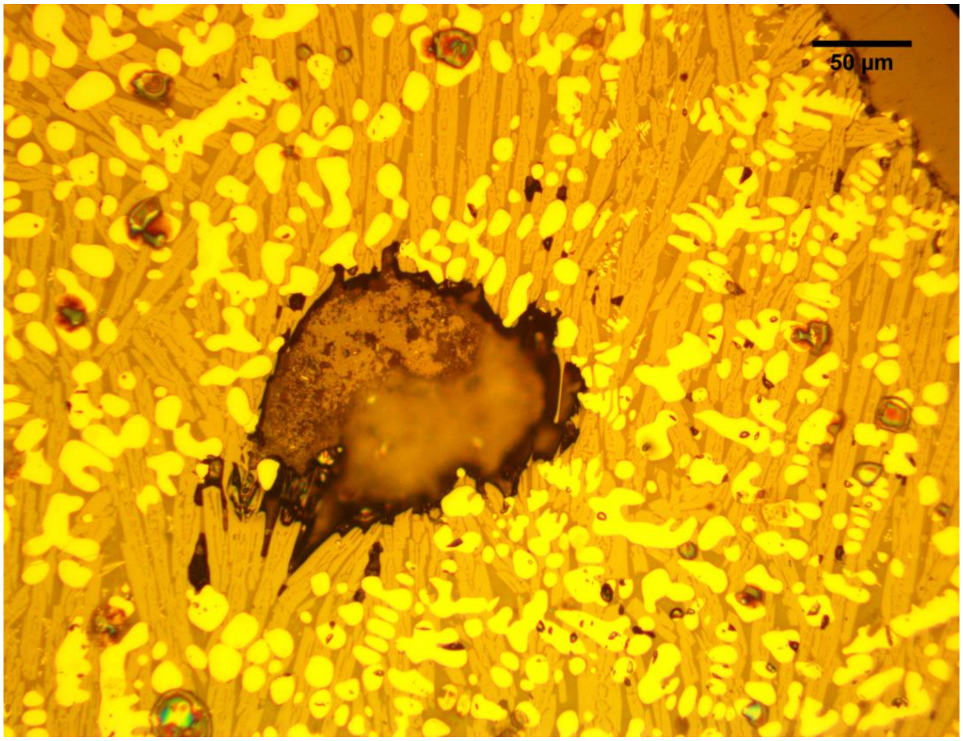

Figure II11j. Optical micrograph showing directionality of silicate flow

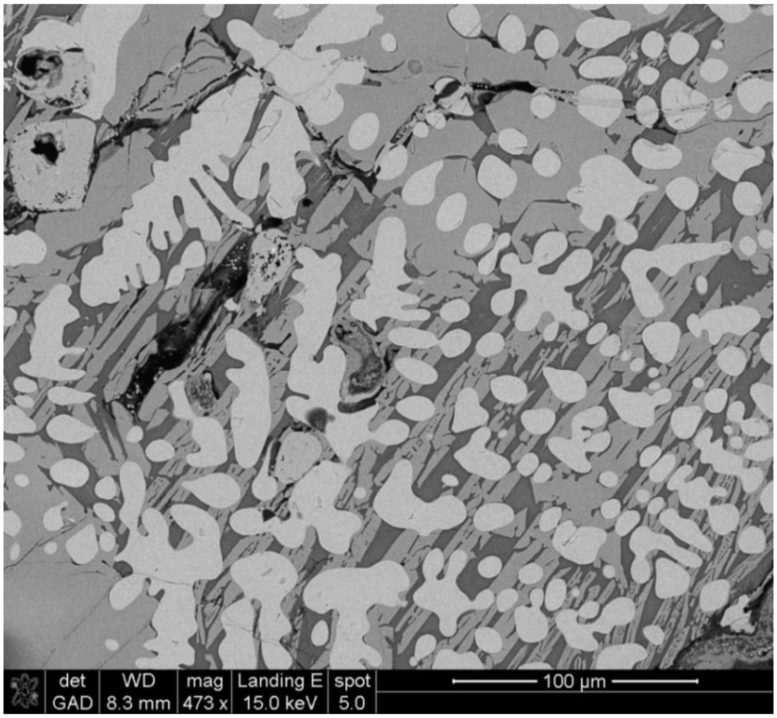

Figure II11k. Backscattered micrograph of phases

Figure II11l. EDS in wt%, spot 1: 19.95Fe 7.21Ca 3.57K 16.58Si 9.27Al 2.19Na 39.25O 1.98C; spot 2: 26.34Fe 5.59Ca 3.16K 15.25Si 8.43Al 0.12Mg 1.98Na 37.82O 1.30C

Figure II11m. EDS in wt%, spot 1: 74.31Fe 0.21Ti 0.19Ca 0.95Si 0.87Al 23.47O, verification of wüstite when excluding remnant impurities from beam size of one micron

Figure II11n. EDS in wt%, spot 1: 20.68Fe 0.23Ti 6.77Ca 2.88K 16.72Si 10.45Al 2.39Na 38.37O 1.51C; spot 2: 51.81Fe 0.70Ca 13.51Si 0.34Al 0.48Mg 31.25O 1.92C, fayalite

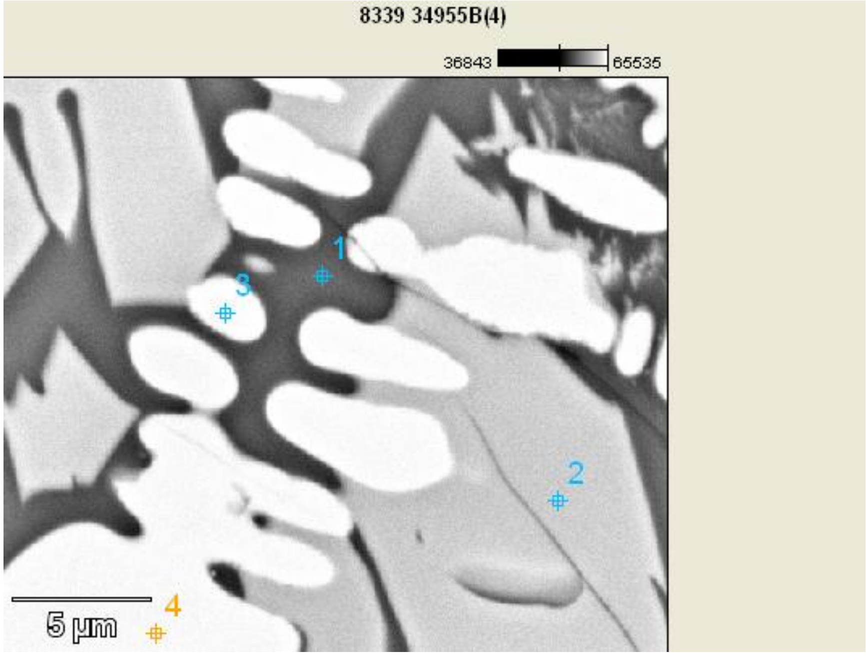

Figure II11o. EDS in wt%, spot 1: 19.84Fe 0.25Ti 6.30Ca 3.51K 17.31Si 10.52Al 2.12Na 38.81O 1.33C; spot 2, fayalite: 50.77Fe 0.30Mn 0.87Ca 0.14K 13.79Si 0.50Al 0.50Mg 31.70O 1.42C; spot 3, wüstite: 71.43Fe 0.42Ti 0.33Ca 0.18K 1.87Si 1.38Al 24.39O; (spot 4 also wüstite)

II12. Locus 8339, Artifact 38255A

Context: 800-600 BC.

Overview: Iron slag, high iron content, with secondary but no primary wüstite. Hammerscales are trapped in detritus. Figure II12d shows a calcium-rich detritus in which scales were trapped. This indicates presence of fluxing and forging activities.

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
8339 38255A	800-600	1	47.781±1.149	4.752±0.208	6.452±0.225	0.432±0.047	—

S	Al	Mn	Zr	Cu
0.245±0.027	—	—	0.008±0.002	—

Sn	Zn	Pb	Ni	As
—	—	—	—	0.007±0.003

Table II12. pXRF slag composition

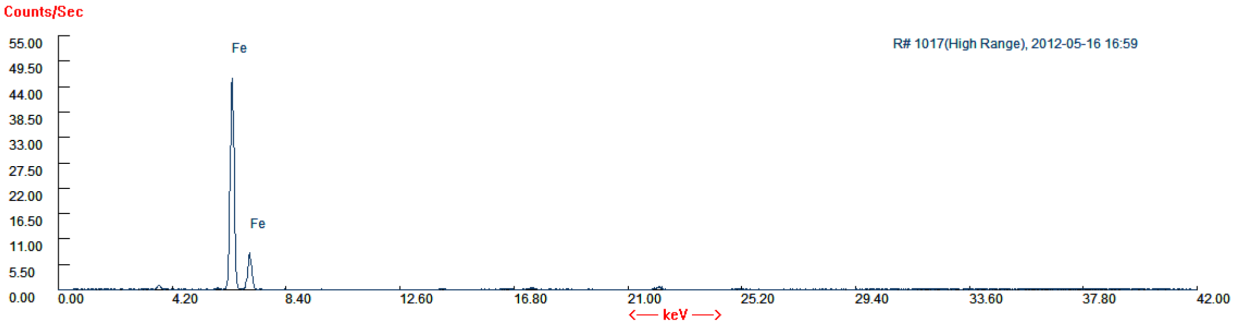

Figure II12a. pXRF spectrum

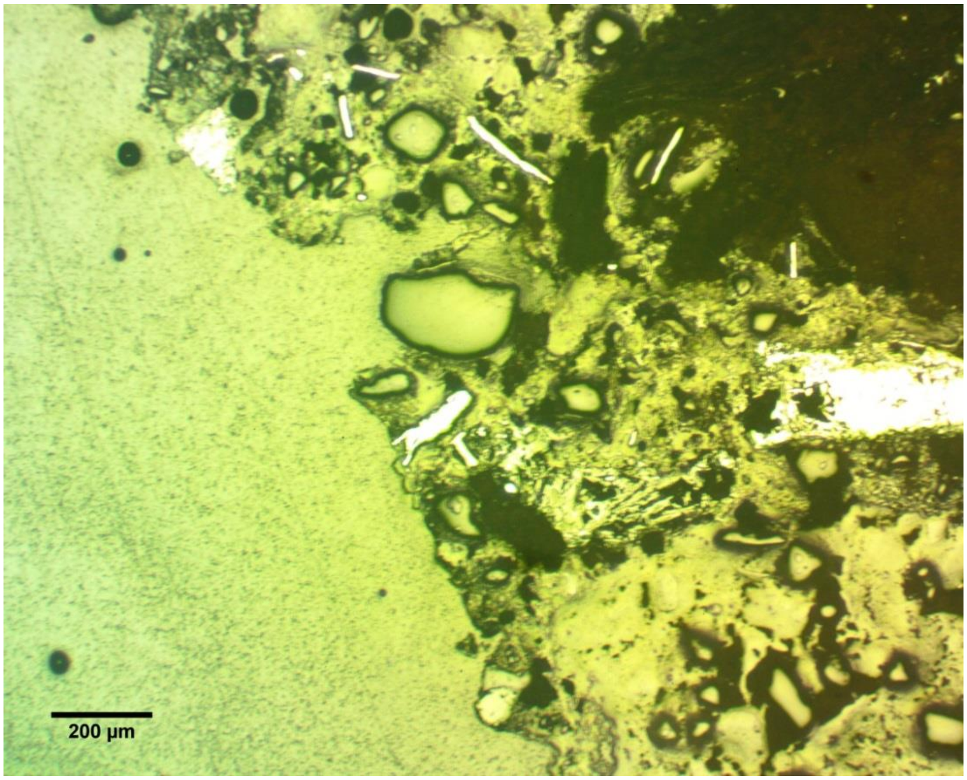

Figure II12b. Optical micrograph of hammer scales caught in detritus

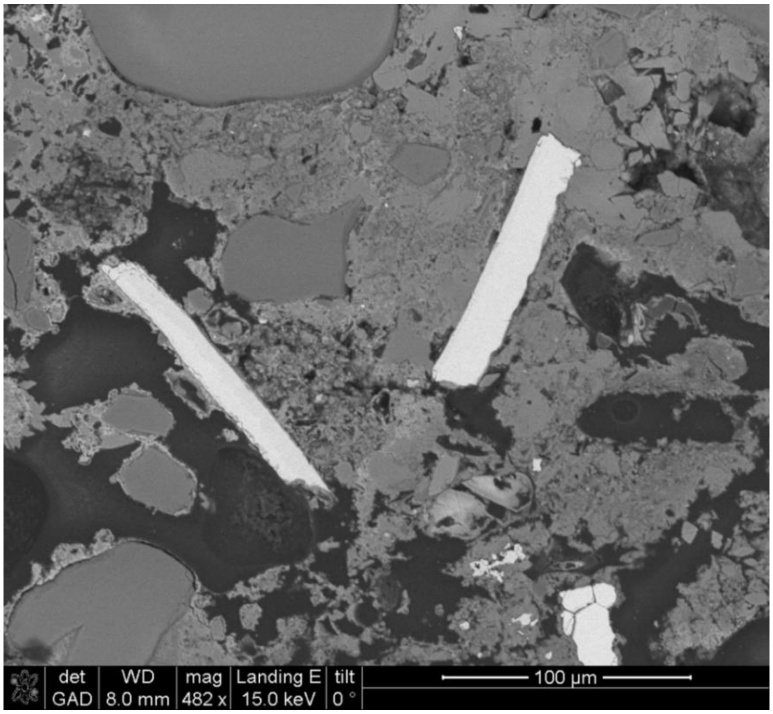

Figure II12c. Backscattered micrograph of hammer scales caught in detritus

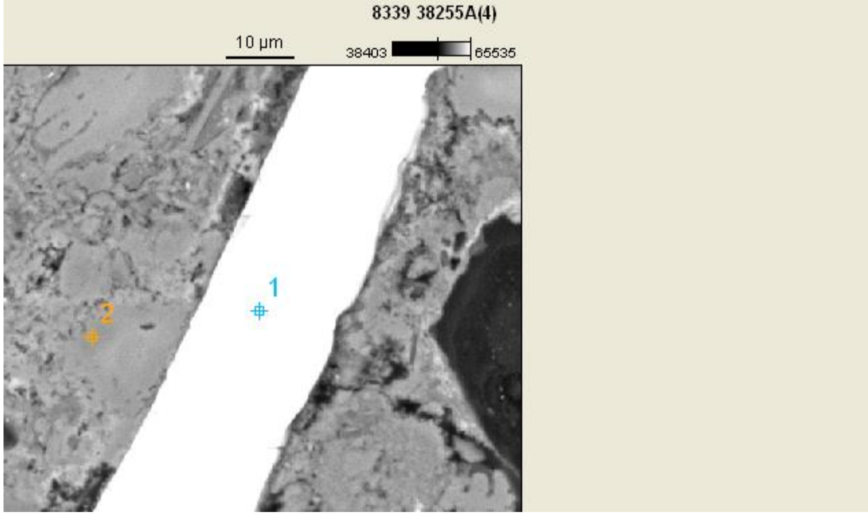

Figure II12d. EDS in wt%, spot 1: 72.24Fe 0.84Ca 0.64Si 0.09Al 24.15O 2.05C; spot 2: 2.95Fe 34.01Ca 0.14S 0.76Si 0.17Al 4.56Mg 0.22Na 50.19O 7.01C

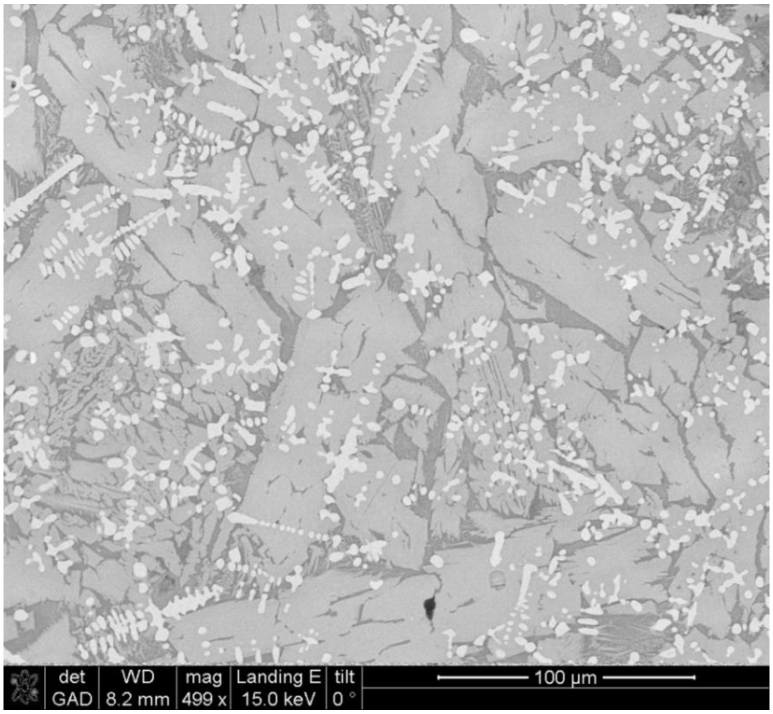

Figure II12e. Backscattered micrograph of various iron and silicate phases

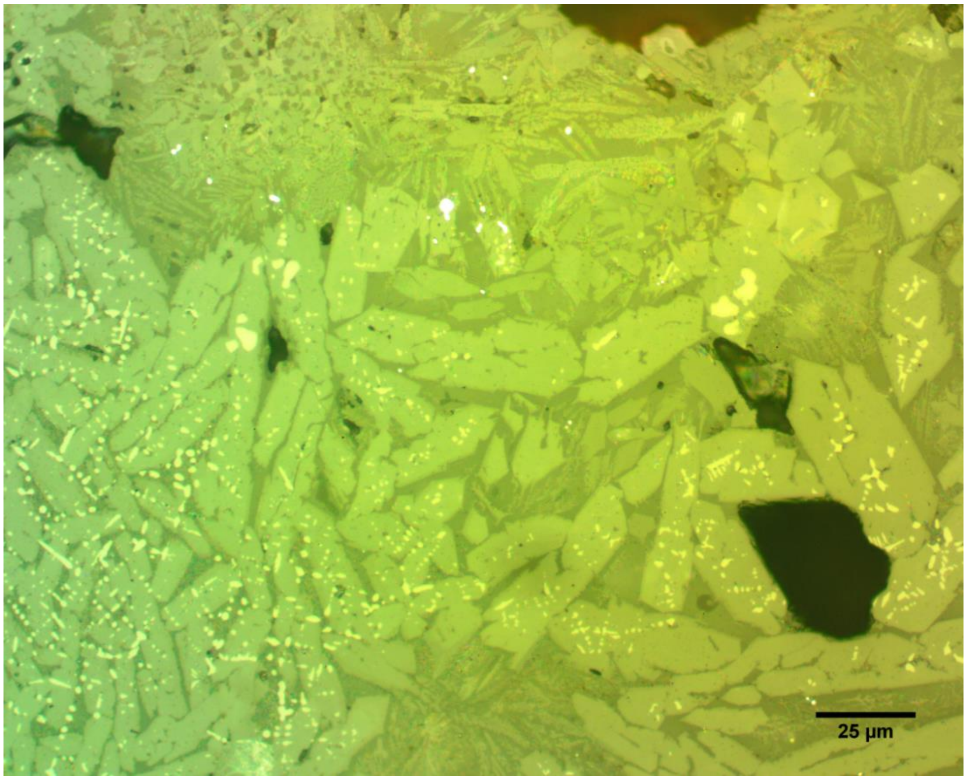

Figure II12f. Optical micrograph of various iron and silicate phases

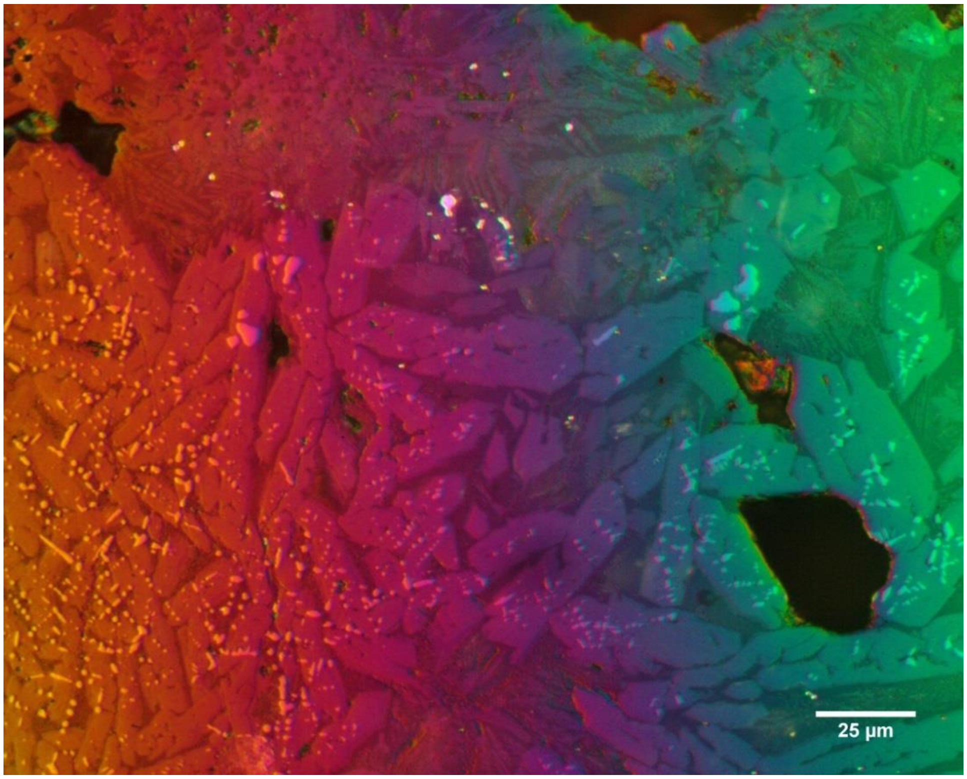

Figure II12g. DIC and red compensator plate micrograph of above Figure II12f

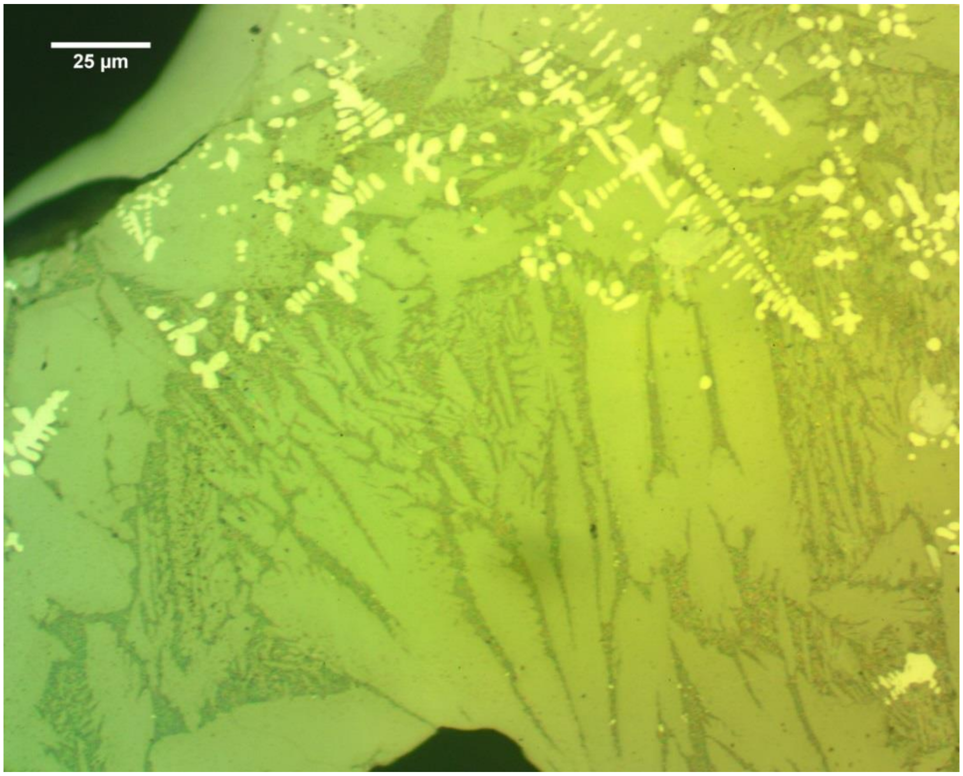

Figure II12h. Optical micrograph of various iron and silicate phases

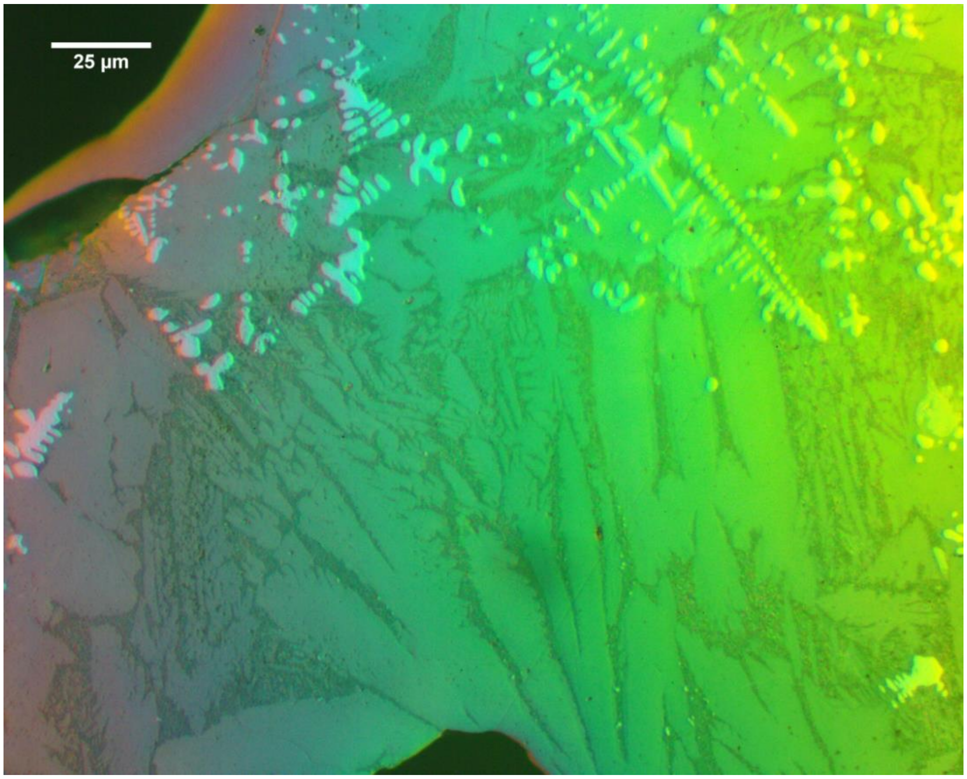

Figure II12i. DIC and red compensator plate micrograph of above Figure II12h

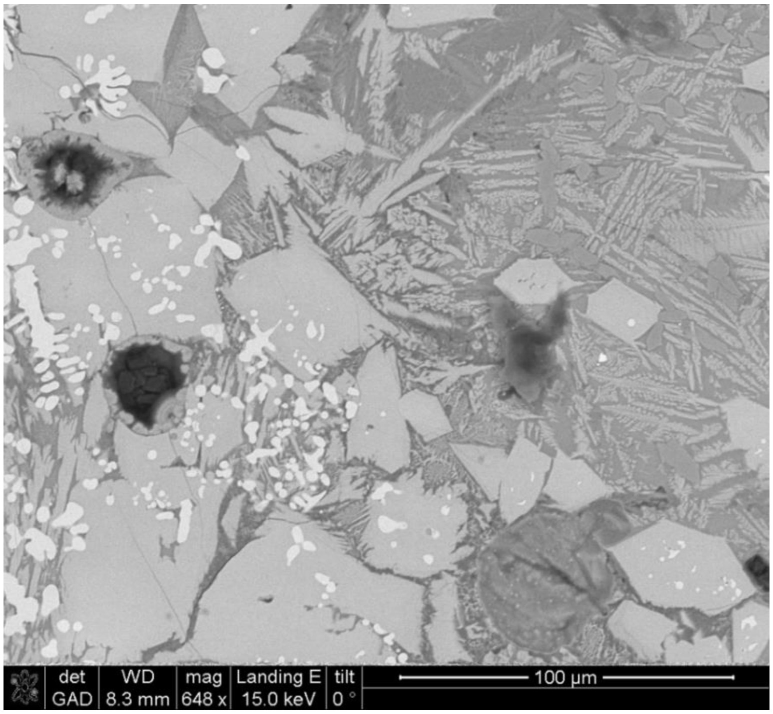

Figure II12j. Backscattered micrograph of various iron and silicate phases

II13. Locus 8339, Artifact 38255B

Context: 800-600 BC.

Overview: Iron slag with secondary wüstite, and fayalite/silicates in a glassy matrix. Figures II13b and c are representative of tap slag.

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P	S	Al	Mn	Zr	Cu	Sn	Zn	Pb	Ni	As
8339 38255B	800-600	1	13.986±0.35	2.785±0.161	8.353±0.278	0.541±0.047	0.23±0.059	0.193±0.021	—	—	0.013±0.002	—	—	—	—	—	—

Table II13. pXRF slag composition

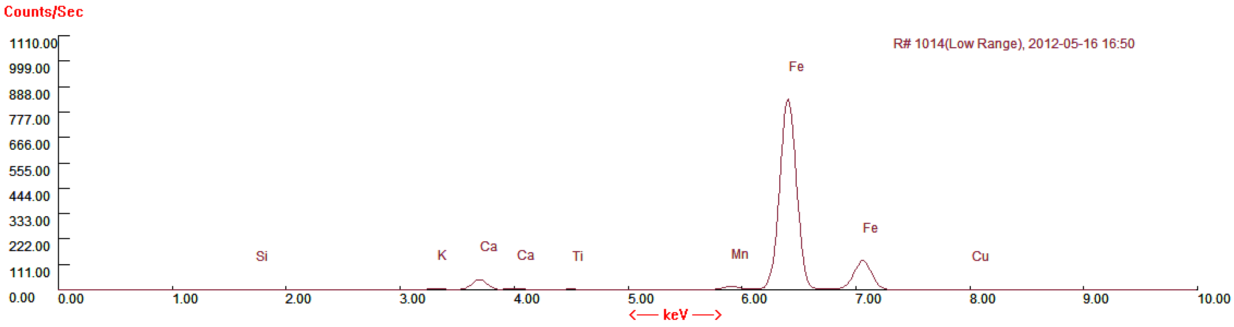

Figure II13a. pXRF spectrum

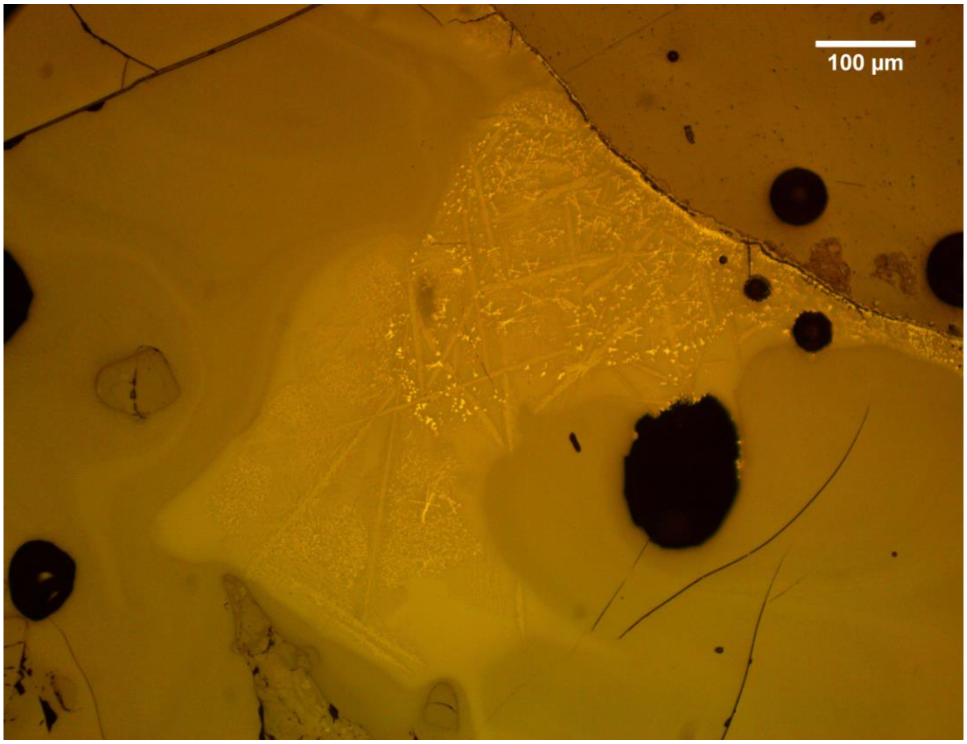

Figure II13b. Optical micrograph of secondary wüstite, and fayalite/silicates in a glassy matrix

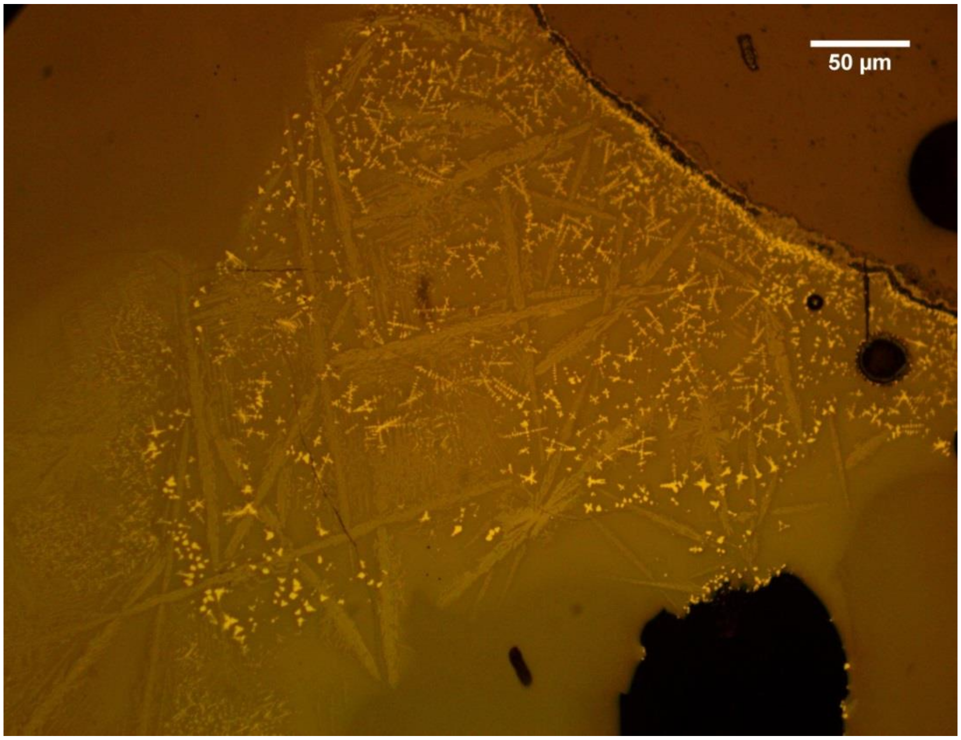

Figure II13c. Optical micrograph of secondary wüstite, and fayalite/silicates in a glassy matrix

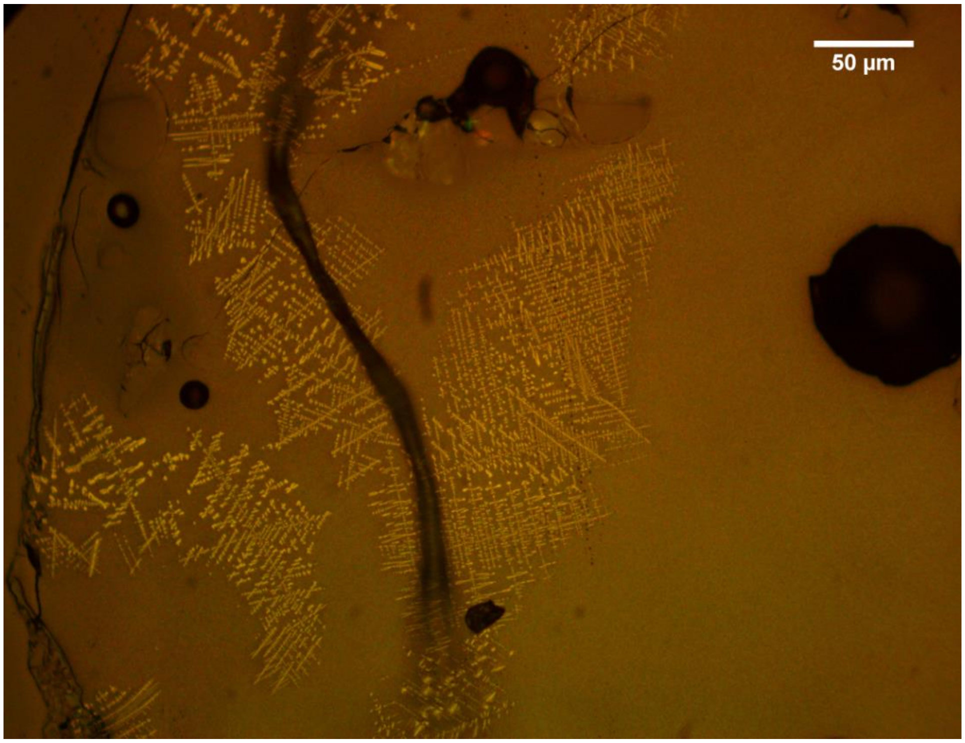

Figure II13d. Optical micrograph of secondary wüstite in a glassy matrix

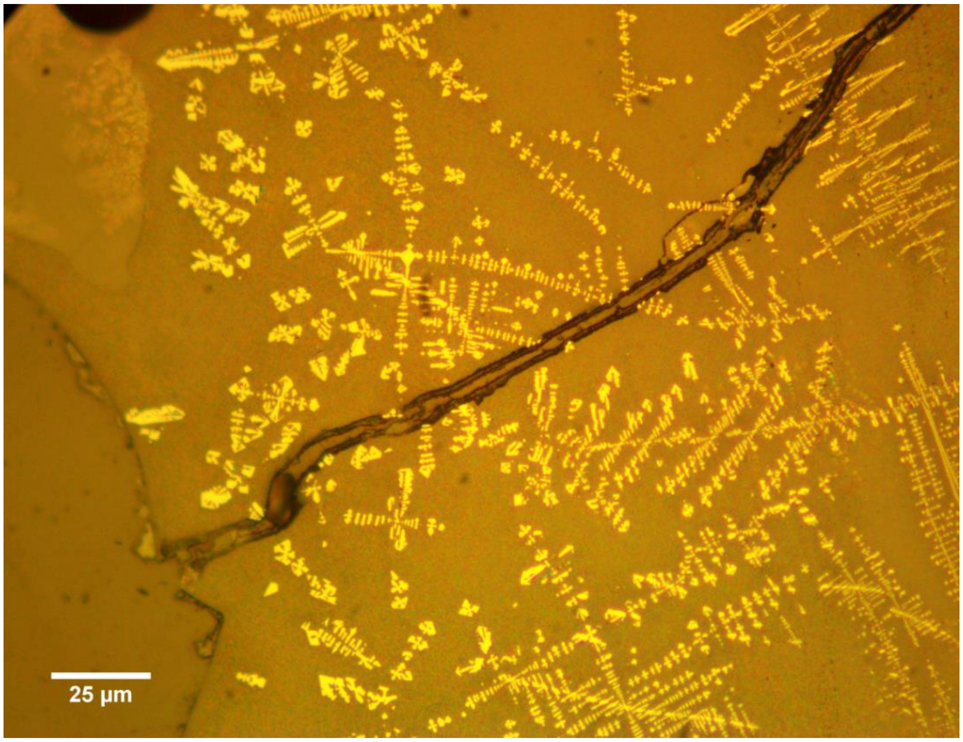

Figure II13e. Optical micrograph of secondary wüstite in a glassy matrix

II14. Locus 8360, Artifact 34930

Context: 700-600 BC.

Overview: Iron slag, high iron content, mostly primary wüstite, with silicate phases. Multiple inclusions of pure iron evidence the goal of iron smelting and smithing.

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P	S	Al	Mn	Zr	Cu	Sn	Zn	Pb	Ni	As
8360 34930	700-600	1	40.103±0.587	4.117±0.145	6.234±0.146	0.218±0.031	—	0.131±0.017	—	—	0.008±0.001	—	—	0.009±0.003	—	—	—

Table II14. pXRF slag composition

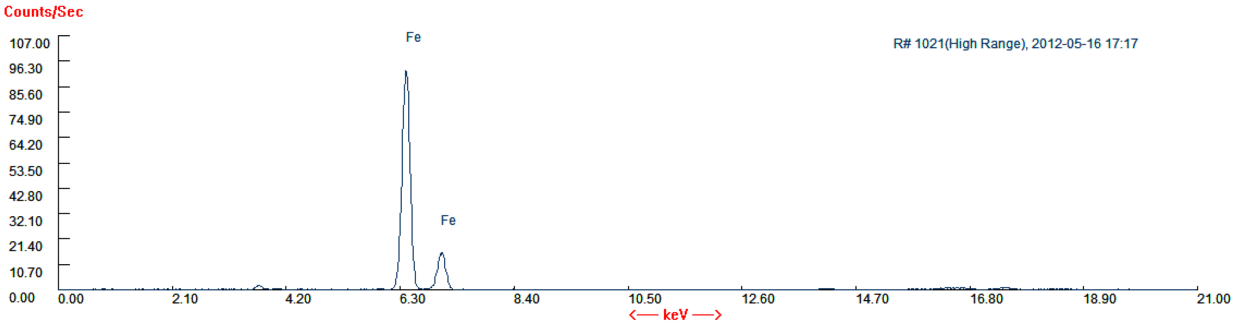

Figure II14a. pXRF spectrum

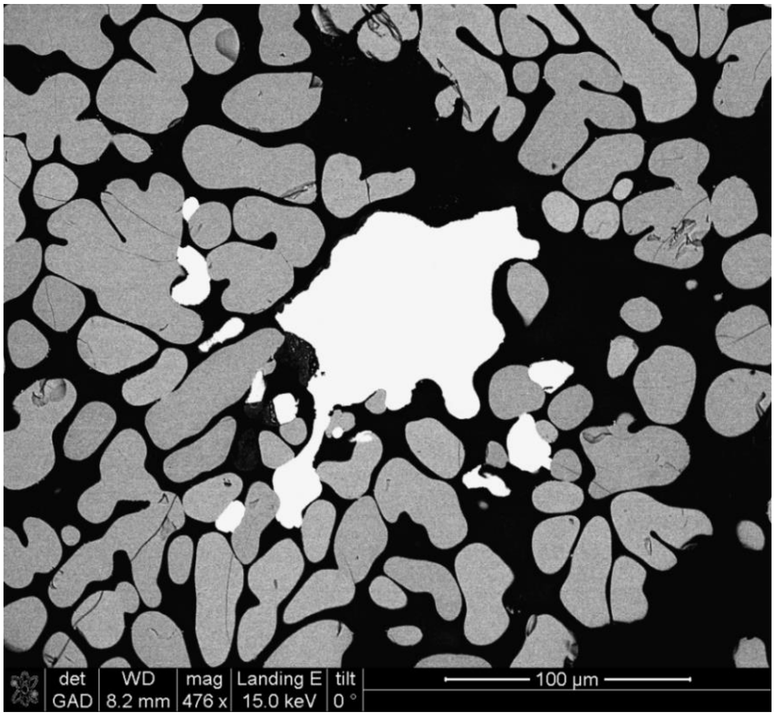

Figure II14b. EDS in wt% of iron blob: 99.27Fe 0.23Ca 0.50Si

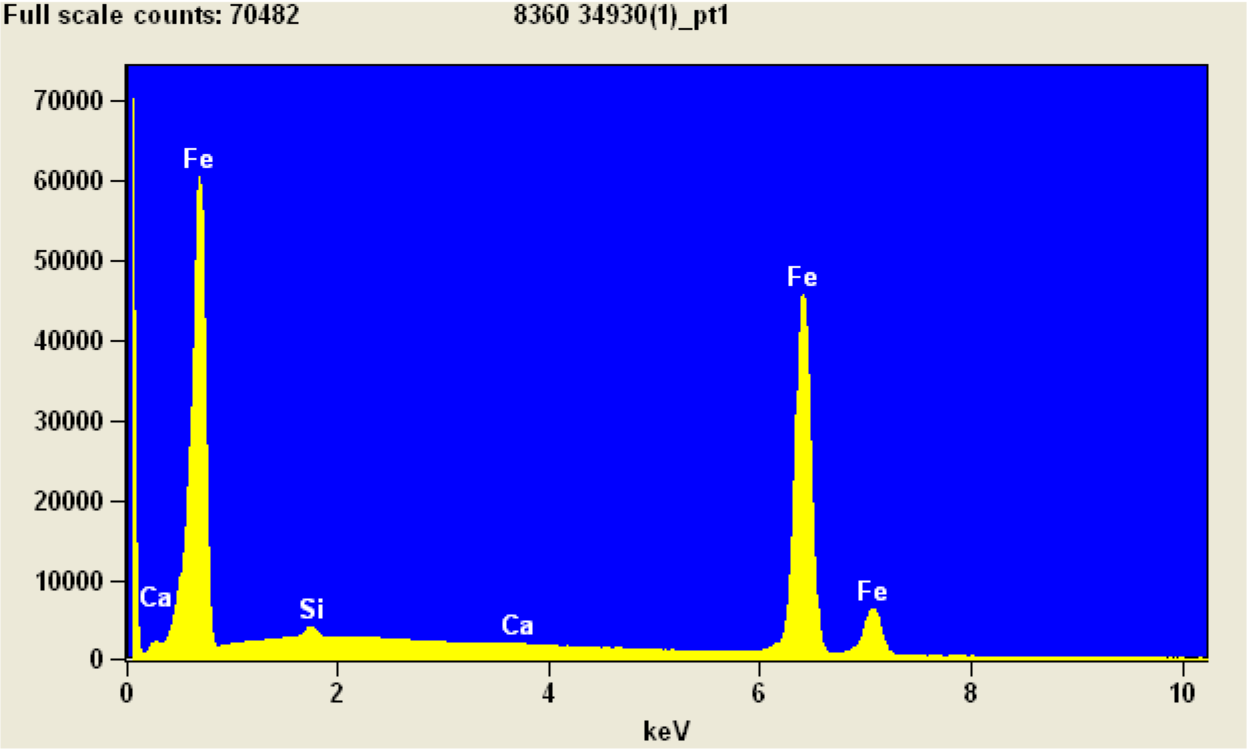

Figure II14c. EDS spectrum of above Figure II14b

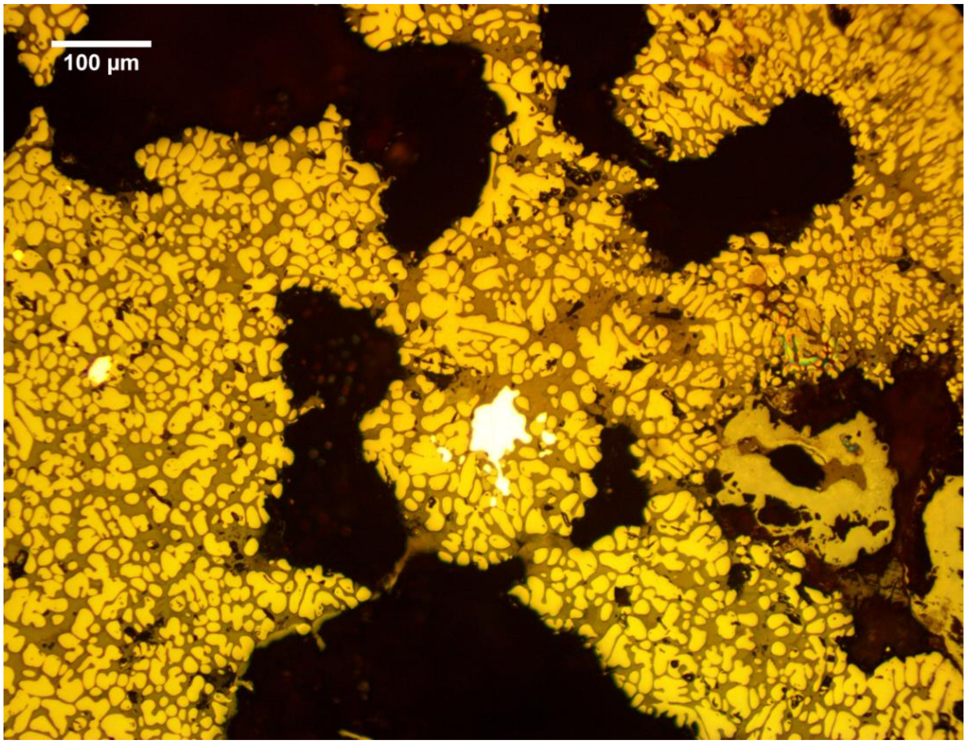

Figure II14d. Optical micrograph of iron prill in primary wüstite and silicates matrix

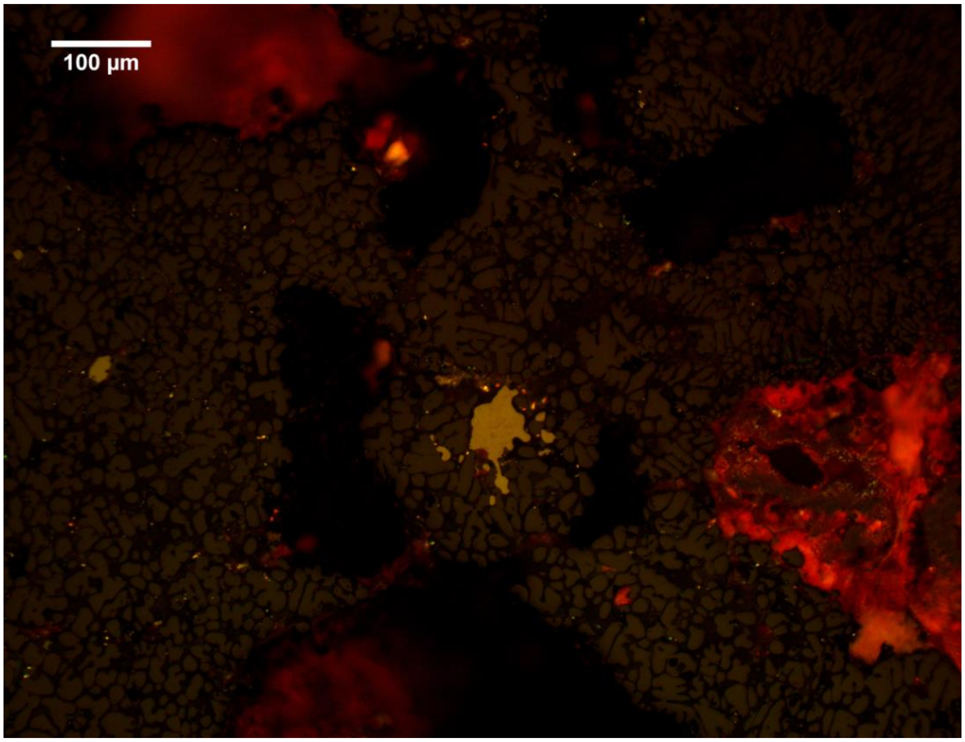

Figure II14e. Polarized optical micrograph of above Figure II14d

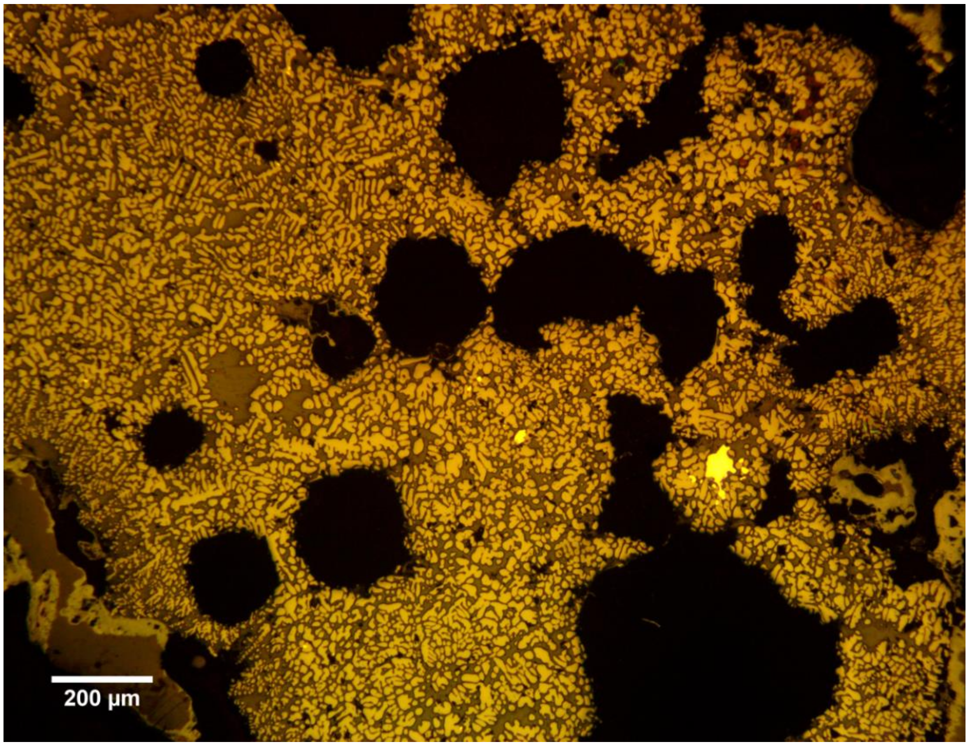

Figure II14e. Optical micrograph of iron prill in primary wüstite and silicates matrix

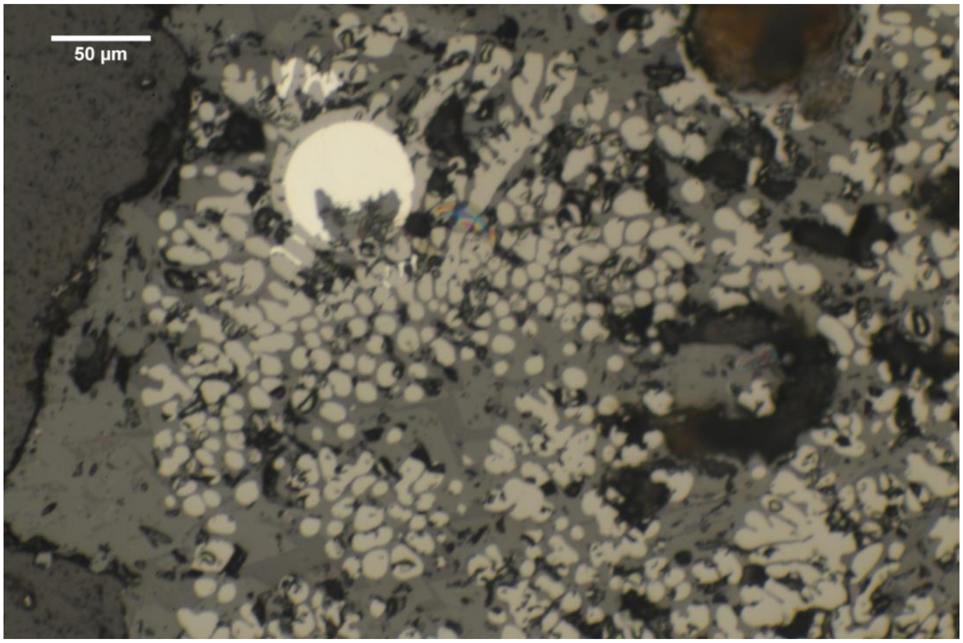

Figure II14f. Optical micrograph of iron prill in primary wüstite and silicates matrix

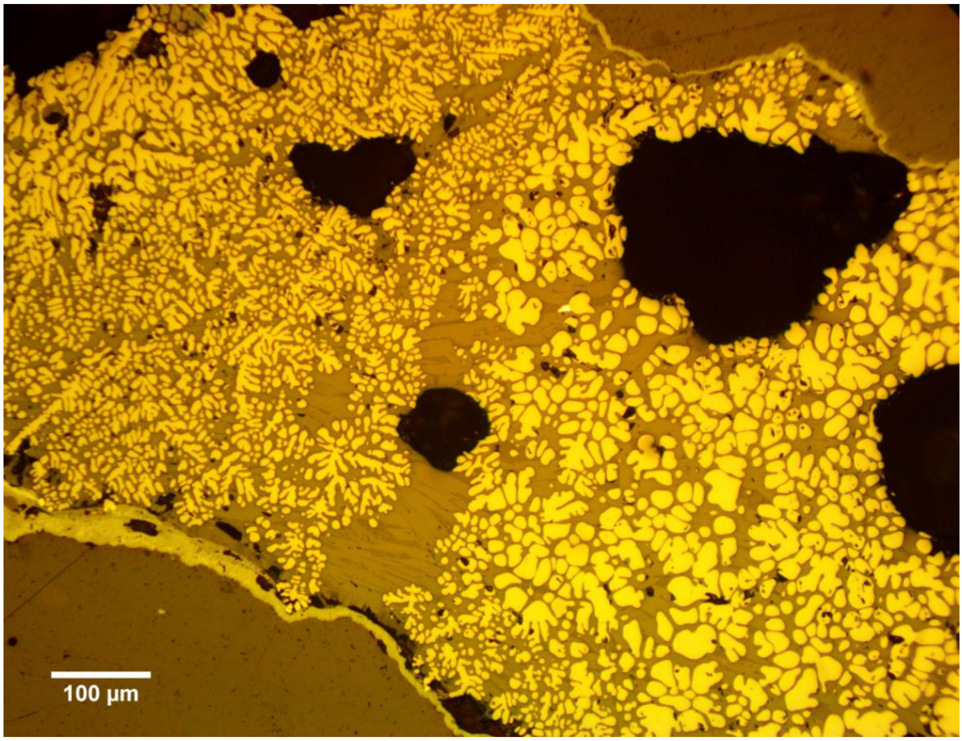

Figure II14f. Optical micrograph of various phases

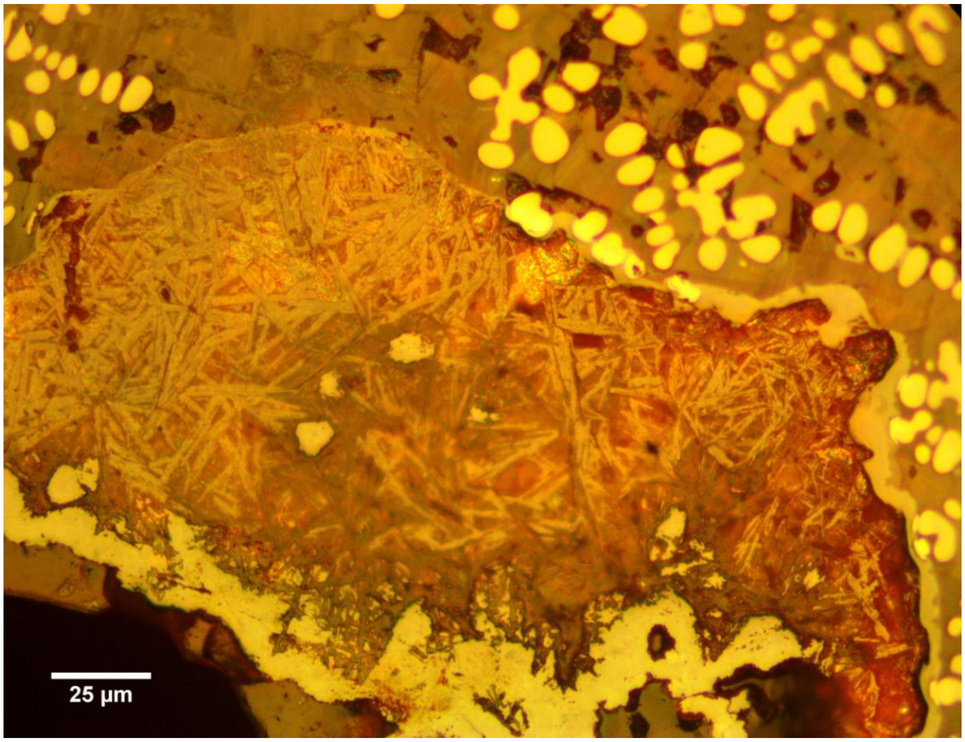

Figure II14f. Optical micrograph of weathered area, primary wüstite, and silicates

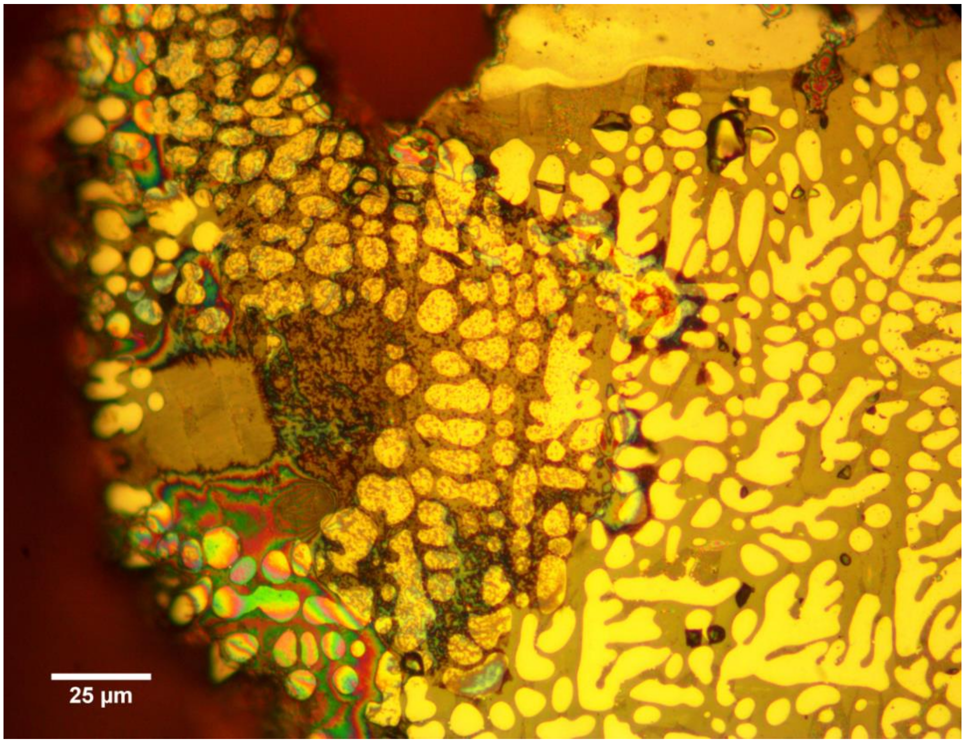

Figure II14g. Optical micrograph of stained wüstite from post-polishing oxidation

ii. *550-475 BC*

II15. Locus 1113, Artifact 38057

Context: 525-475 BC – "= 1104, 1105, 1106, 1107, 1108, (below) 1109, 1110, (next to) 1114, (above) 1117, 1118, 1122: Compact levelling layer."

Overview: Iron slag, high iron content, with primary and secondary wüstite, and fayalite in glassy matrix. The portions with fayalite and secondary wüstite are indicative of tap slags.

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
1113 38057	525-475	2	39.71±0.398	3.909±0.132	3.814±0.097	0.367±0.057	0.907±0.032

S	Al	Mn	Zr	Cu
0.279±0.015	0.453±0.167	—	0.008±0.001	0.017±0.004

Sn	Zn	Pb	Ni	As
0.006±0.003	0.017±0.002	0.012±0.002	—	0.052±0.002

Table II15. pXRF spectrum

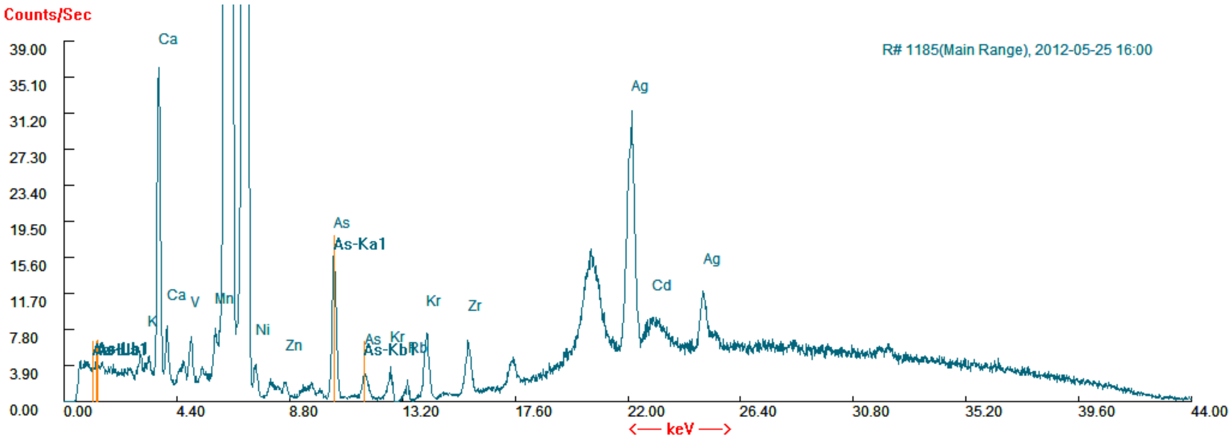

Figure II15a. pXRF spectrum with arsenic peaks

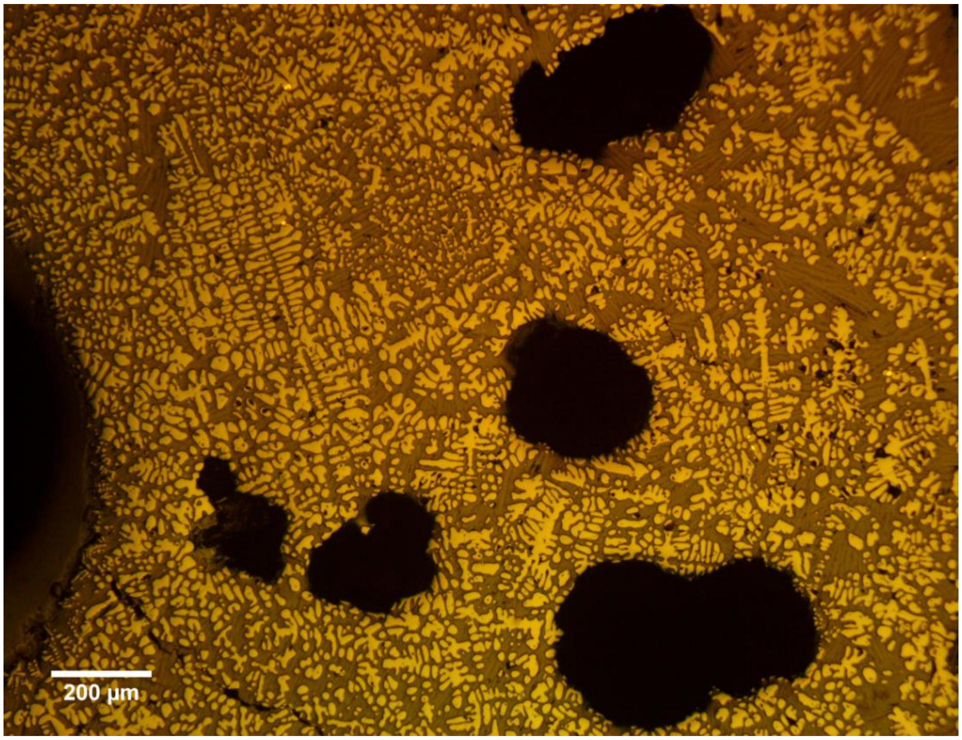

Figure II15b. Optical micrograph of various iron and silicate phases

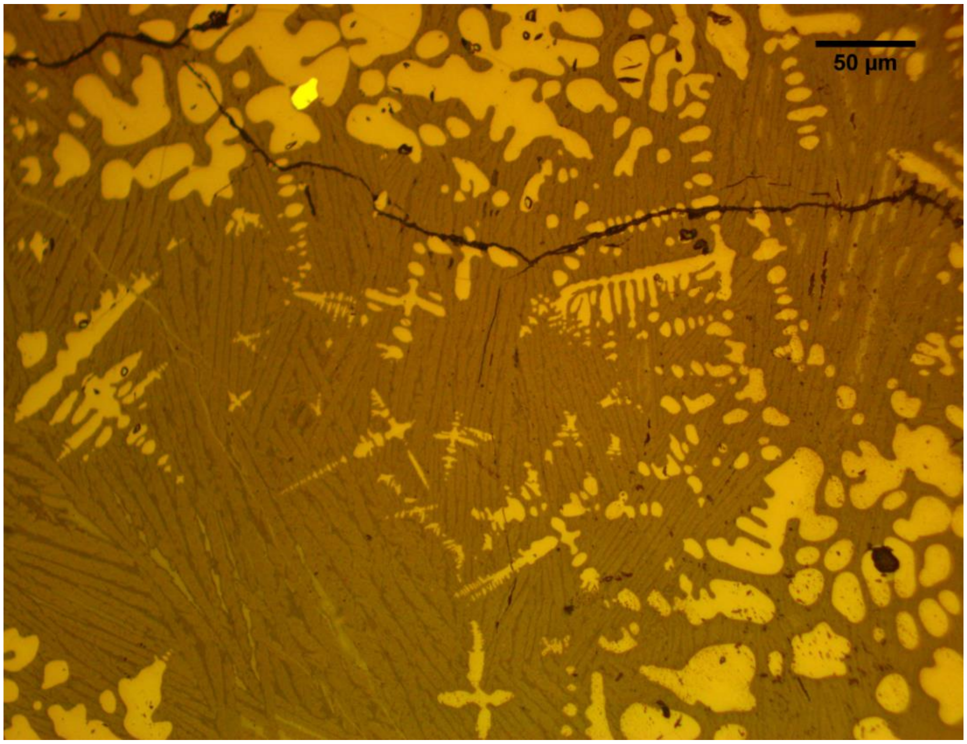

Figure II15c. Optical micrograph of primary and secondary wüstite, and fayalite in glassy matrix

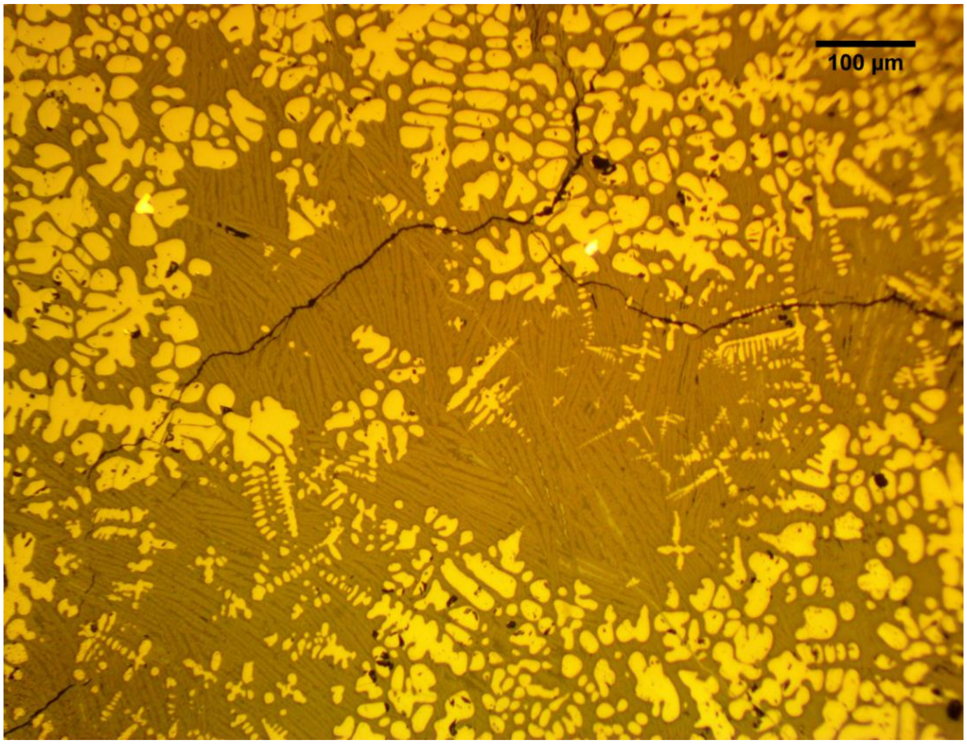

Figure II15d. Optical micrograph of primary and secondary wüstite, and fayalite in glassy matrix

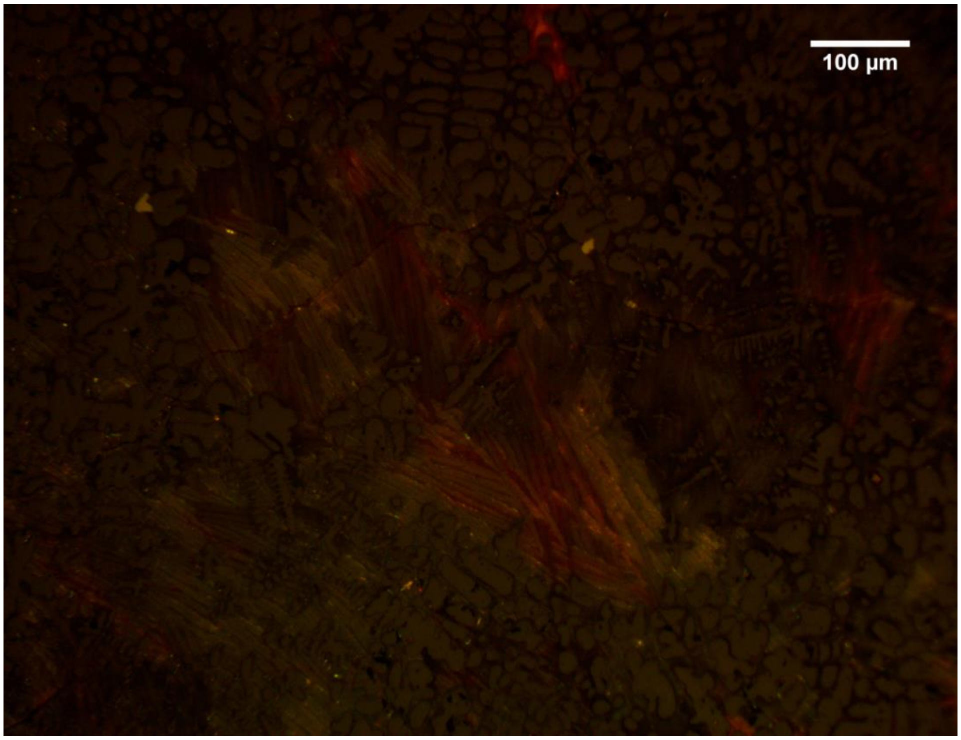

Figure II15e. Polarized optical micrograph of above Figure II15d

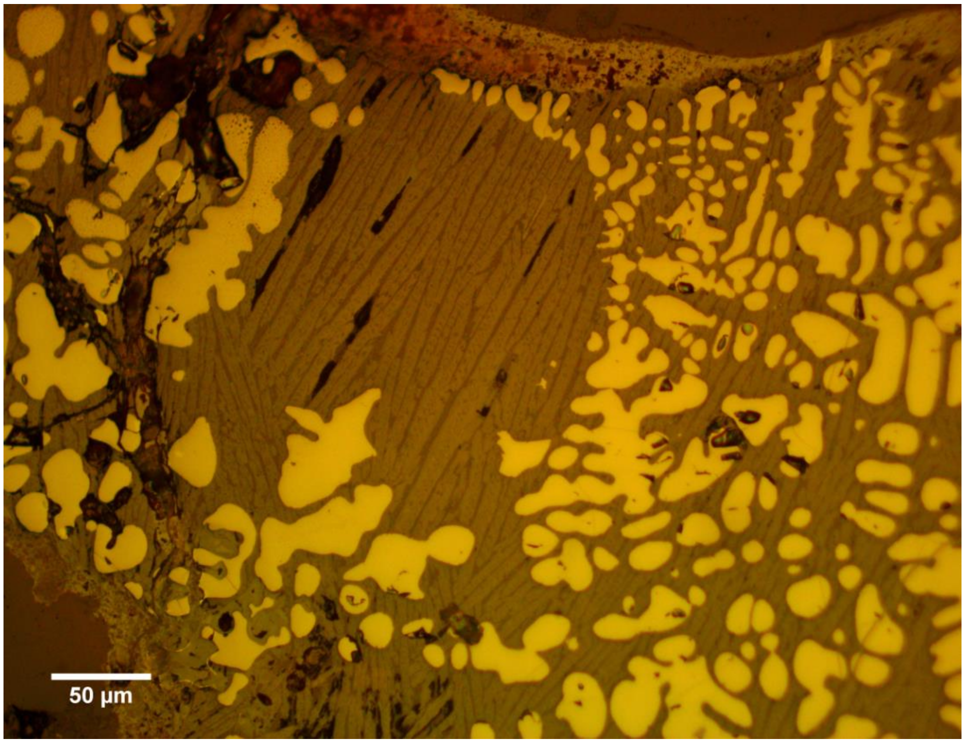

Figure II15f. Optical micrograph of primary and secondary wüstite, and fayalite in glassy matrix

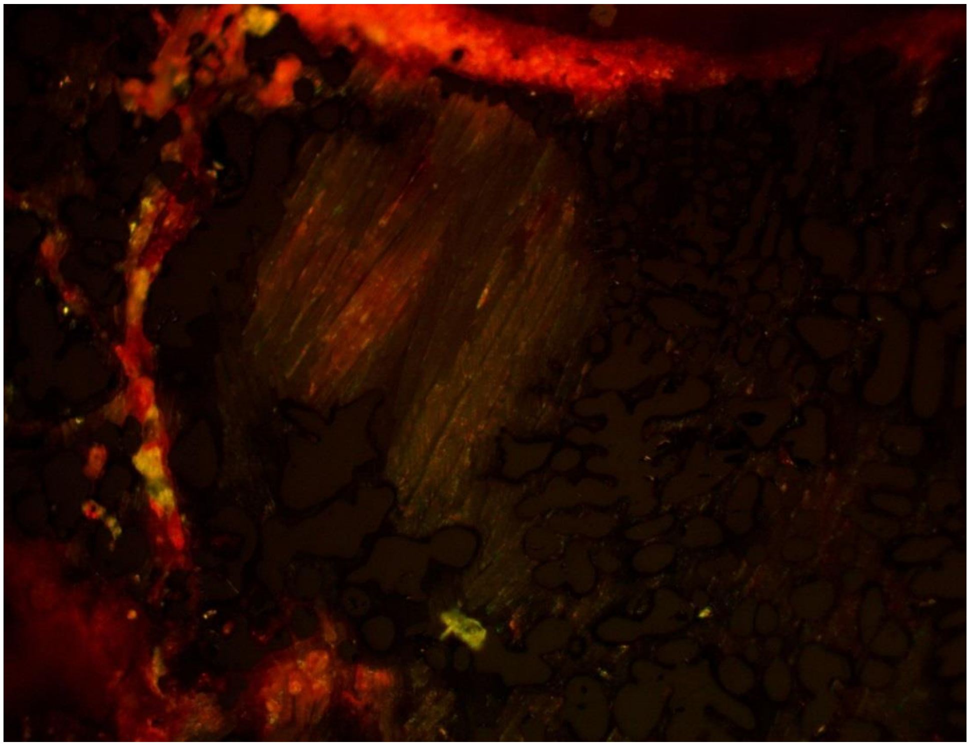

Figure II15g. Polarized optical micrograph of above Figure II15f

II16. Locus 1249

Context: 525-500 BC – “Street layer.”

Overview: Iron slag, high iron content, with primary and secondary wüstite, and fayalite in glassy matrix. The upper part of Figure II16b indicates a tap slag.

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
1249	525-500	1	47.511±0.486	10.986±0.202	1.645±0.066	0.083±0.033	0.386±0.026

S	Al	Mn	Zr	Cu
0.07±0.012	—	—	—	0.01±0.004

Sn	Zn	Pb	Ni	As
—	—	0.009±0.002	—	0.003±0.001

Table II16. pXRF slag composition

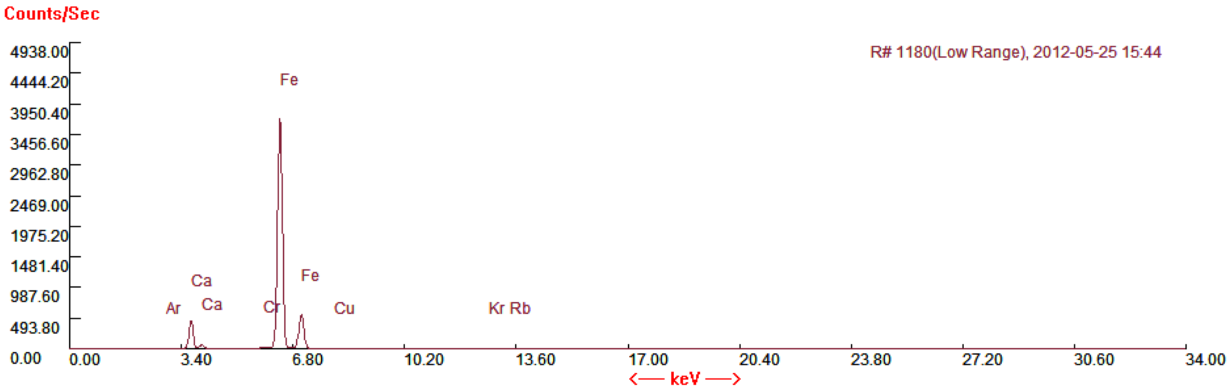

Figure II16a. pXRF spectrum

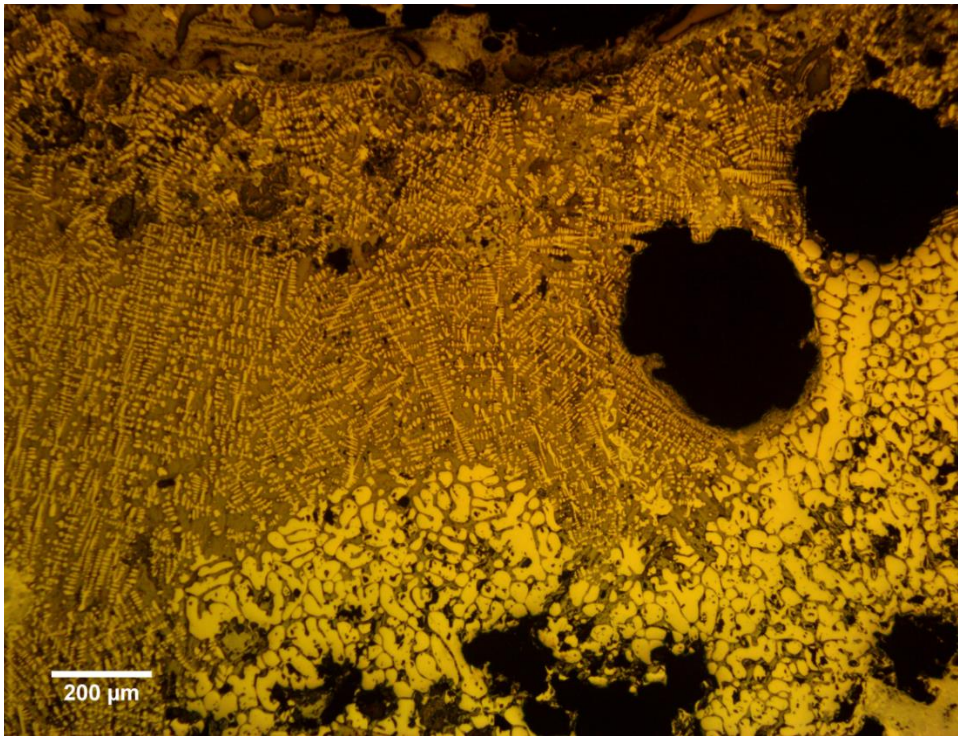

Figure II16b. Optical micrograph of primary and secondary wüstite, and fayalite in glassy matrix

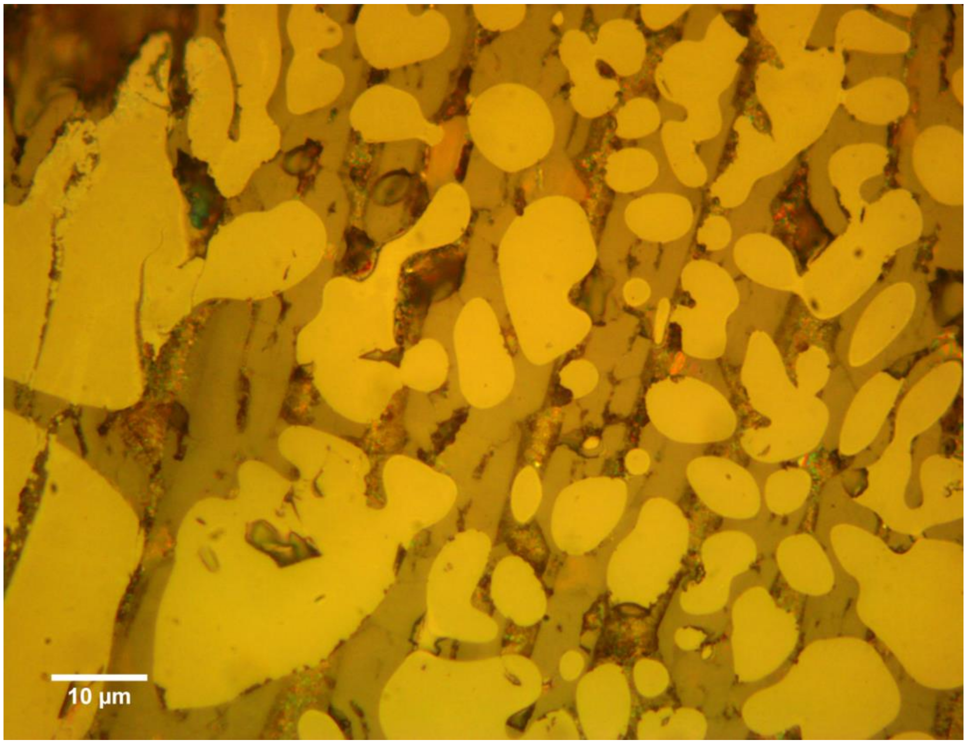

Figure II16c. Optical micrograph of primary wüstite, and fayalite in glassy matrix

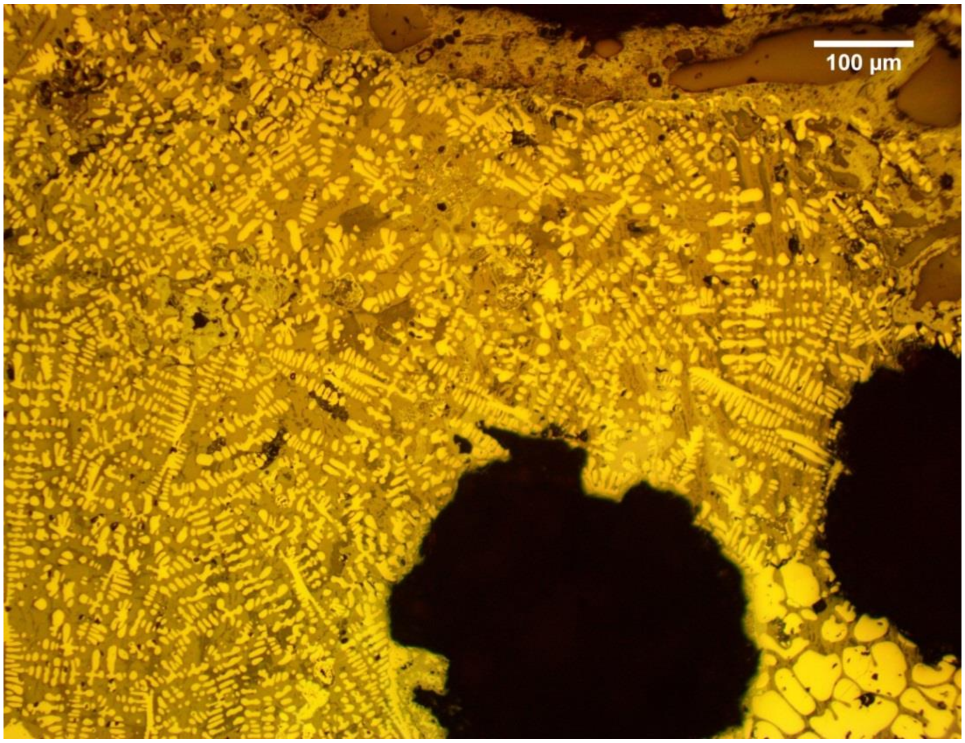

Figure II16d. Optical micrograph of primary and secondary wüstite, and fayalite in glassy matrix

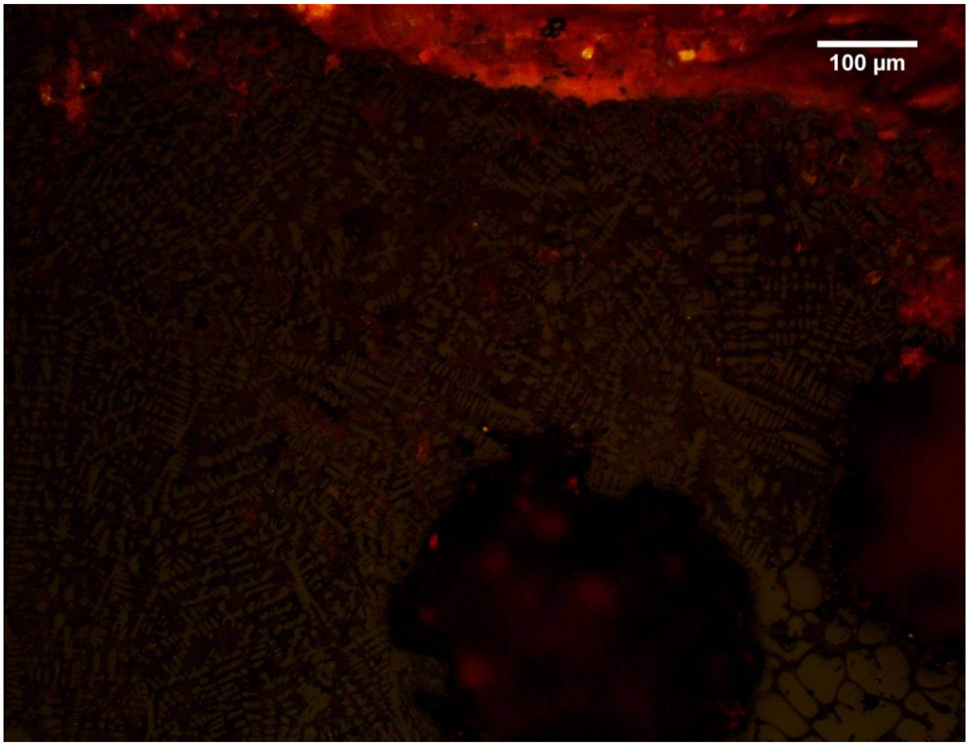

Figure II16e. Polarized optical micrograph of above Figure II16d

iii. *330-300 BC*

II17. Locus 2504, Artifact 45012

Context: 330-300 BC – = 2420?; 1 coin. Sandy layered level below 2503.”

Overview: Iron slag, high iron content, various iron phases including iron oxide stringers. These stringers are identified as two eutectics in a bloomery slag, Bachmann 1982: 32, plate XXIVb and c).

Artifact	Dates BC	Spots	Fe	Ca	Si	K	P
2504 45012	330-300	1	48.79±1.008	2.184±0.153	5.047±0.178	0.286±0.042	0.499±0.048

S	Al	Mn	Zr	Cu
0.262±0.024	—	—	0.011±0.002	—

Sn	Zn	Pb	Ni	As
—	0.011±0.004	—	—	0.009±0.003

Table II17. pXRF slag composition

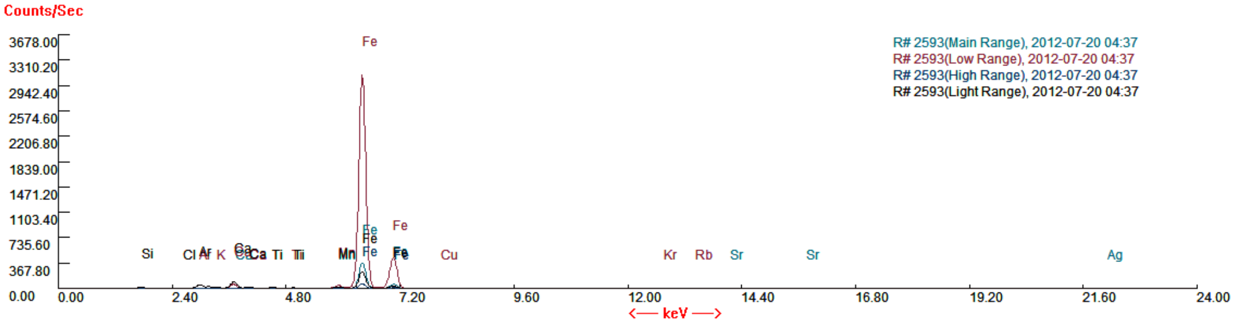

Figure II17a. pXRF spectrum

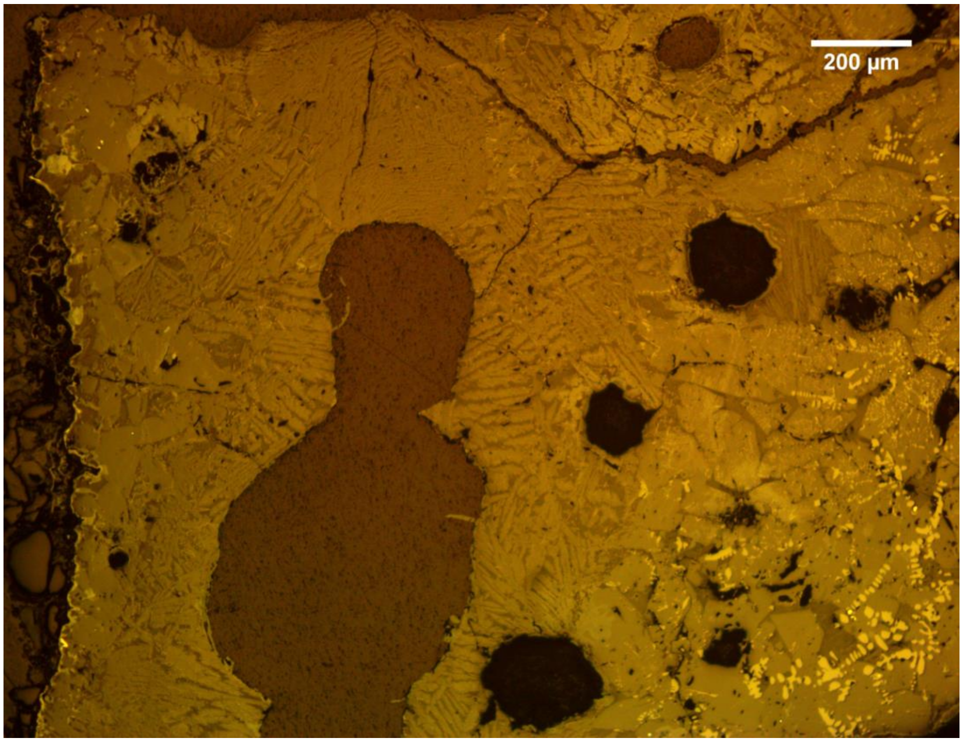

Figure II17b. Optical micrograph of various iron and silicate phases

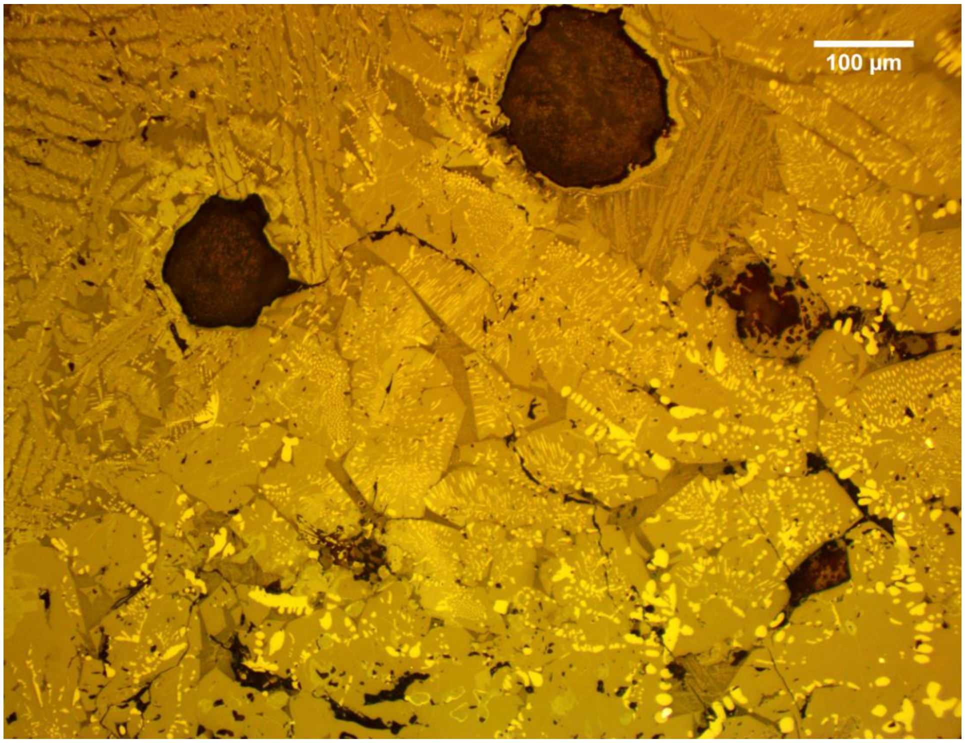

Figure II17c. Optical micrograph of various iron and silicate phases, including iron oxide stringers

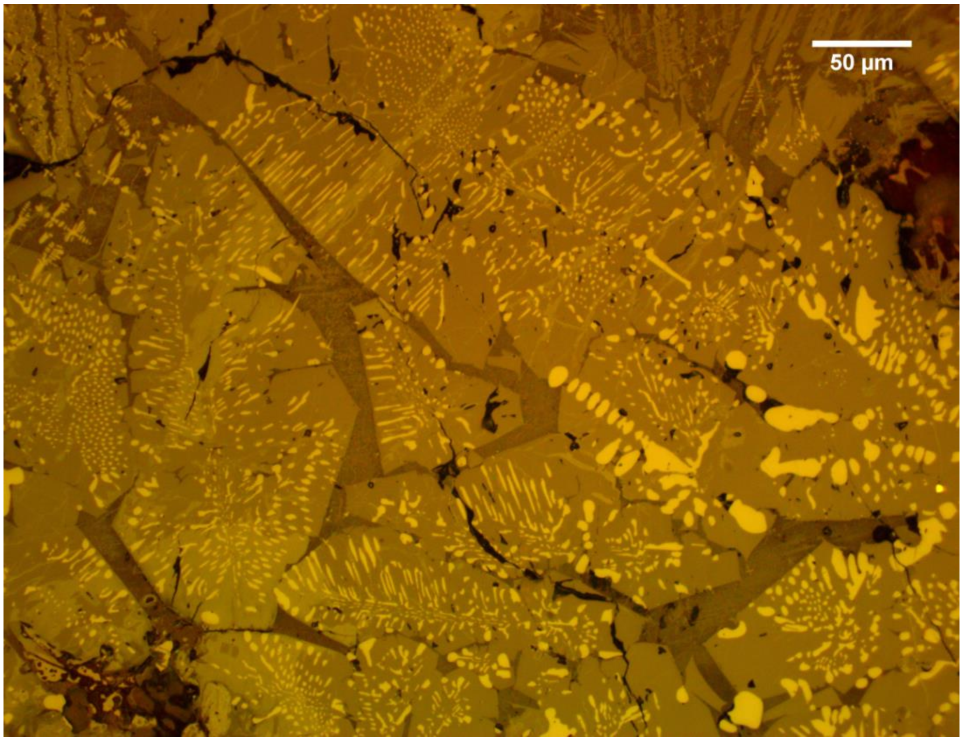

Figure II17d. Optical micrograph of various iron and silicate phases, including iron oxide stringers

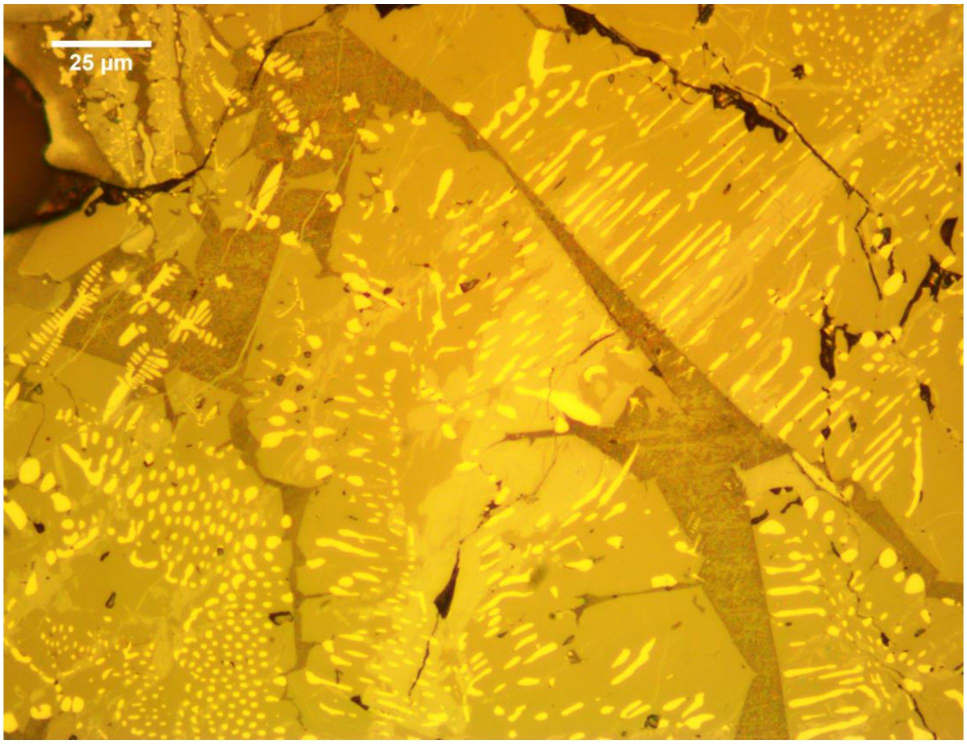

Figure II17e. Optical micrograph of various iron and silicate phases, including iron oxide stringers

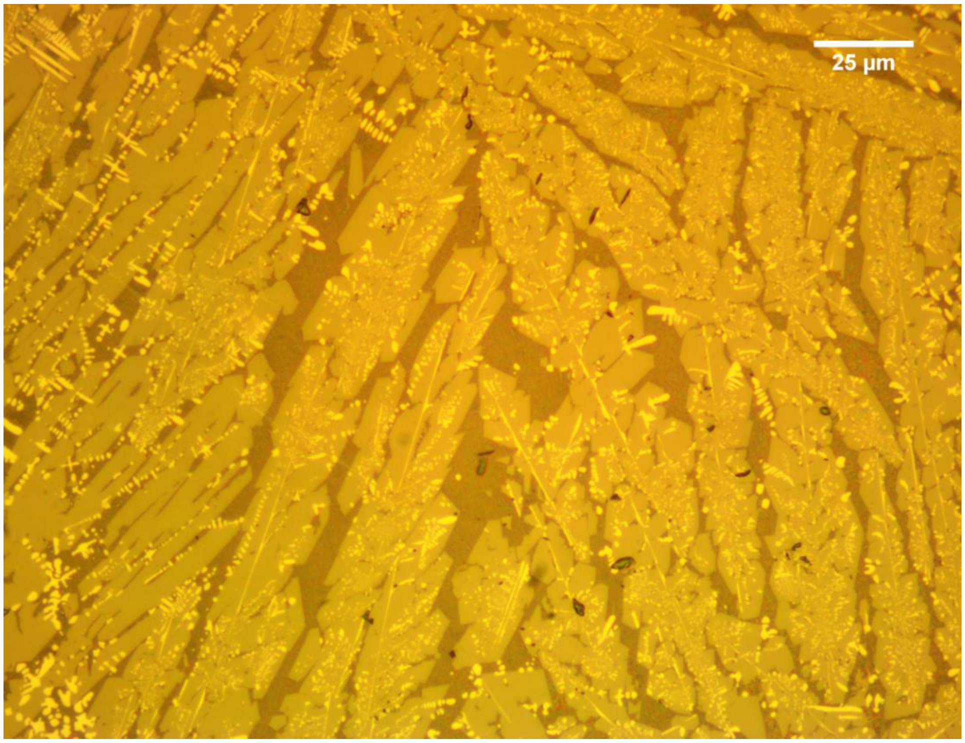

Figure II17f. Optical micrograph of various iron and silicate phases, including iron oxide stringers

Appendix III. Alloys and Corrosion

A. *Copper Alloys*

i. *800-530 BC*

III1: Locus 4490, Artifact 38458

Context: 800-530 BC - “Gray layer, somewhat greasy, that appears at the place where the 4488 Torba disappears, context equivalent to 4433.”

Overview: This tin bronze fibula demonstrates Liesegang phenomenon (Scott 1985). The artifact is completely corroded. Tin rich internal core reaches around 90 wt% tin, with lead, silver, iron, and arsenic inclusions. The core was excluded from the average, as the high tin content poses a risk of skewing the average tin content. Therefore, the most conservative estimate for tin is at the exclusion of the core (4 spot average instead of 5), rendering 10.63 wt % tin. Counting the core would result in an average tin content of 26.55 wt %.

Figure III1a. L. 4490 38458

Artifact	Dates	Instrument	Spots	Cu	Sn	As	Fe	Pb	S	Ag	Ni
4490 38458	800-530	SEM-EDS	4	88.90	10.63	—	—	—	0.48	—	—

Table III1. SEM-EDS alloy results

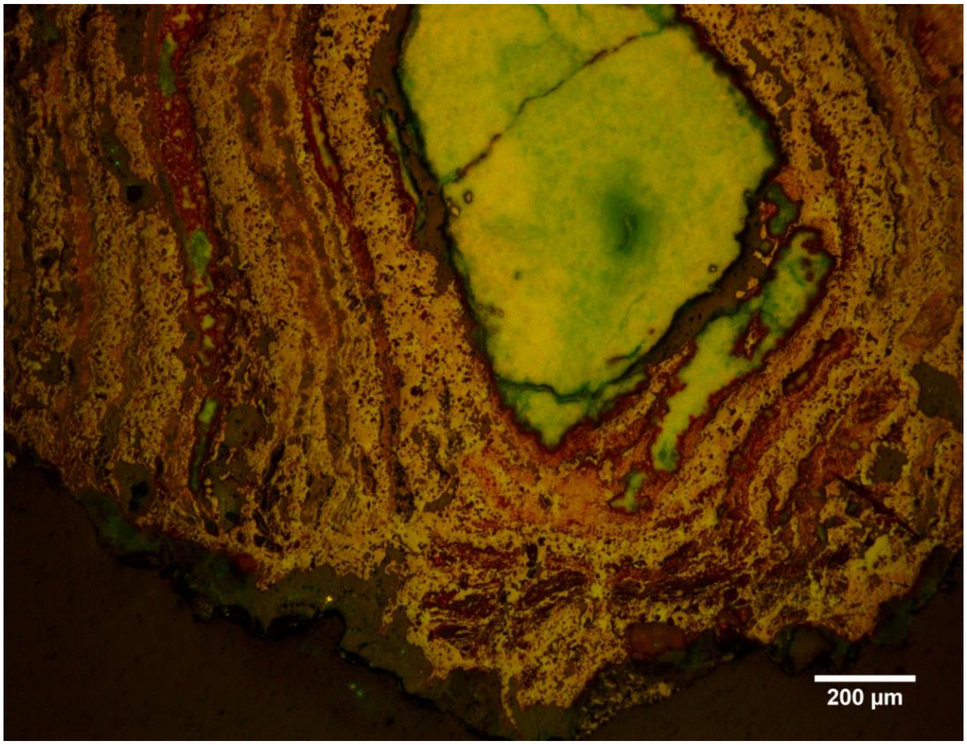

Figure III1b. Liesegang phenomenon with tin rich green core, tin content around 90 wt%

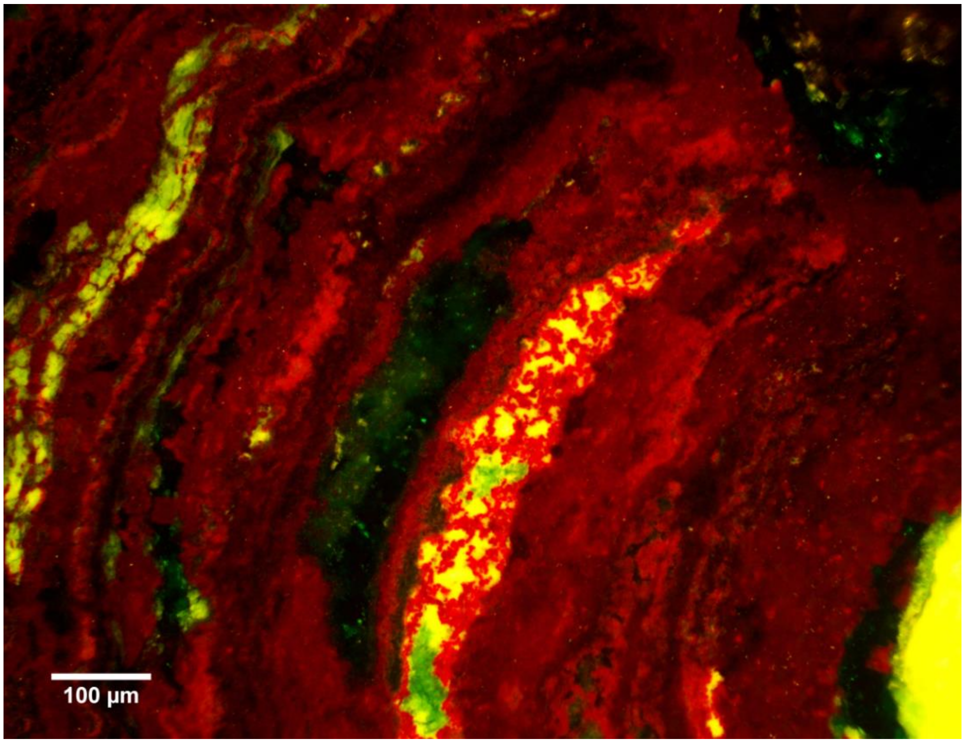

Figure III1c. Polarized micrograph of laminated corrosion structure characteristic of Liesegang phenomenon

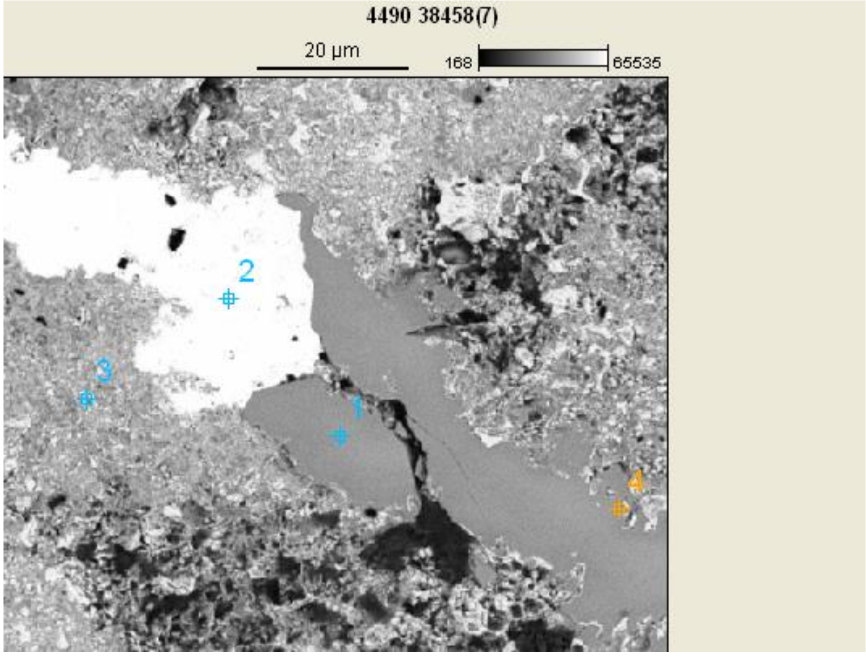

Figure III1d. Backscattered micrograph of core with silver impurities (bright white, spot 2).

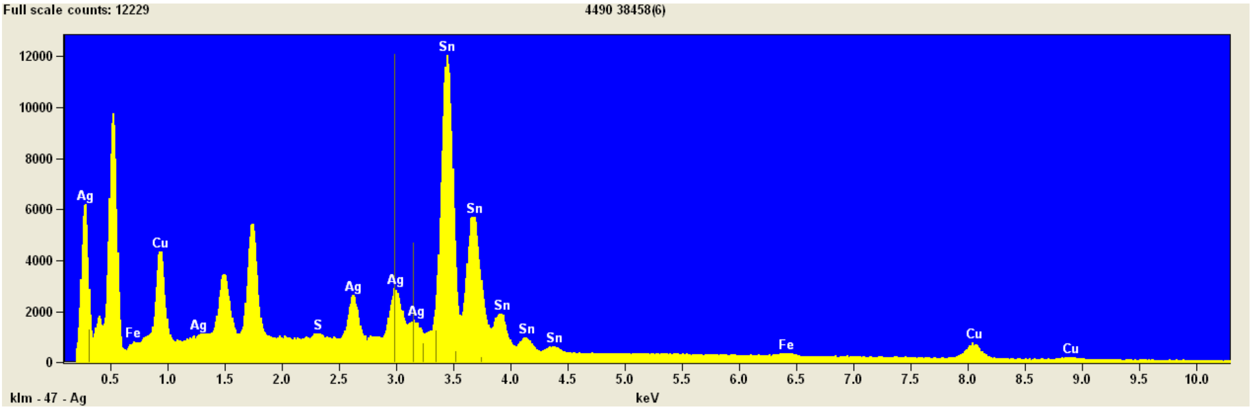

Figure III1e. Another spectrum from the core, wt% 10.69Cu 75.69Sn 11.33Ag 1.15Fe 1.12S

III2: Locus 7466, Artifact 40820

Context: 800-530 BC – “Rich level in relation to workshops, rich in charcoal consumption and bones.”

Overview: This ternary bronze artifact was mostly corroded but some metal remained. The five average spots were taken only from the metal components, relatively low in tin content. Inverse segregation of tin was substantial, with outer edges richest in tin. Therefore, the average tin content is conservative. Strain lines are observed in the corrosion, but the preserved bulk metal (alpha + delta eutectoid) was unaffected by the working. No observable grains - the object was cast but not annealed. Outer corrosion layers begin to include <1 wt% of calcium and phosphorus, and high levels of tin and lead, demonstrating the bleeding out of these outer metallic layers into the soil. Lead seems to be inversely segregated as well. Evidence of silver impurities.

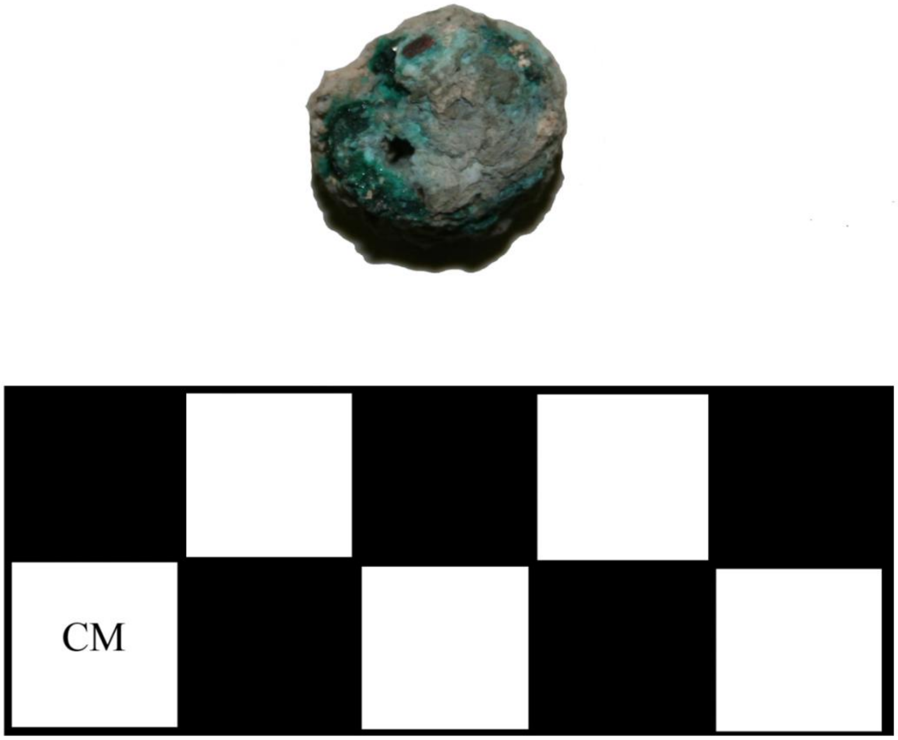

Figure III2a. L. 7466 40820

Artifact	Dates	Instrument	Spots	Cu	Sn	As	Fe	Pb	S	Ag	Ni
7466 40820	800-530	SEM-EDS	5	76.69	16.37	1.82	—	5.01	—	0.10	—

Table III2. SEM-EDS alloy results.

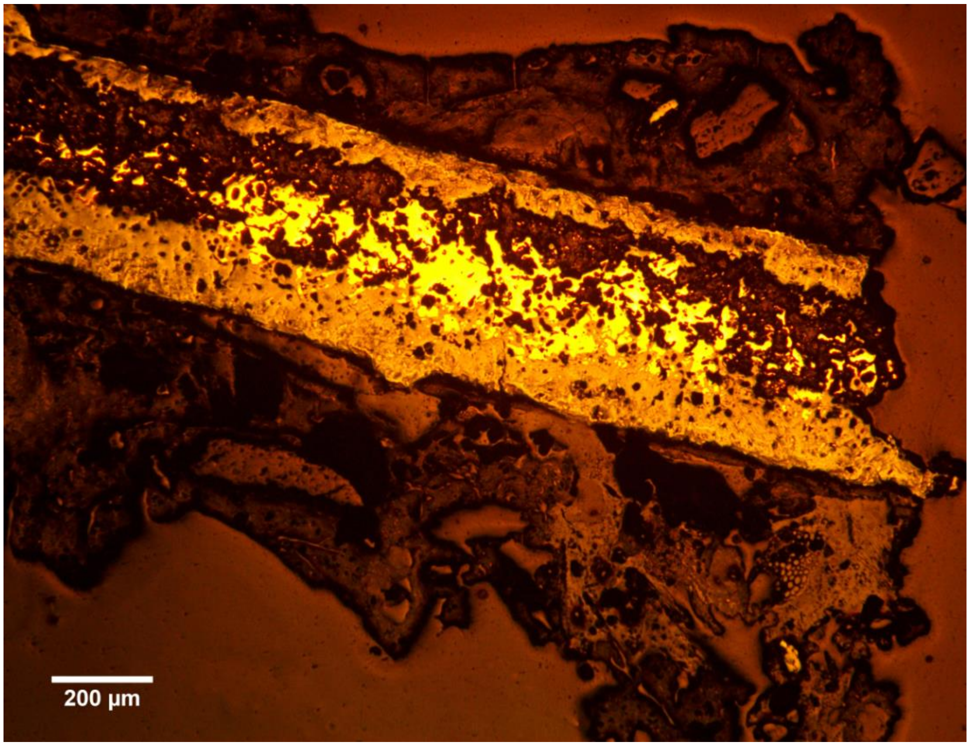

Figure III2b. Unetched optical micrograph of outer and inner corrosion layers, metal-remnant core

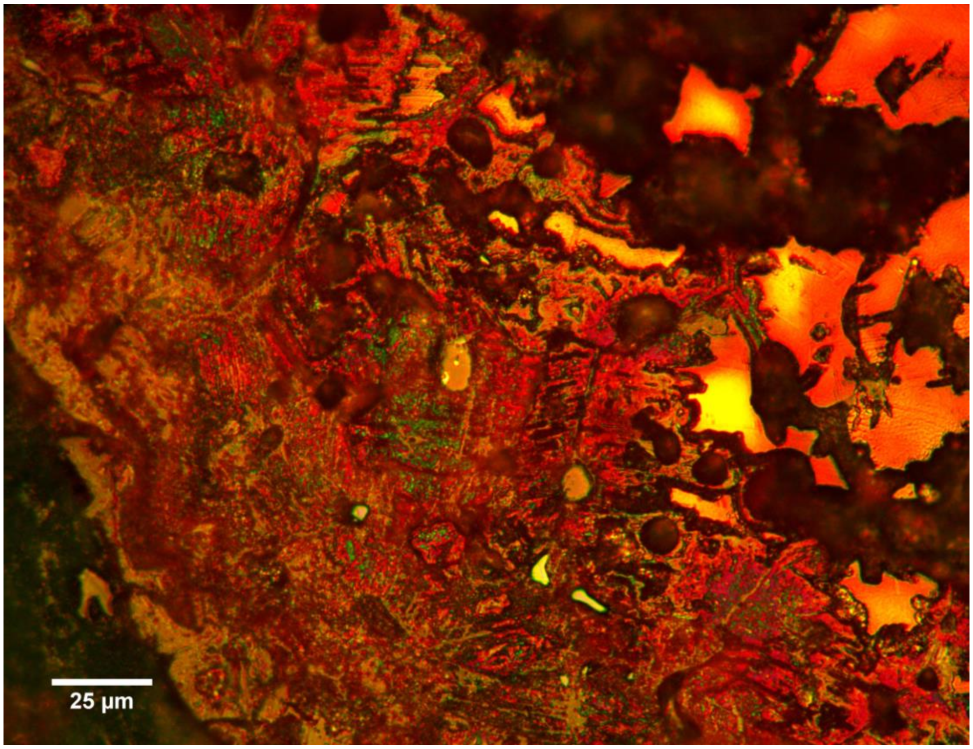

Figure III2c. Etched with ferric chloride, strain lines visible in corrosion but not metal

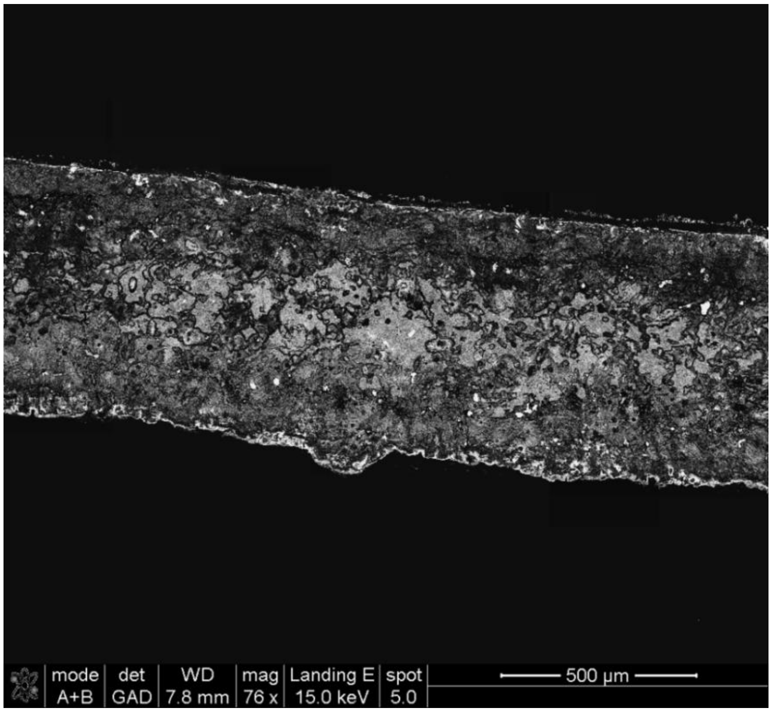

Figure III2d. Backscattered micrograph montage

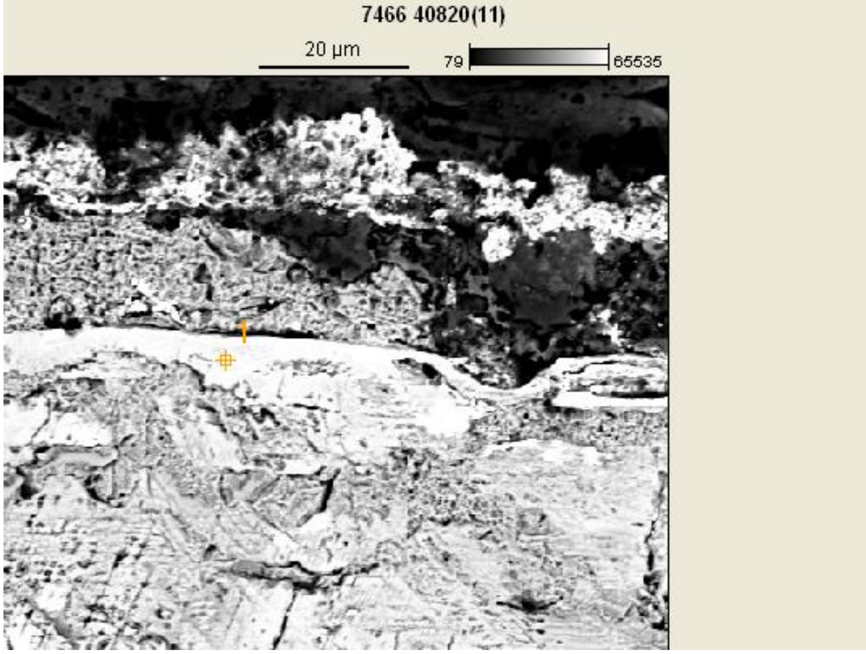

Figure III2e. Micrograph corresponding with spectrum in Figure 4CIIf. Tin, lead, arsenic rich outer corrosion layer

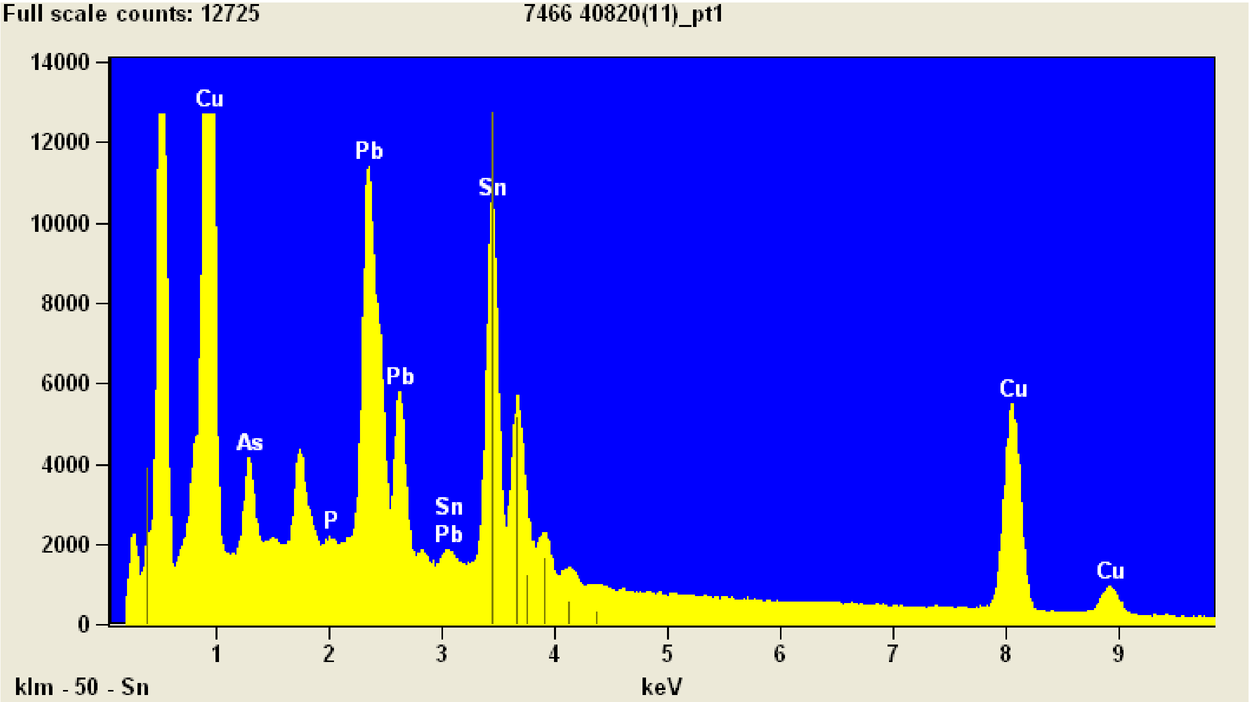

Figure III2f. EDS spot of bulk alloy in wt% 46.08Cu 29.96Sn 18.74Pb 4.79As

III3: Locus 4460, Artifact 38465

Context: 800-530 BC – “Ochre sandy layer with many pottery and bone fragments, below 4459 (*Beyond the homeland*, ##, figs 4–6a–d, 12; cat. 24–52).”

Overview: This pure copper artifact is completely corroded. Some of the broken segments, circular in nature, suggest a fibula. The circular morphology is also attested in the corroded circular core. The artifact was lumped together with a ferrous chunk of corrosion as well. The sulphur content is high – unlikely from the original cast but more probably from post-depositional interactions with the soil. Two of the averages contained arsenic, 1.47 and 1.67 wt%. This indicates that it was originally perhaps an arsenical bronze before corrosion has skewed the alloy reading.

Figure III3a. L. 4460 38465

Artifact	Dates	Instrument	Spots	Cu	Sn	As	Fe	Pb	S	Ag	Ni
4460 38465	800-530	SEM-EDS	5	96.12	—	0.33	0.28	—	3.27	—	—

Table III3. SEM-EDS alloy results

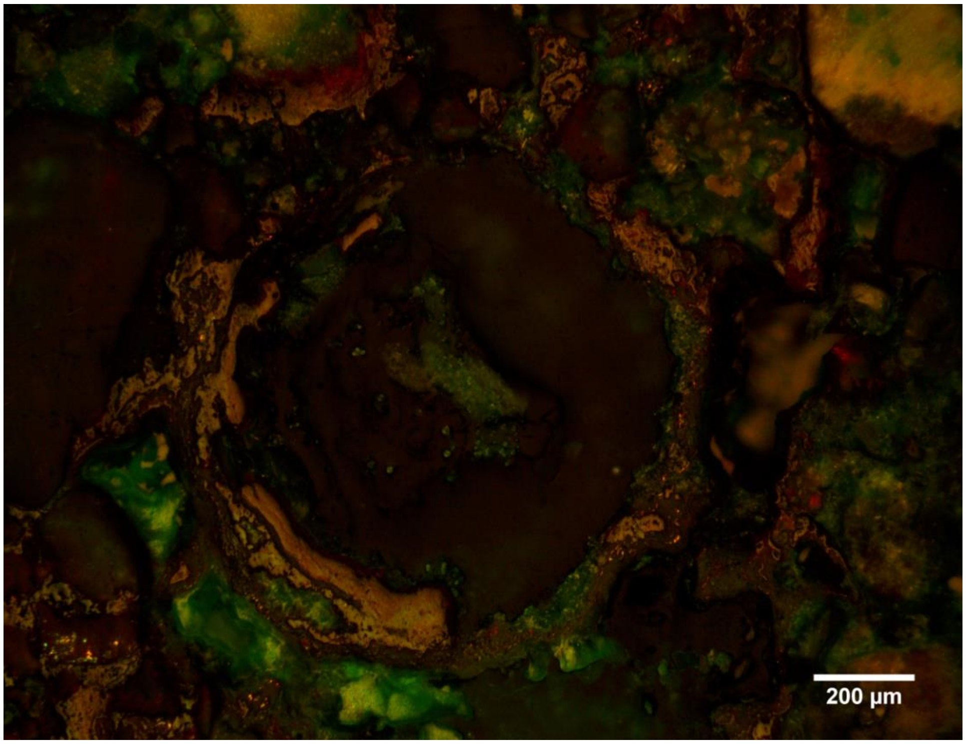

Figure III3b. Polarized micrograph of central corroded core maintaining original circular casting

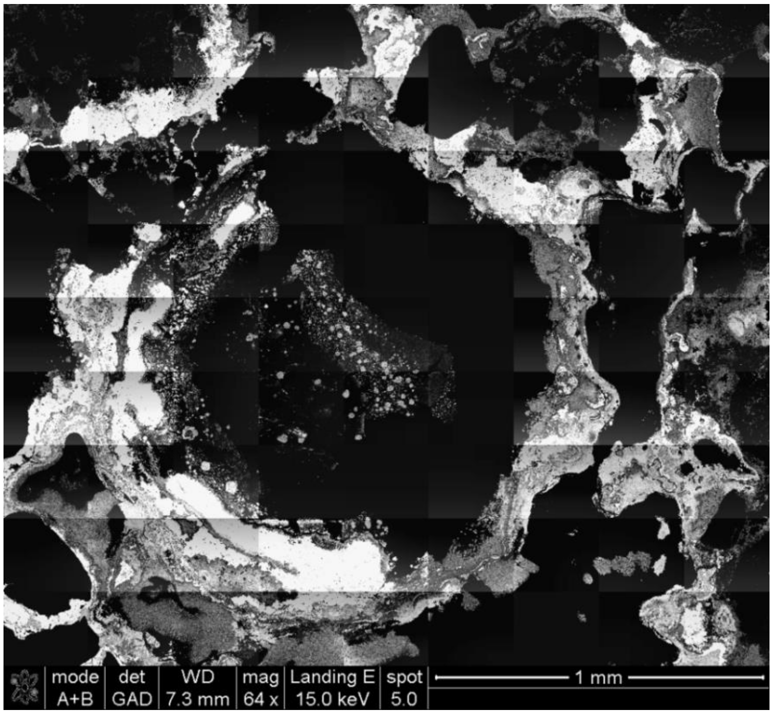

Figure III3c. Backscattered micrograph montage

ii. *530-300 BC*

III4: *Locus 7452*, *Artifact 40812*

Context: 530-300 BC – “Bedding of basin 7441 (BABesch 2006, 49).”

Overview: This corroded tin bronze artifact maintained its shape well, although its original purpose is unclear. The tin content is deviated across the spots, meaning that throughout the five averaged spots the content fluctuates from ~6-22 wt%. The average yields a good tin bronze. Corrosion products include cuprite, malachite, and azurite.

Figure III4a. L. 7452 40812

Artifact	Dates	Instrument	Spots	Cu	Sn	As	Fe	Pb	S	Ag	Ni
7452 40812	530-300	SEM-EDS	5	84.40	13.62	0.34	0.31	—	1.34	—	—

Table III4. SEM-EDS alloy results

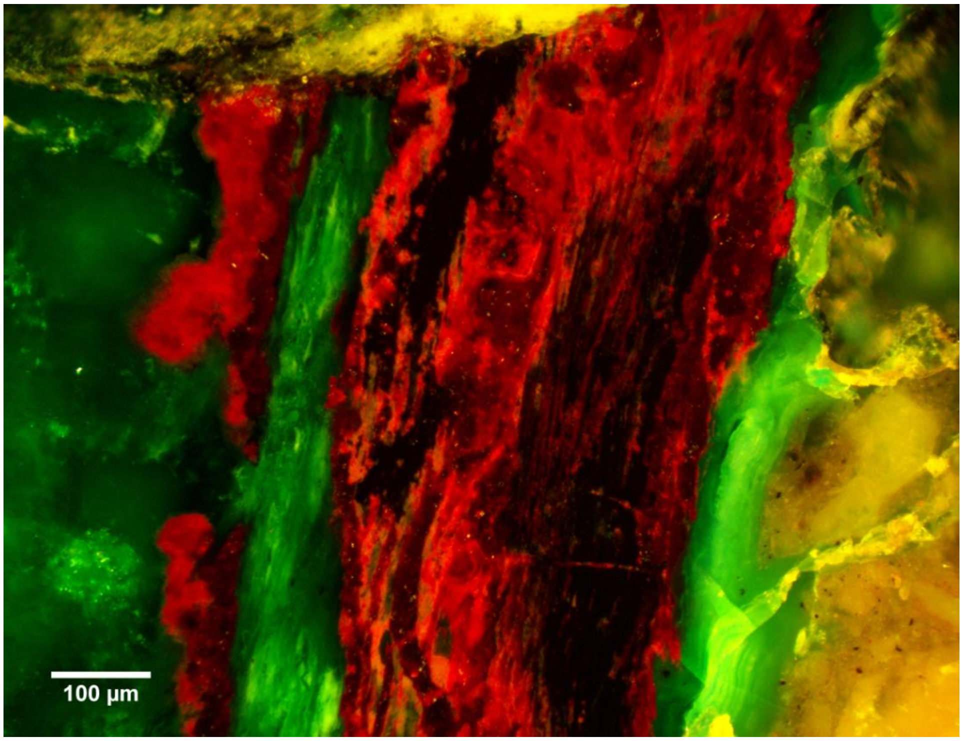

Figure III4b. Dark field micrograph of alternating cuprite and malachite corrosion layers.

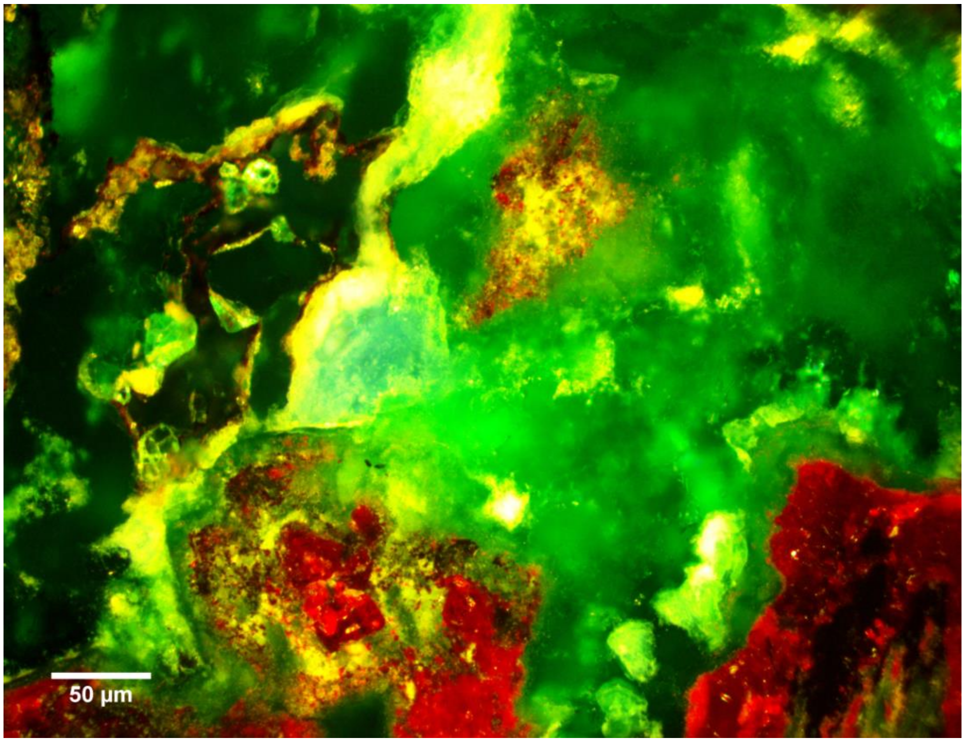

Figure III4c. Azurite, malachite, and cuprite

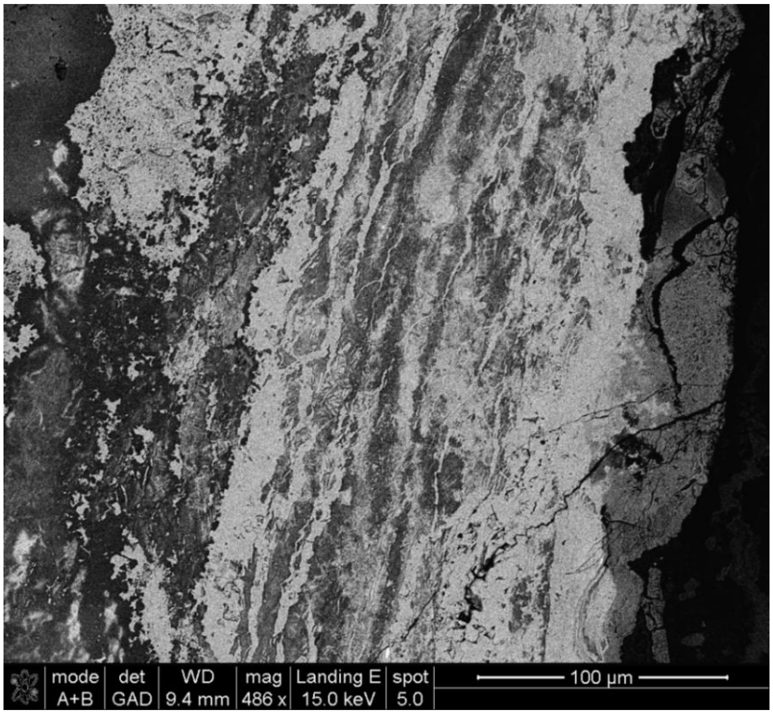

Figure III4d. Backscattered micrograph of alternating corrosion layers

III5: Locus 1104, Artifact 30007

Context: 500-400 BC “1104= (next to) 1105 (which is 500-400 BC), (above) 1106, 1107, 1108, 1109, 1110, 1113, 1114, 1117, 1118, 1122: Compact levelling layer below 1103.”

Overview: This low tin bronze clenched nail had metal preserved to a high degree. The minor constituents of arsenic, iron, and lead are likely due to recycling activities. Equiaxed grains and proliferation of twins indicate repeated episodes of working and annealing. Some irregular slip planes and elongated grains suggest that the final act was working, not annealing. Good patination as evidenced from the unetched samples, with limited, superficial intergranular corrosion. There may be some coring. Some silver impurities at high magnification.

Figure III5a. L. 1104 30007

Artifact	Dates	Instrument	Spots	Cu	Sn	As	Fe	Pb	S	Ag	Ni
1104 30007	500-400	SEM-EDS	5	97.11	1.90	0.25	0.34	0.28	0.13	—	—

Table III5. SEM-EDS alloy results

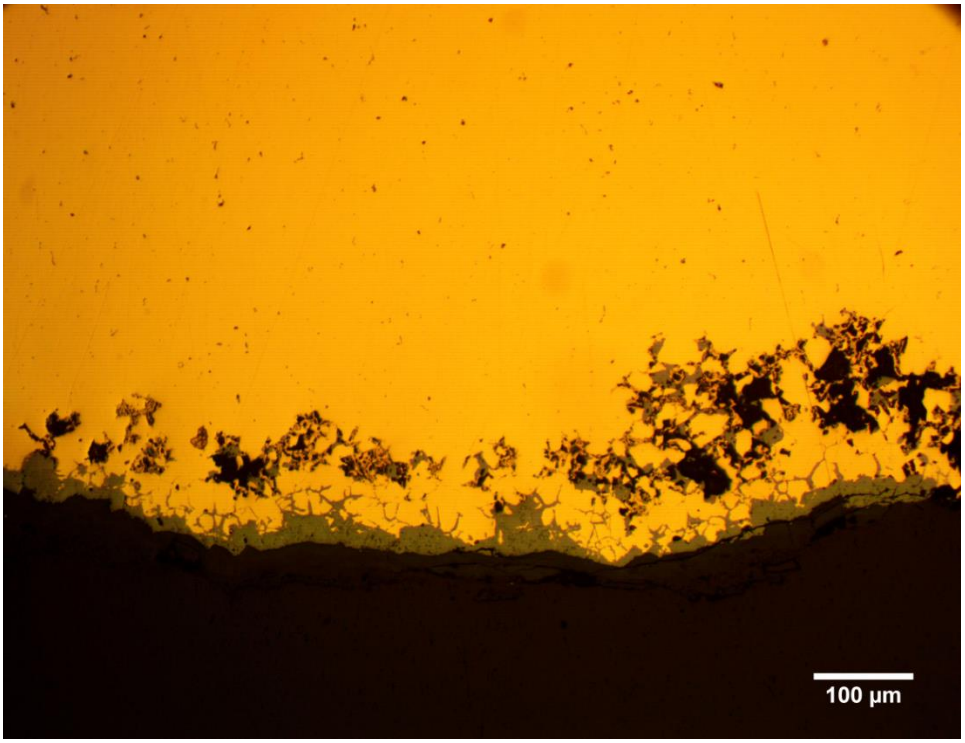

Figure III5b. Unpolished optical micrograph showing patination and superficial intergranular corrosion

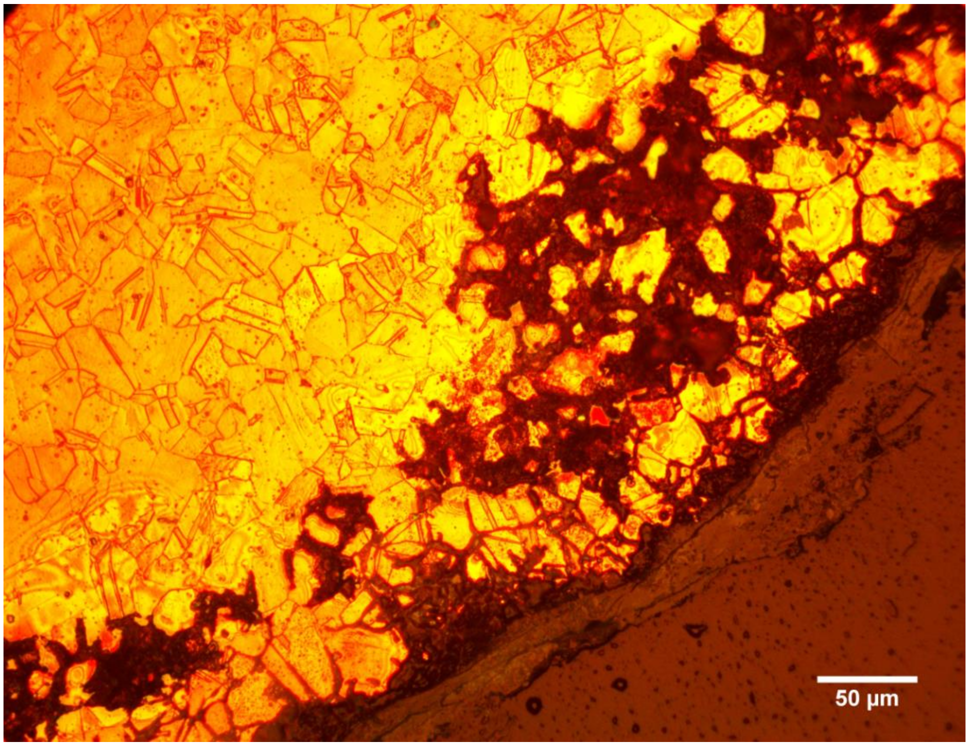

Figure III5c. Color etched optical micrograph of edge showing various grain sizes and twins

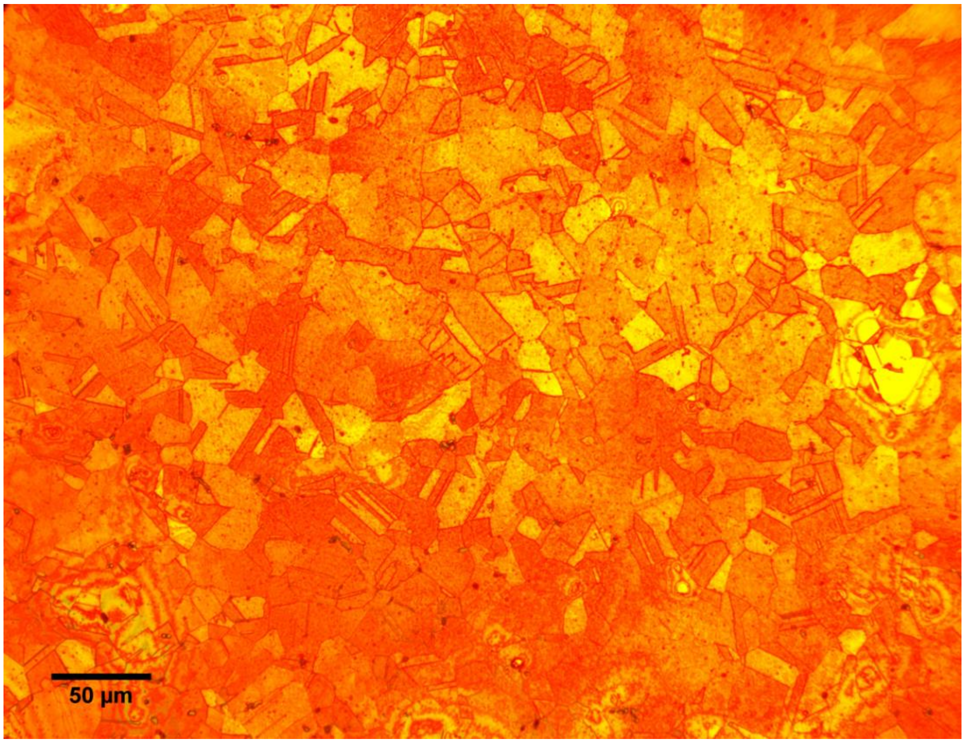

Figure III5d. Color etched optical micrograph of bulk showing slip planes and twins

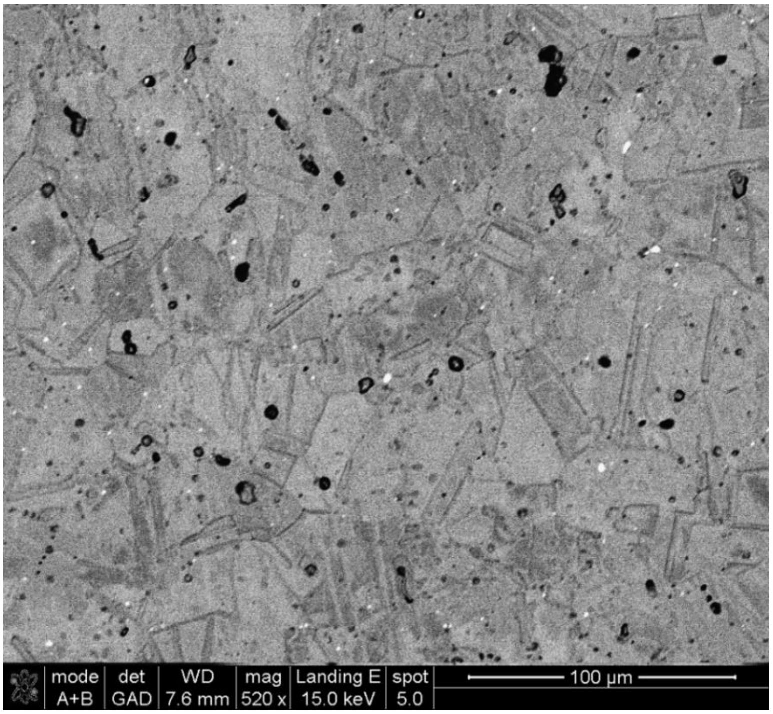

Figure III5e. Remnant etchant captures slip planes; the bright white speckles are lead impurities

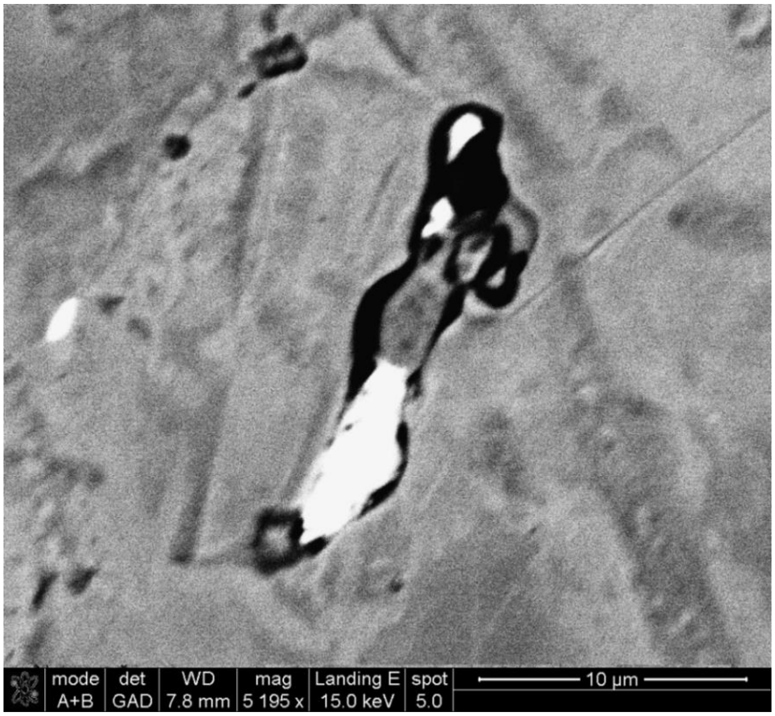

Figure III5f. Backscattered micrograph of impurity, wt% 93.64Cu 2.24Sn 0.26As 2.79Pb 0.36Fe 0.09Ag 0.62S

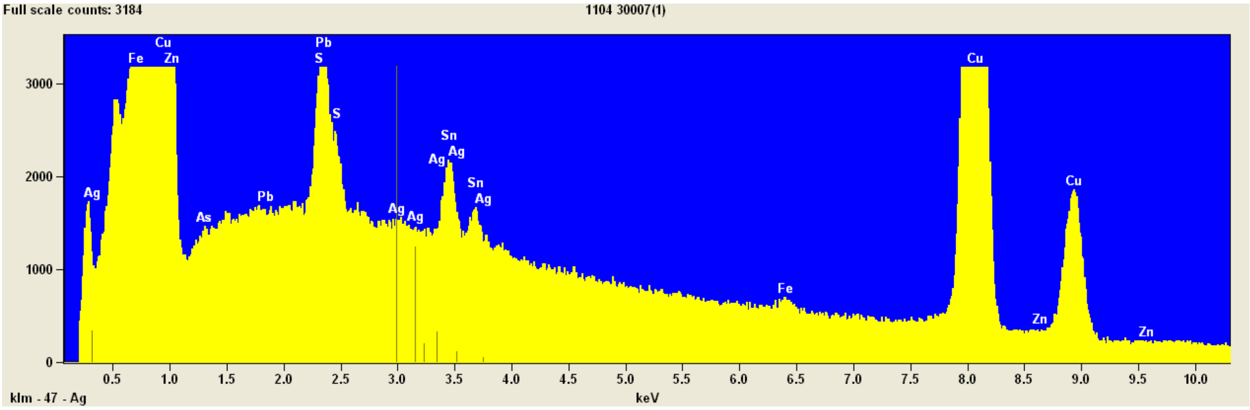

Figure III5g. Spectrum of Figure 4CVf

III6. Locus 4440, Artifact 38441

Context: 360-340 BC.

Overview: This pure copper artifact is heavily attacked by corrosion but still maintains a type of “swirling” pattern that remains from the original casting. The artifact was heavily worked with some annealing. Cold work created the deformed slip planes. The elongated grains and directionality resulted from cold work as well. The green blotches throughout the bulk metal include various elements such as lead, iron, sulfur, and selenium, coupling of the latter two common in Ancient Near Eastern bronzes (Rehren 1991).

Figure III6a. L. 4440 38441

Artifact	Dates	Instrument	Spots	Cu	Sn	As	Fe	Pb	S	Ag	Ni
4440 38441	360-340	SEM-EDS	5	99.87	—	—	—	0.13	—	—	—

Table III6. SEM-EDS alloy results

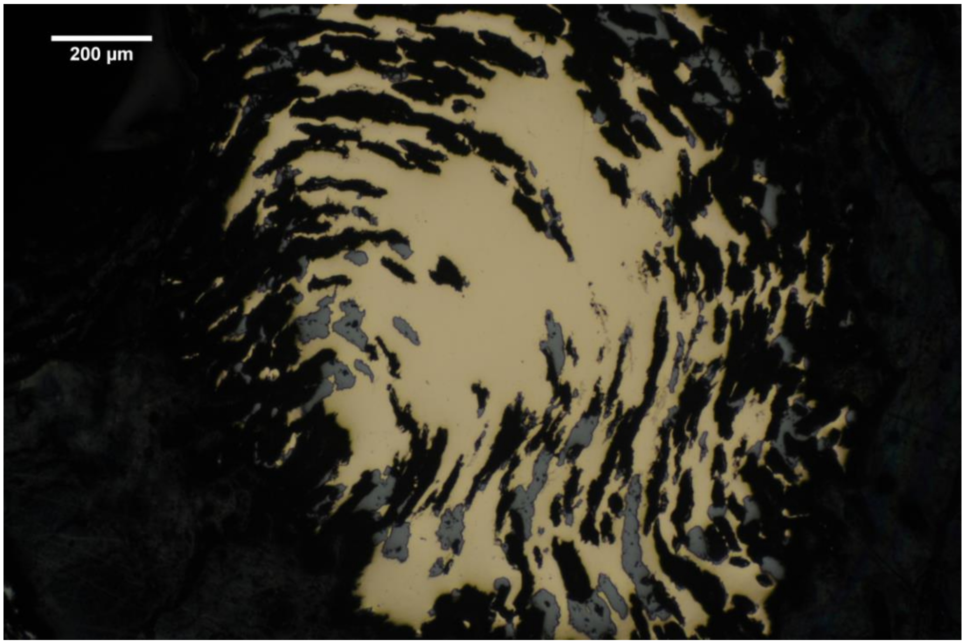

Figure III6b. Optical micrograph of “swirling” microstructure remnant from the cast.

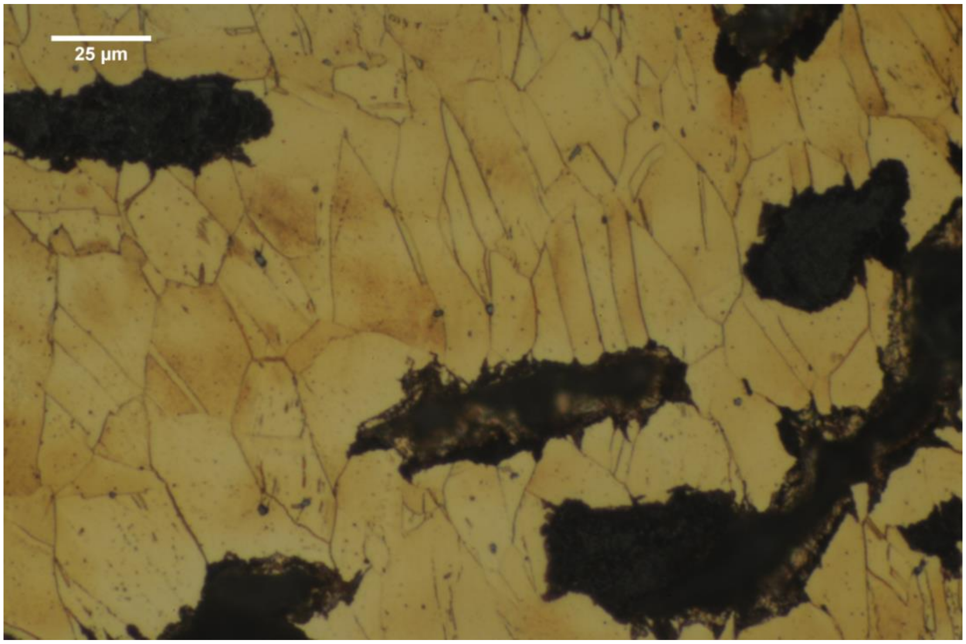

Figure III6c. Etched with ferric chloride showing elongation, directionality, and slip planes

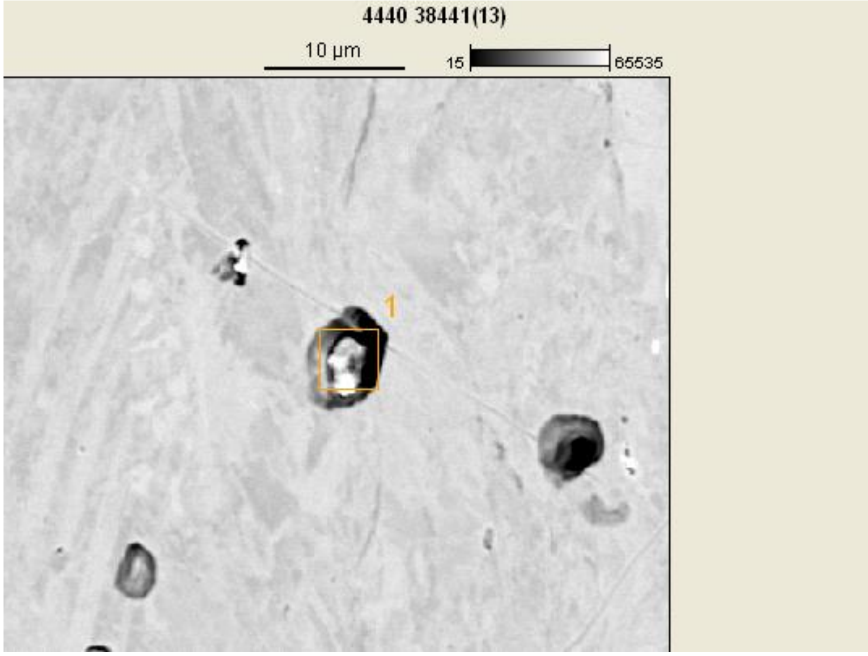

Figure III6d. Backscattered micrograph of impurity-rich inclusion with wt% 10.08Pb 2.63Se 3.47S 0.46Fe and the remainder copper

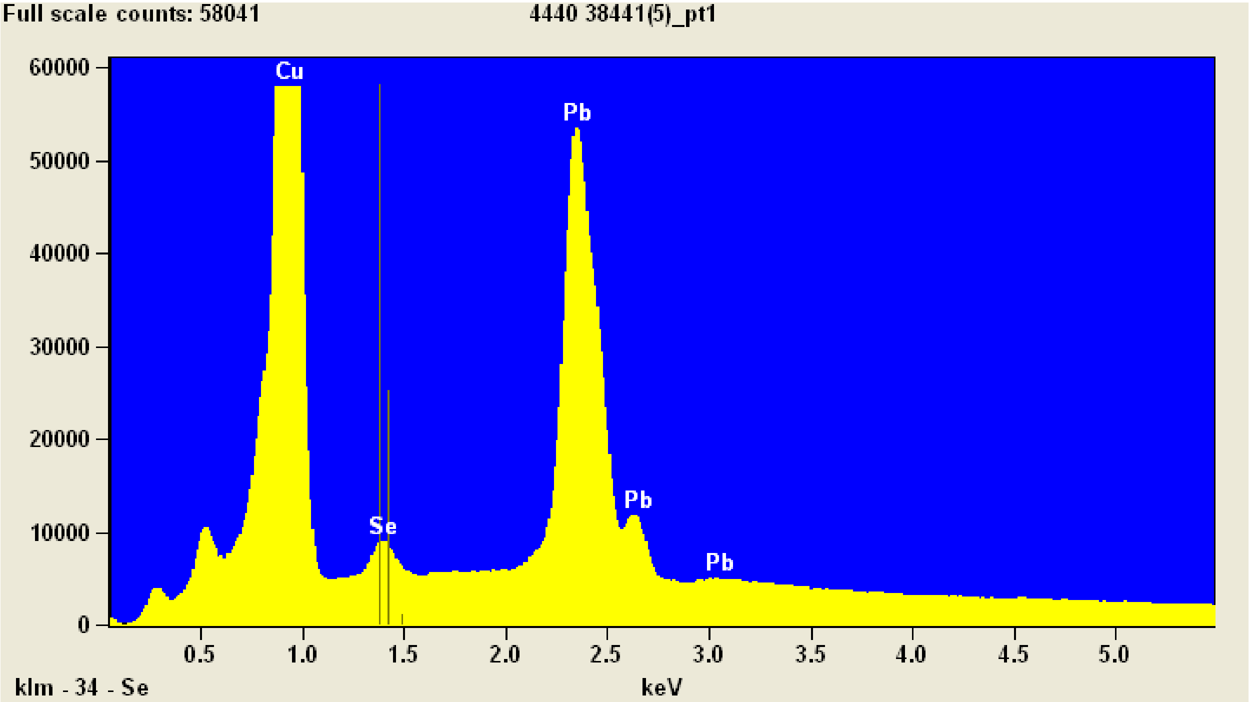

Figure III6e. Confirmation of selenium content in another impurity area

III7. Locus 2420, Artifact 38597

Context: 330-300 BC – “Coin (Carthage 370-340 BC); context completely sieved.”

Overview: This copper alloy stake or peg has a low arsenic content which may be the result of recycling. The three-pronged pure copper central corrosion area seems to be an intentional feature of this unique artifact. Since the corrosion is pure copper and the alloy is different, it seems that a pure copper metal core was placed in the cast. The elongated grains in “swirling” microstructure that abut the central core show that the molten alloy was smashed against the central core. Equiaxed grains show excellent production technique with many annealing and working events, despite the substantial sulfur content. Variously colored grains reflect different phases of higher or lower sulfur and arsenic content.

Figure III7a. L. 2420 38597

Artifact	Dates	Instrument	Spots	Cu	Sn	As	Fe	Pb	S	Ag	Ni
2420 38597	330-300	SEM-EDS	5	97.89	—	0.65	0.06	—	1.40	—	—

Table III7. SEM-EDS alloy results

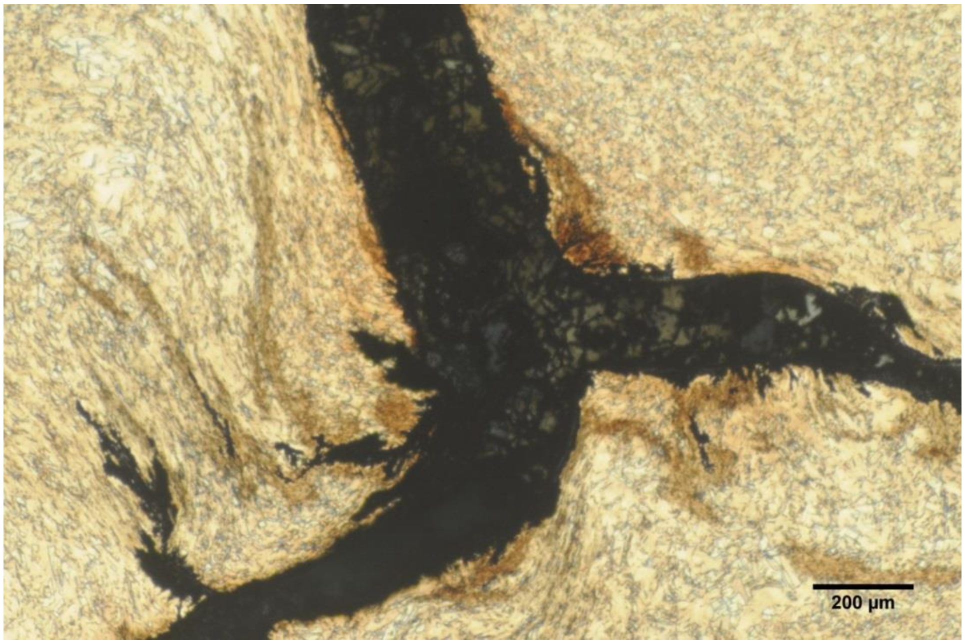

Figure III7b. Optical micrograph of central core, etched with ferric chloride.

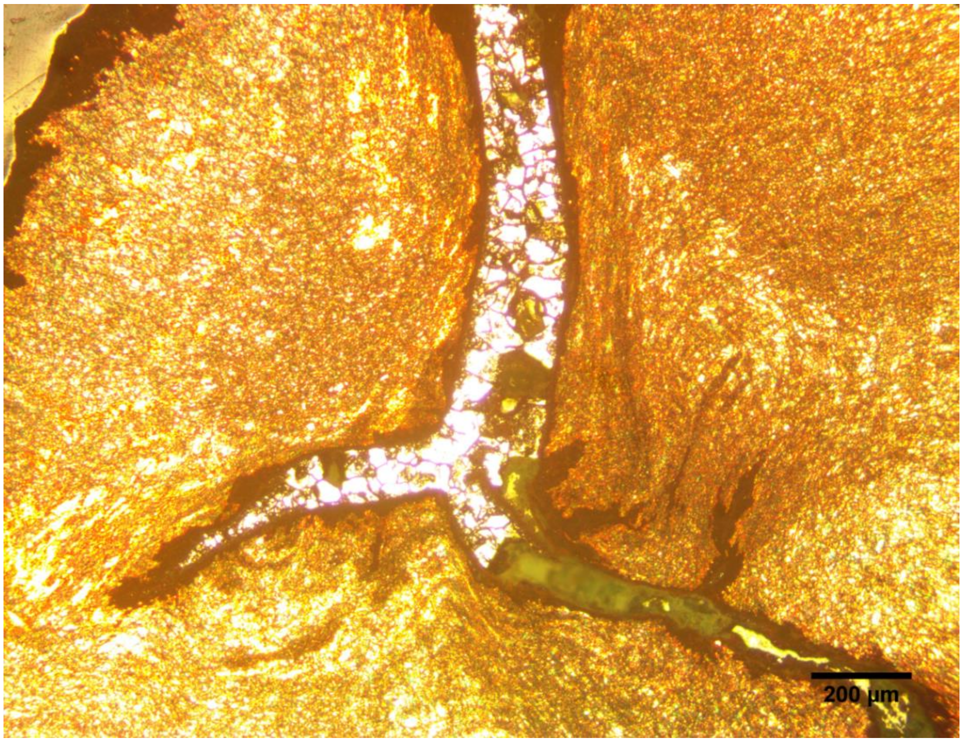

Figure III7c. Optical micrograph of central core, color etched.

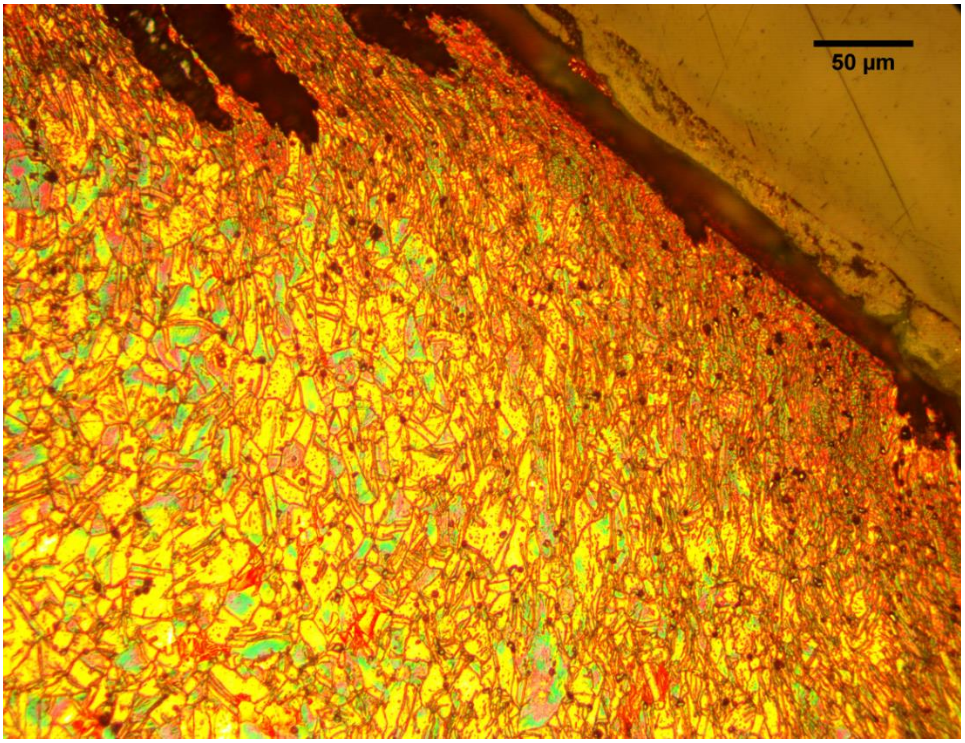

Figure III7d. Optical micrograph of “swirling” pattern against the external core of the cast, color etched.

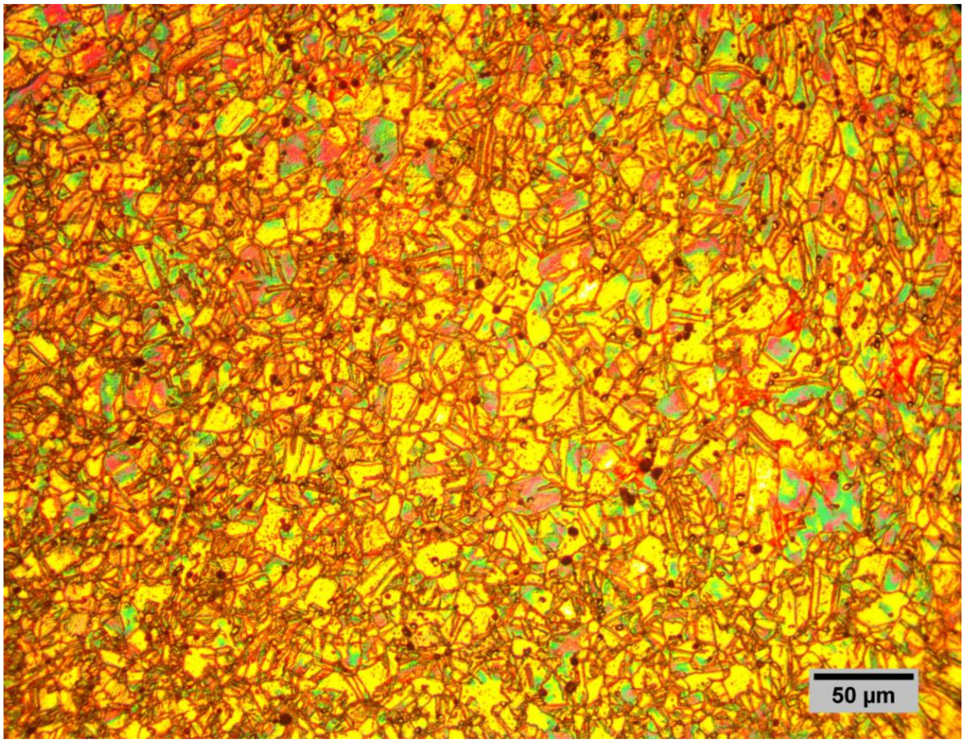

Figure III7e. Color etched micrograph of equiaxed grains with heavy working.

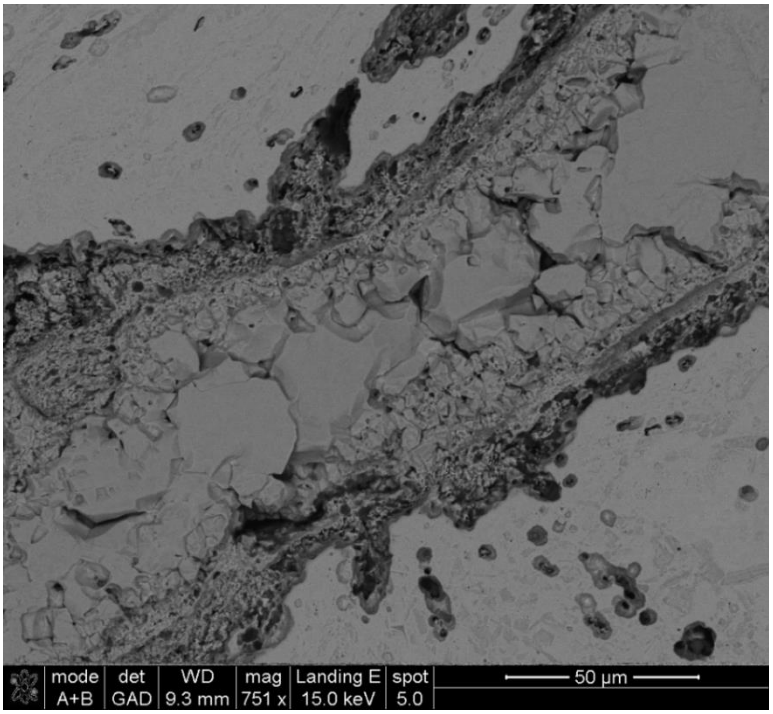

Figure III7f. Central core. The brighter internal part is pure copper, the external sides that interacted with the alloy have some iron and sulfur

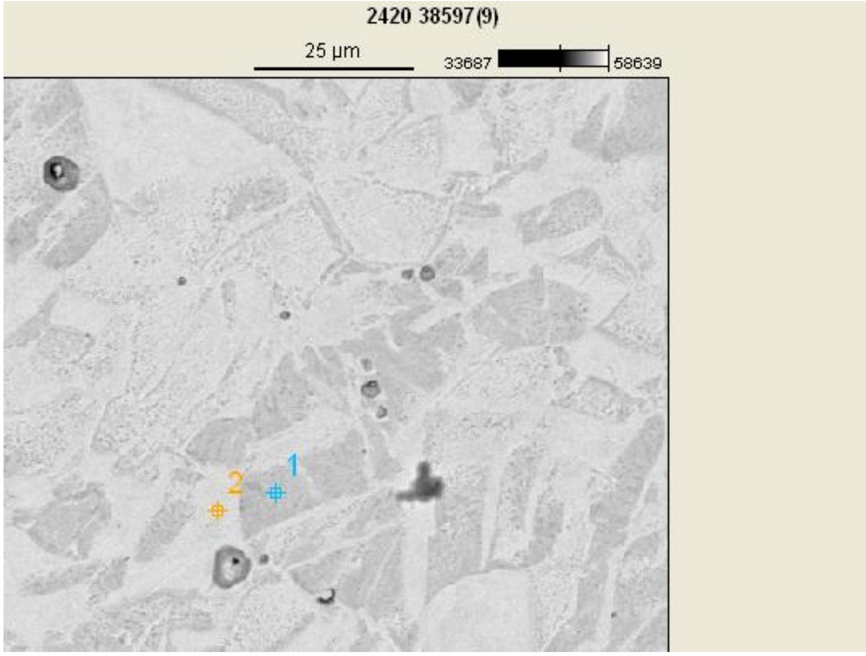

Figure III7g. Backscattered micrograph of grains, wt% spot 1: 92.64Cu 0.96 As 6.39S, spot 2: 99.40Cu 0.35As 0.26S. Other point-and-shoot locations also indicated that the major difference is sulfur content, not necessarily arsenic

III8. Locus 2420, Artifact 38599

Context: 330-300 BC - “Coin (Carthage 370-340 BC); context completely sieved.”

Overview: This hook or brooch is excellently produced like its companion of the same locus above. There are many twins with some elongated grains, but many are equiaxed showing repeated working and annealing. The corrosion layers are a textbook example of patination, essentially making this artifact a standard against which to test authenticities of alleged forgeries. In other words, look for this type of corrosion pattern to verify authenticity.

Figure III8a. L. 2420 38599

Artifact	Dates	Instrument	Spots	Cu	Sn	As	Fe	Pb	S	Ag	Ni
2420 38599	330-300	SEM-EDS	5	98.75	—	0.55	0.62	—	0.09	—	

Table III8. SEM-EDS alloy results

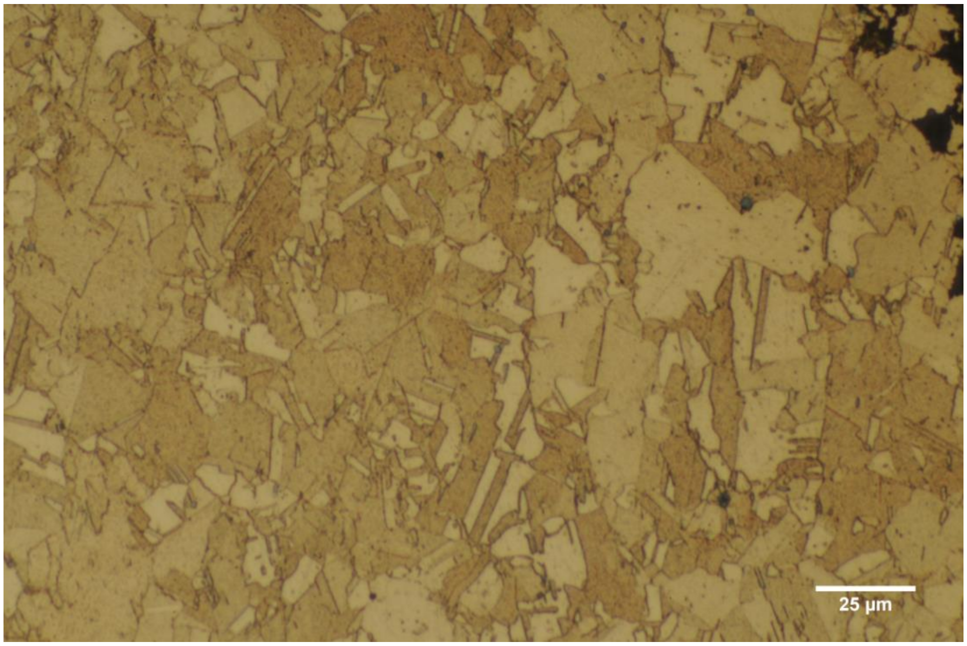

Figure III8b. Twins, elongated grains, recrystallized grains, etched with ferric chloride

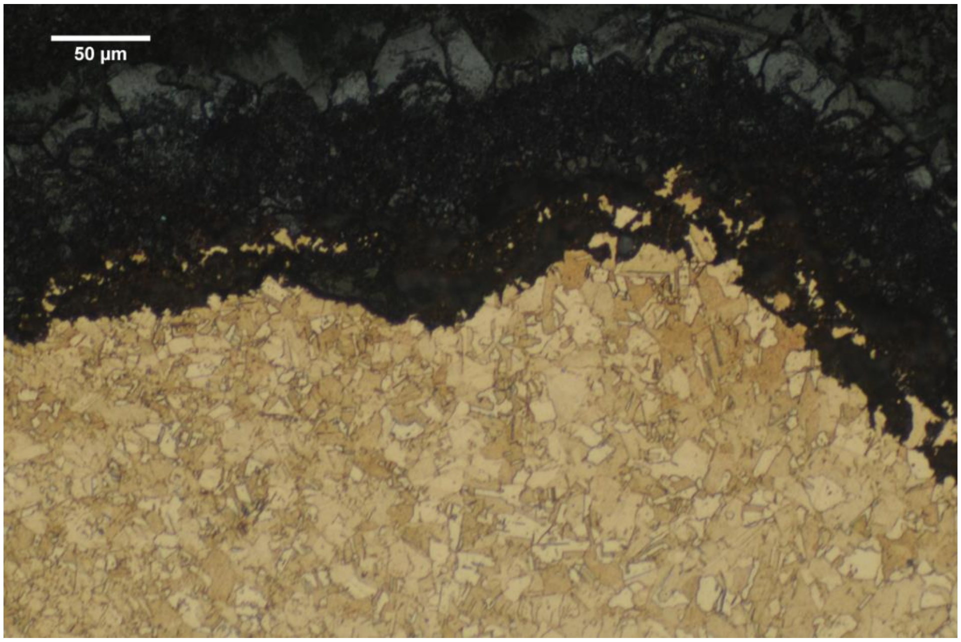

Figure III8c. Interaction of bulk metal with first patina layers, etched with ferric chloride

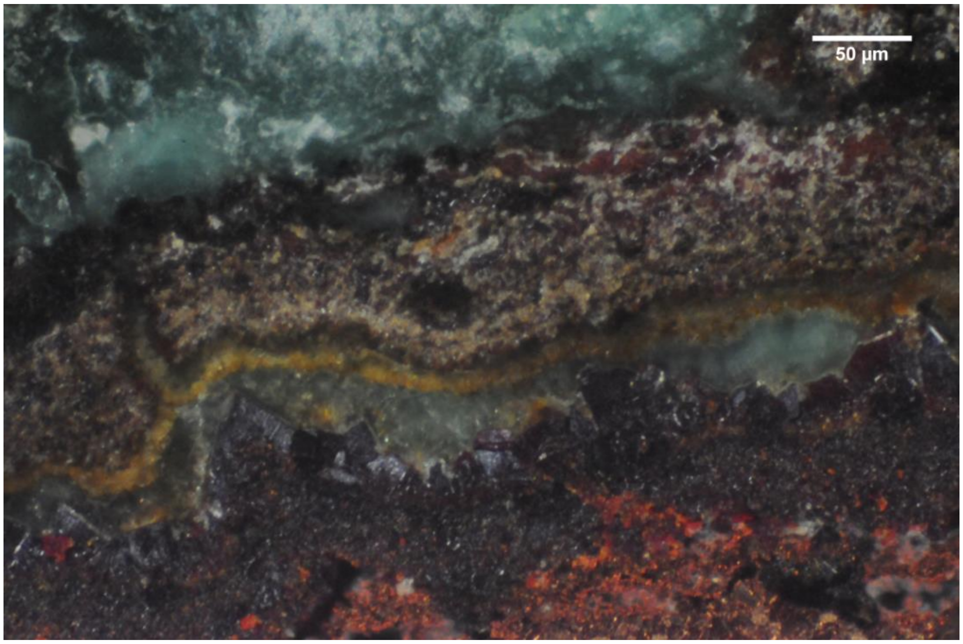

Figure III8d. Polarized micrograph of patination, metal being the lowest reddish level

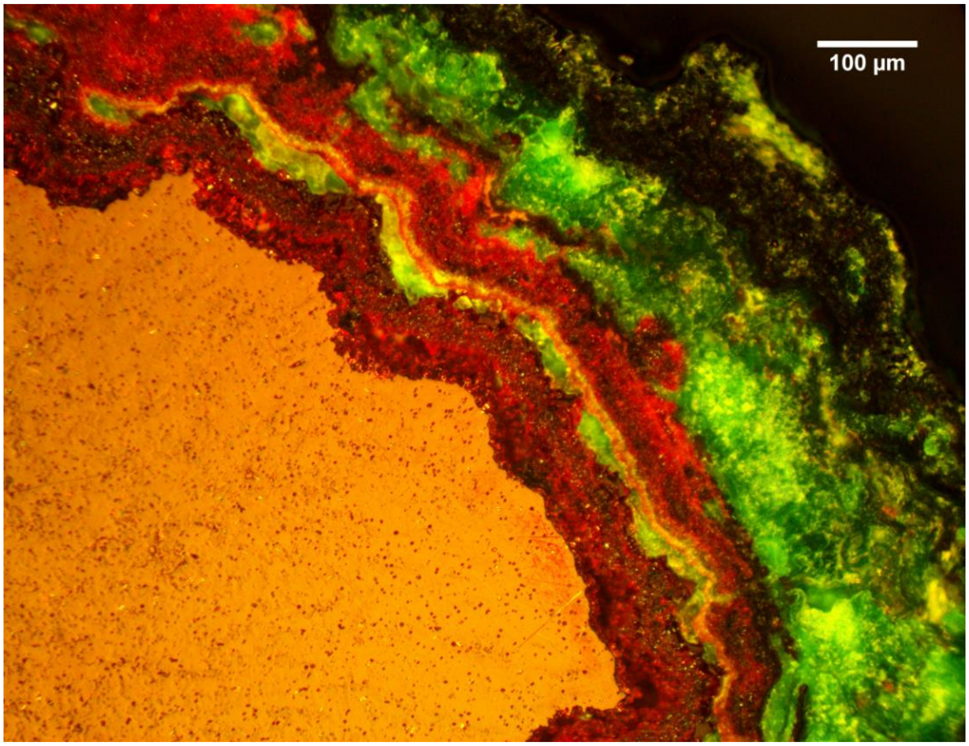

Figure III8e. Polarized micrograph of bulk alloy and patina layers

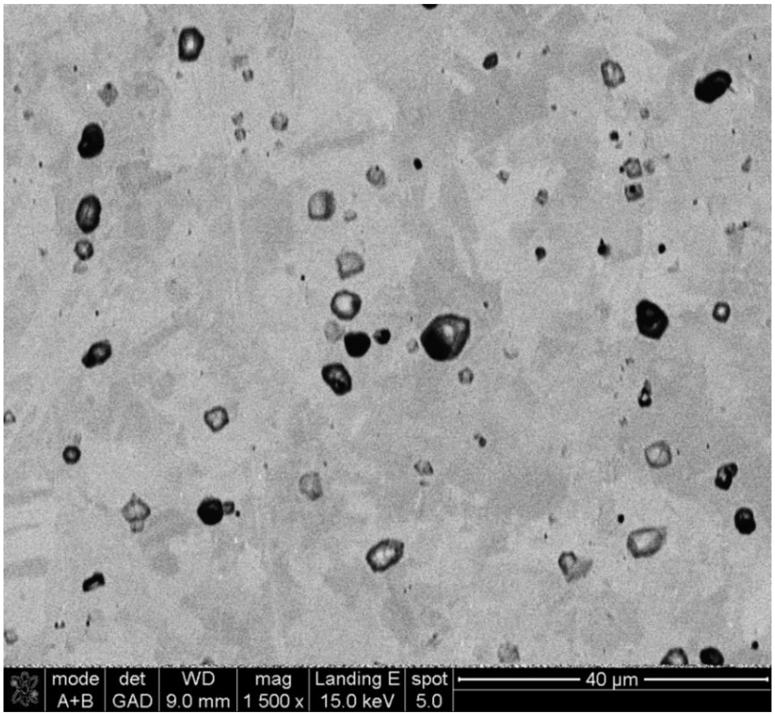

Figure III8f. Backscattered micrograph of third average spot, impurities and phases, wt% 98.61Cu 0.65As 0.63Fe 0.11S

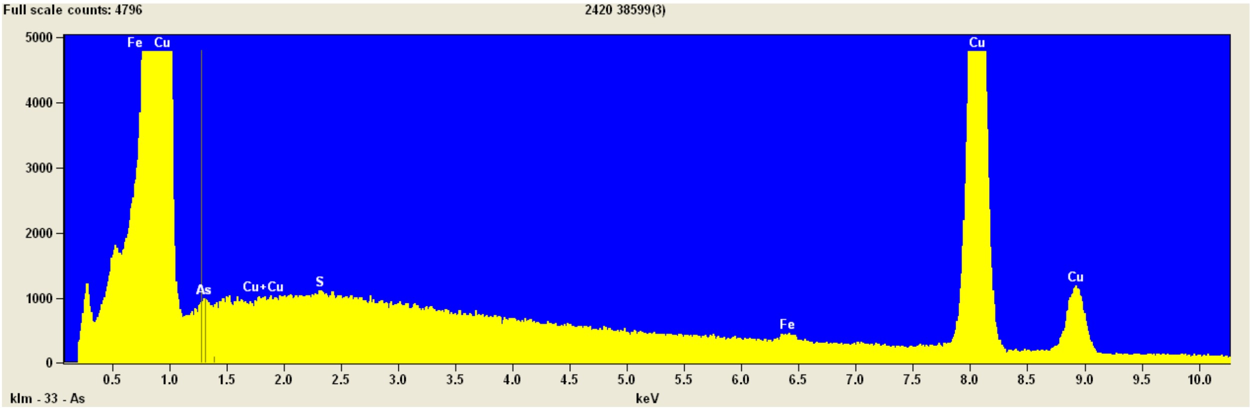

Figure III8g. Spectrum of third average spot

iii. *300-146 BC*

III9. Locus 4438, Artifact 38439

Context: 300-146 BC – “Only 1 diagnostic fragm. + 1 terracotta to be studied.”

Overview: The typology of this tin bronze artifact is unidentified, but the alloy and microstructure is rather complex and anomalous. It was probably cast in an open mould due to the evident porosity. It was heavily cold-worked as evidenced by strain lines found throughout. There are some small twins and equiaxed grains indicating that it was annealed, recrystallized, and cold-worked. Differential recrystallization occurred in the different colored areas. The lighter areas seem to be most affected by the strain and contain the twins and recrystallized grains, whereas the darker areas have less microstructural complexity. In the optical micrographs, the darker phases proved to be tin rich (on SEM backscattered mode these are the lighter areas), the lighter areas tin poor, and the green blotches rich in zinc and sulfur.

Figure III9a. L. 4438 38439

Artifact	Dates	Instrument	Spots	Cu	Sn	As	Fe	Pb	S	Ag	Ni
4438 38439	300-146	SEM-EDS	5	90.77	5.39	0.68	0.63	1.50	1.04	—	—

Table III9. SEM-EDS alloy results

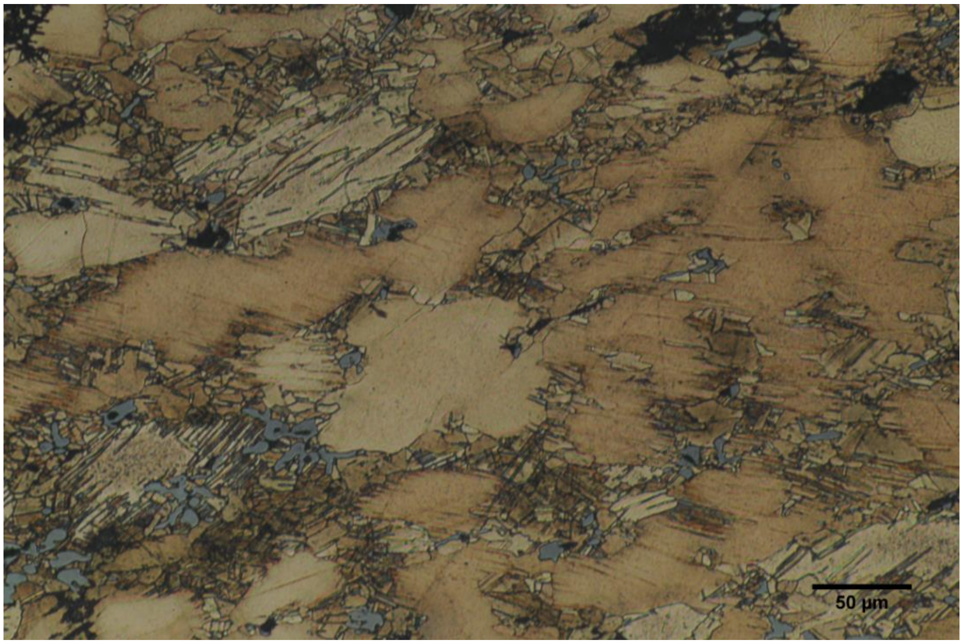

Figure III9b. Optical micrograph showing phase differentiation, sulphidic green zinc blotches, and strain lines, etched with ferric chloride

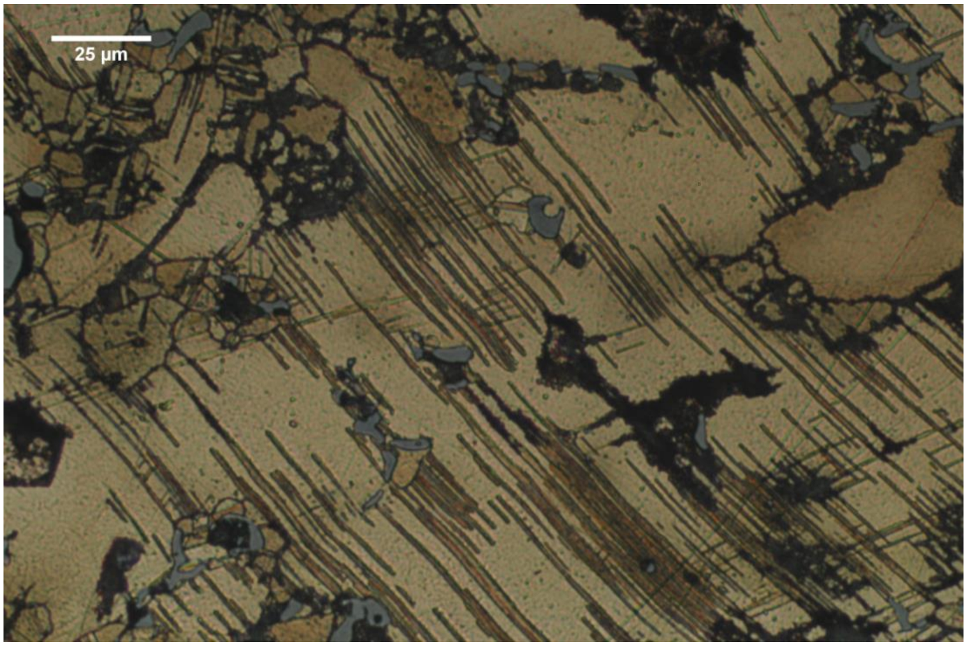

Figure III9c. Strain lines concentrated in lighter, tin poor phases

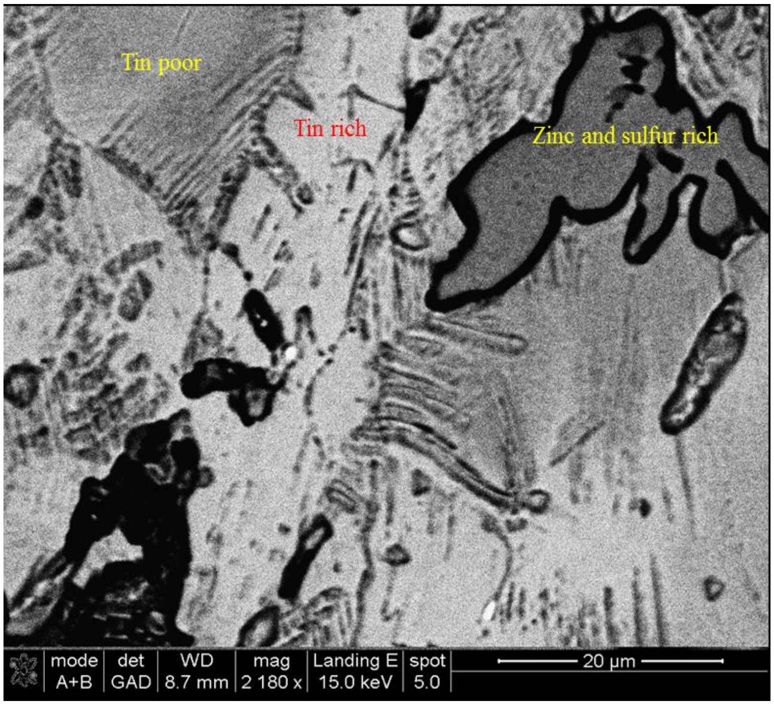

Figure III9d. Backscattered micrograph of phases in wt%: zinc and sulfur rich phase, 73.20Cu 1.50Sn 0.63As 1.74Fe 3.57Zn 19.36S; tin poor phase 94.23Cu 2.69Sn 1.02As 0.39Fe 1.66S; tin rich phase 90.42Cu 8.37Sn 0.77As 0.44S

III10. Locus 1295, Artifact 33573

Context: 300-146 BC – “Bedding of floor 1291 (=pavement of the Late Punic period).”

Overview: This artifact is an incredibly pure copper tool or accoutrement of some kind. The minimal inclusions testify to a very successful smelt. Twins and equiaxed grains are evidence of annealing and cold-working.

Figure III10a. L. 1295 33573

Artifact	Dates	Instrument	Spots	Cu	Sn	As	Fe	Pb	S	Ag	Ni
1295 33573	300-146	SEM-EDS	5	99.42	—	0.09	0.37	0.01	0.11	—	—

Table III10. SEM-EDS alloy results

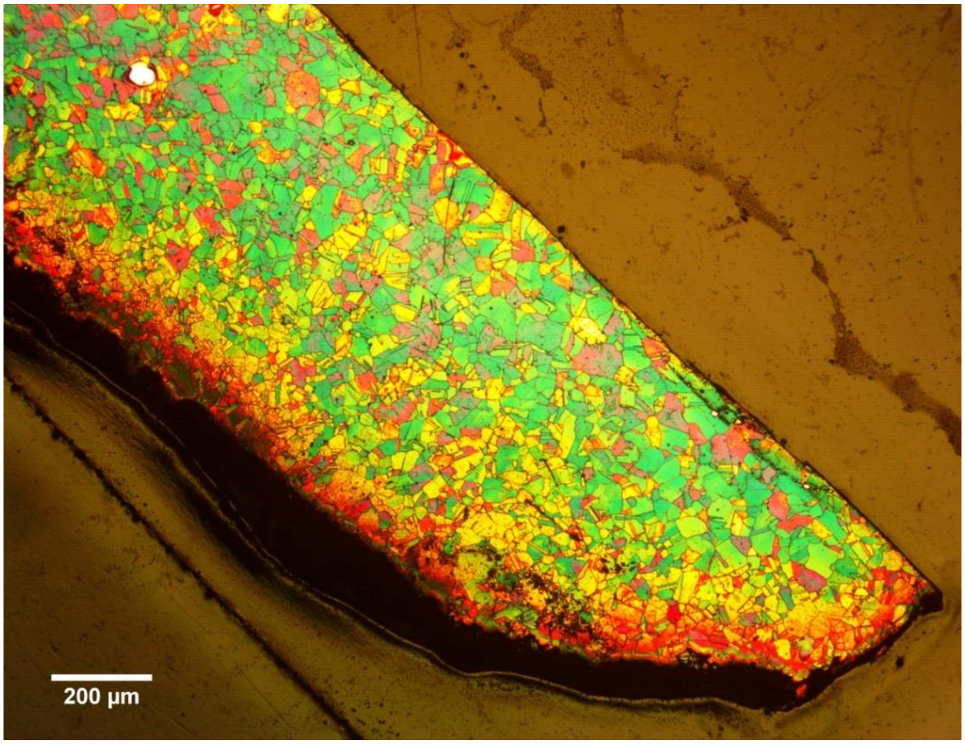

Figure III10b. Optical micrograph showing mostly equiaxed grains, color etched

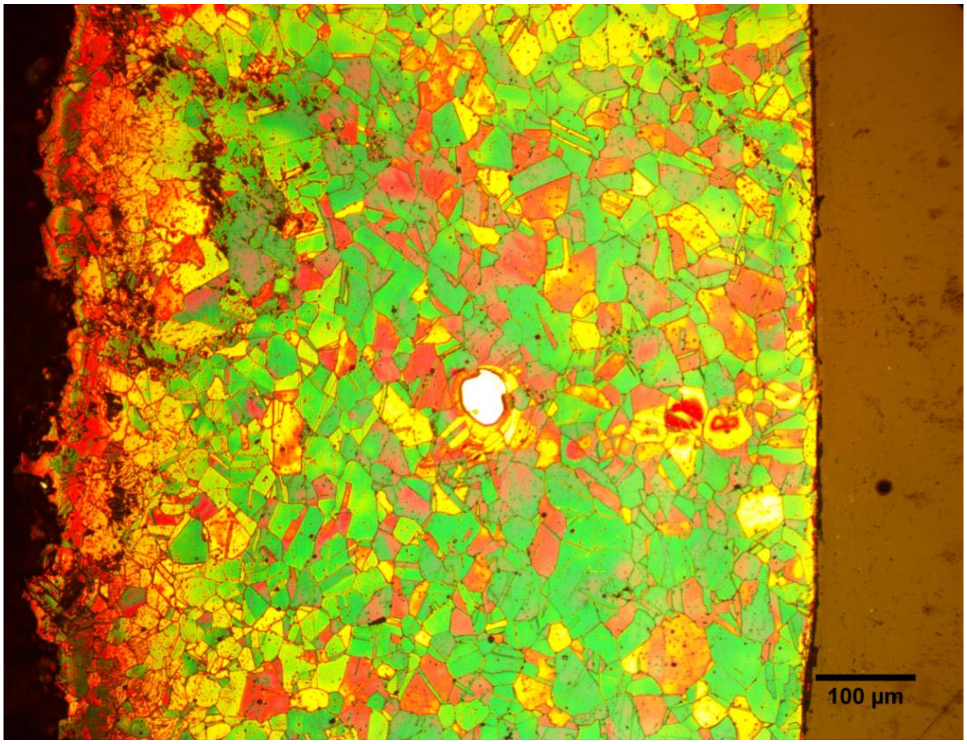

Figure III10c. Despite what appears to be clear evidence for inverse segregation on the red and yellow side, it is not and this color differentiation apparently reflects different oxidation states

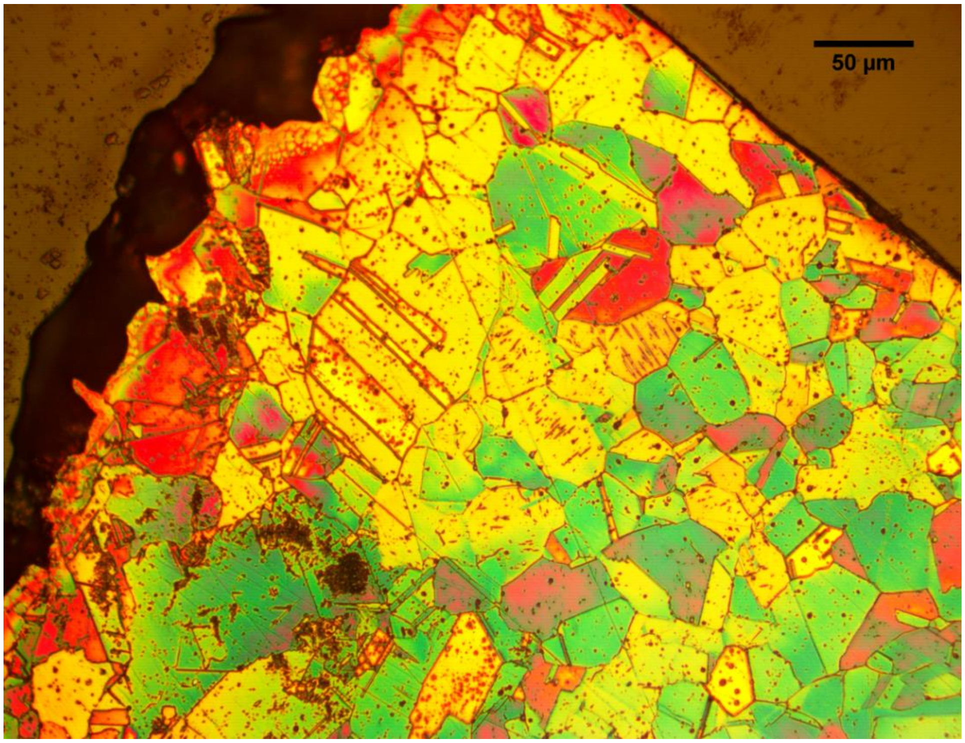

Figure III10d. Twins and slip planes

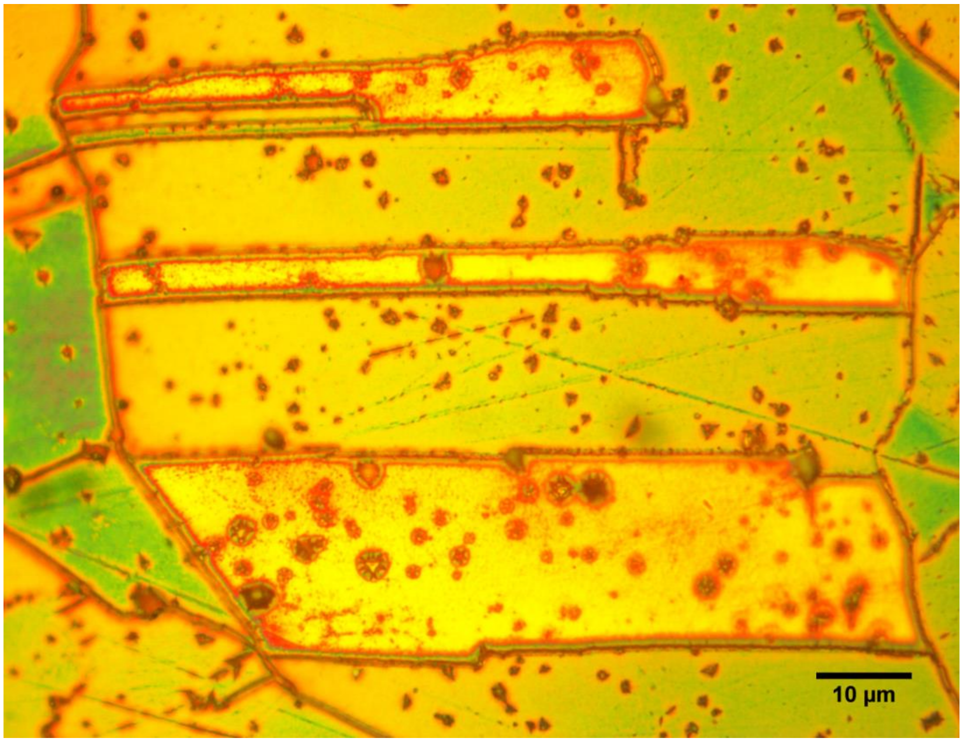

Figure III10e. Close-up of twins

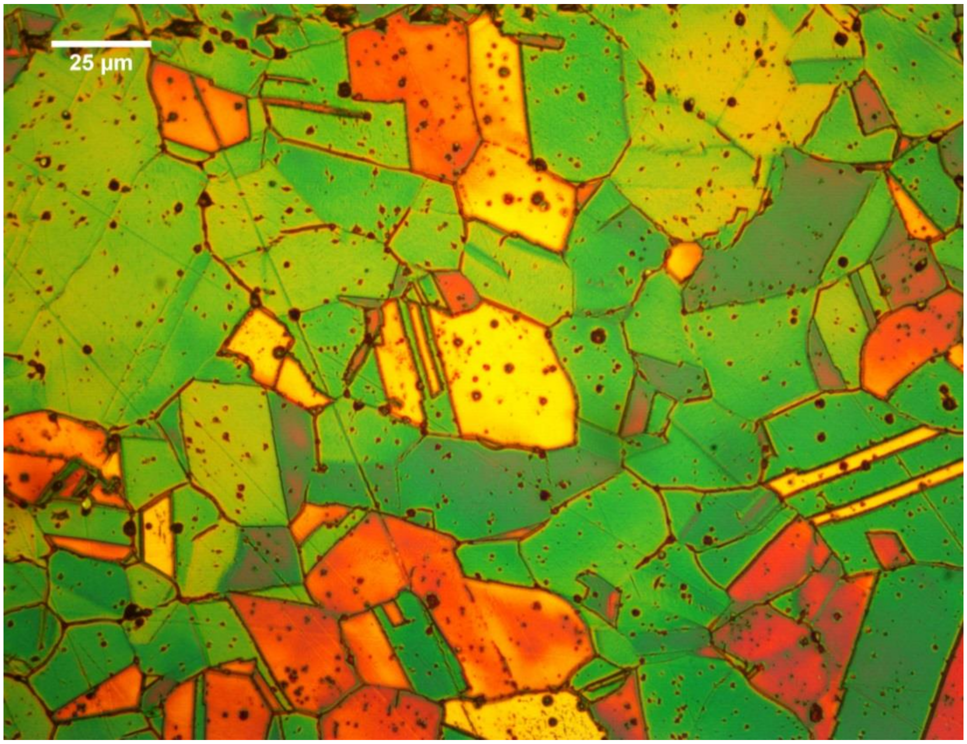

Figure III10f. Twins and slip planes

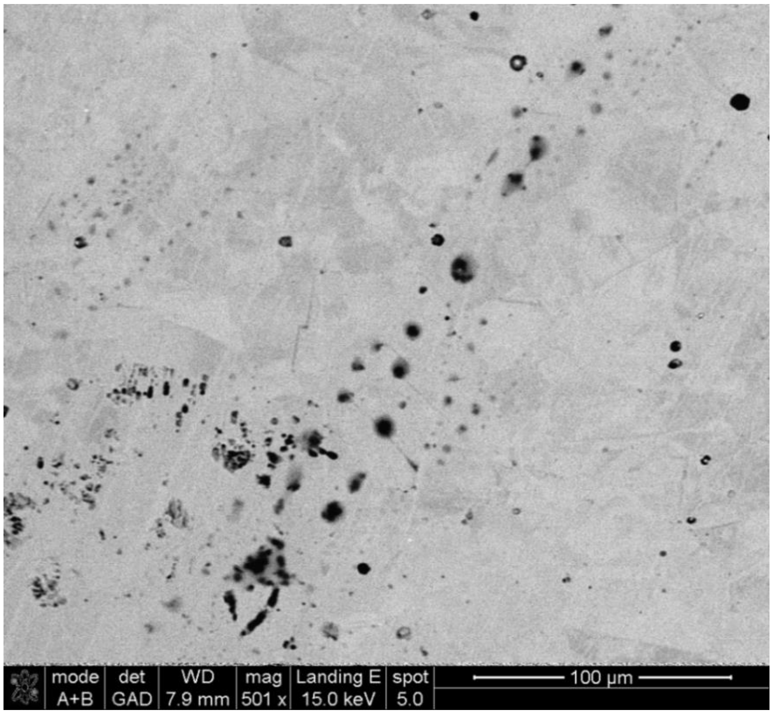

Figure III10g. Slag stringer

III11: Locus 7271, Artifact 33531

Context: 300-146 BC – “Brown - orange sandy fill with large and small stones, N of wall 7270, below N part of 7267.”

Overview: This clenched nail with round head has a low arsenic content that may be the result of recycling, but can be considered an arsenical copper due to the absence of other impurities excluding sulfur. Furthermore, the other clenched nail in the corpus (7288 33539) has 1.34 wt% arsenical content. It seems that a low arsenic content was used for clenched nail to make them hard enough for use but not too brittle for repeated loosening and clenching. Cracks in the head of the nail attest to its use. Some zones display equiaxed grain and twins indicate annealing and hammering, whereas others show differential grain size. Lack of a weld shows that this artifact was cast. Grain boundaries are attacked by intergranular corrosion, especially in the shank. The shank also possesses a peculiar microstructure in some areas.

Figure III11a. L. 7271 33531

Artifact	Dates	Instrument	Spots	Cu	Sn	As	Fe	Pb	S	Ag	Ni
7271 33531	300-146	SEM-EDS	5	98.93	—	0.77	—	—	0.29	—	—

Table III11. SEM-EDS alloy results

Figure III11b. Mounted with double cross section for analysis of both head and shank, cracks on top of head are visible to naked eye

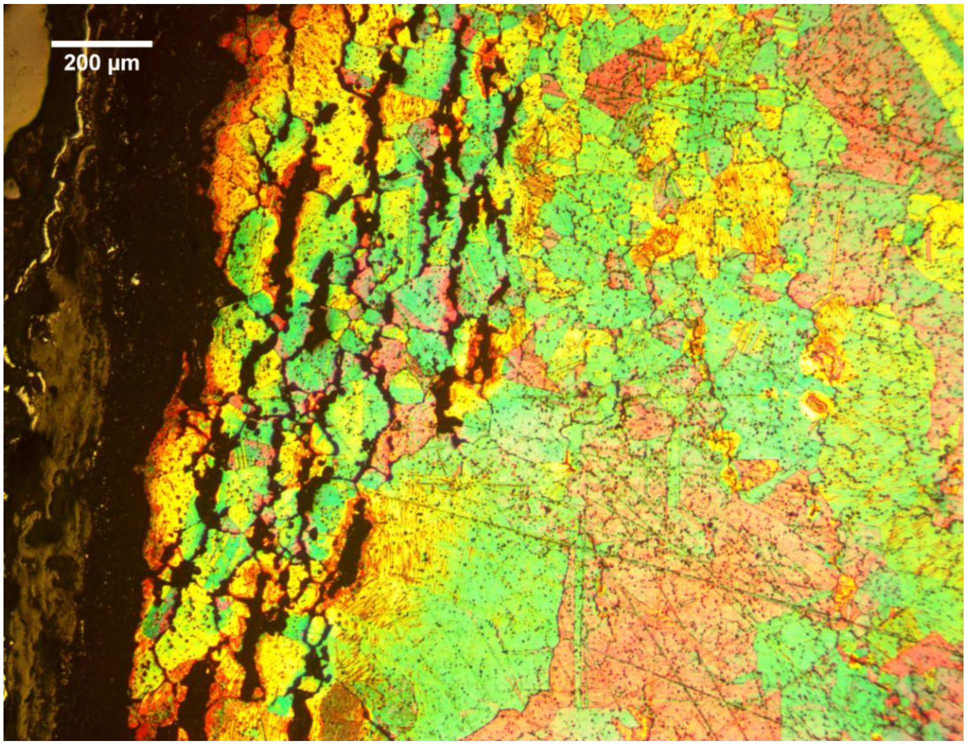

Figure III11c. Optical micrograph showing cracks alongside head from hammering during use lifetime (turned, on the left), color etched

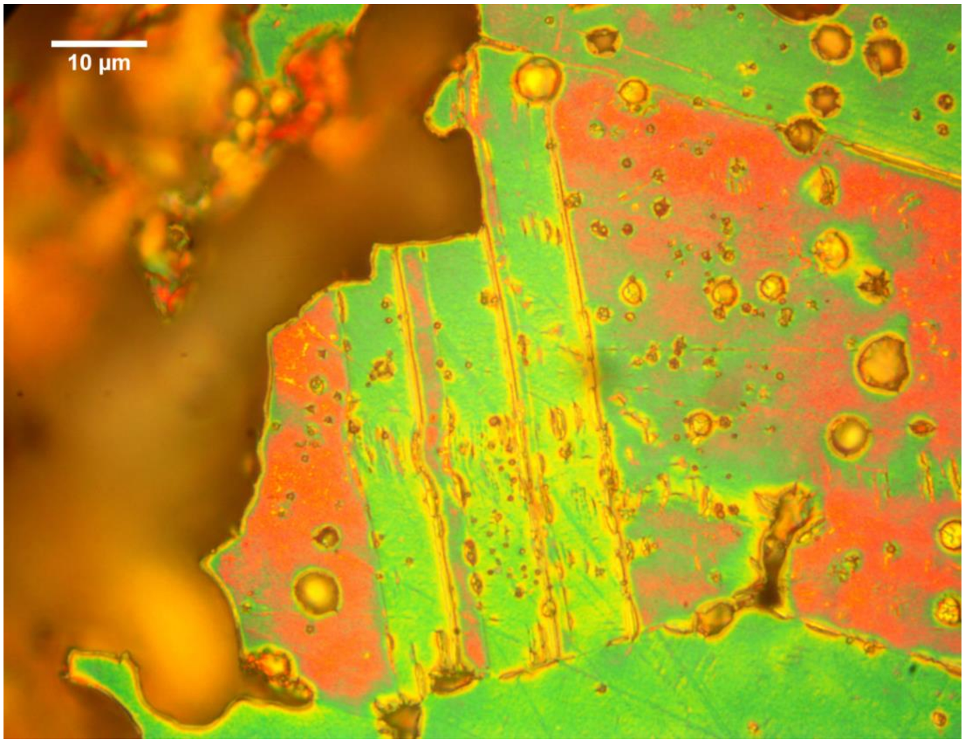

Figure III11d. Twins in the head from hammering during production

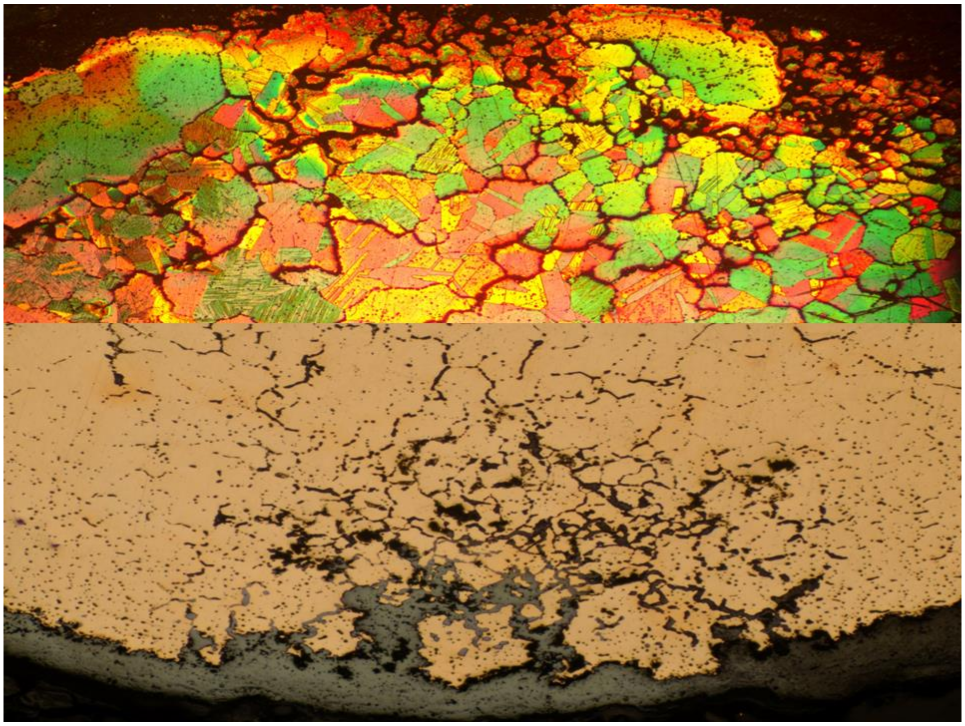

Figure III11e. Mirror image of half of the shaft, the top color etched, the bottom unetched. Intergranular corrosion attacking into the shaft as seen on the bottom, with differential grain size throughout the alloy as seen on top

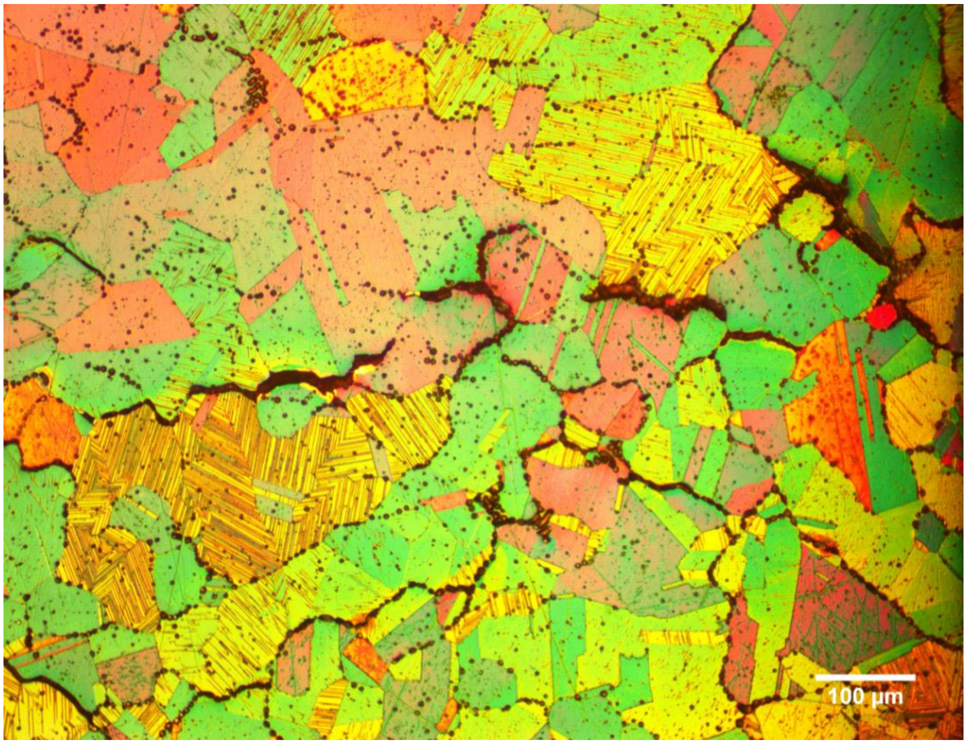

Figure III11f. Peculiar geometric microstructure in shank

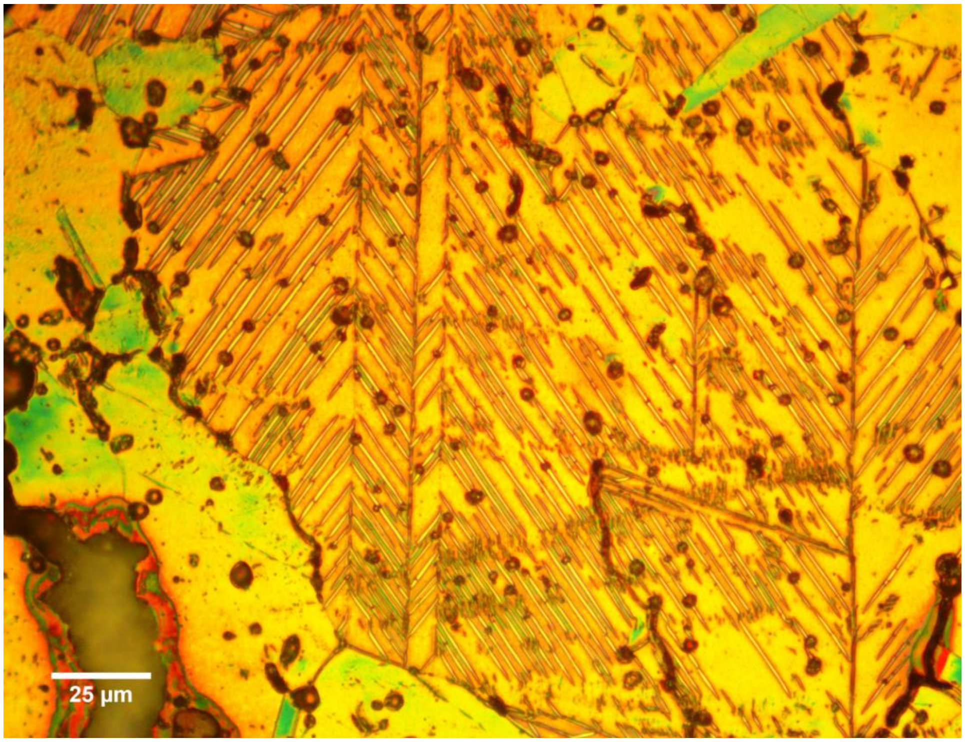

Figure III11g. Peculiar microstructure in head

III12. Locus 7288, Artifact 33539

Context: 300-146 BC – "Brown loose sandy layer below 7285; destruction layer?"

Overview: This arsenical copper clenched nail exhibits the "swirling" microstructure that is characteristic of the cast alloys in this corpus. Heavy strain lines close to top of head, indicating hammering either in production or in use lifetime. There is no weld. The "swirling" and directionality of grains with relatively low twinning indicates a casting episode with light hammering. This nail also has regions with peculiar microstructure similar to 7271 33531, and was also mounted in a like fashion with doubly exposed cross sections of the head and shank.

Figure III12a. L. 7288 33539

Artifact	Dates	Instrument	Spots	Cu	Sn	As	Fe	Pb	S	Ag	Ni
7288 33539	300-146	SEM-EDS	5	97.30	—	1.34	0.44	—	0.92	—	—

Table III12. SEM-EDS alloy results

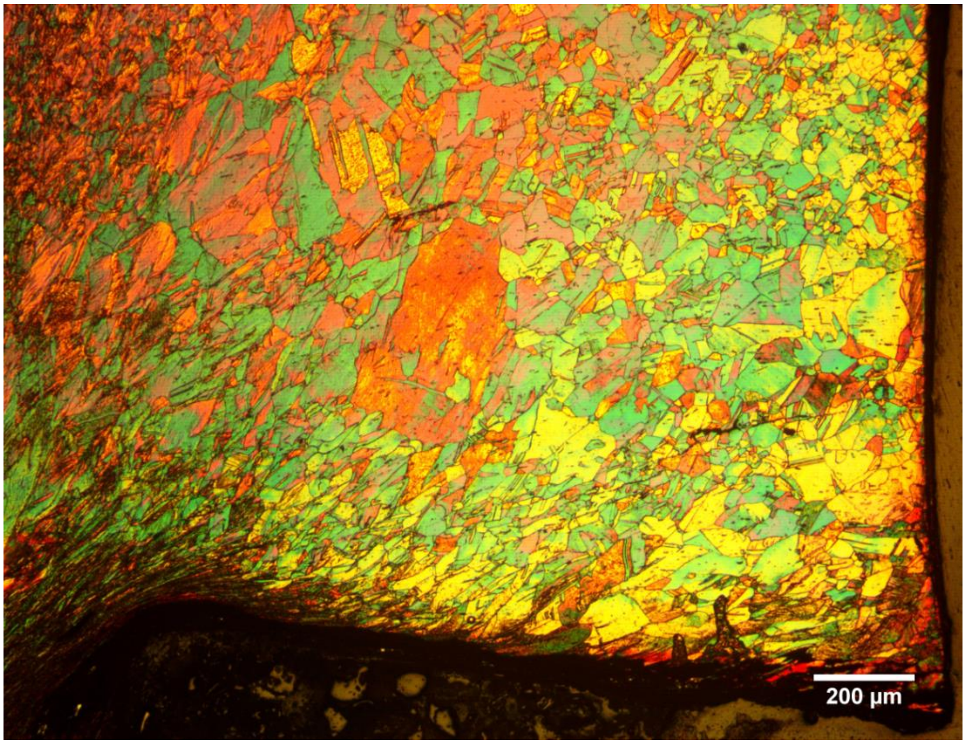

Figure III12b. Interface of head and shank with “swirling” microstructure, color etched

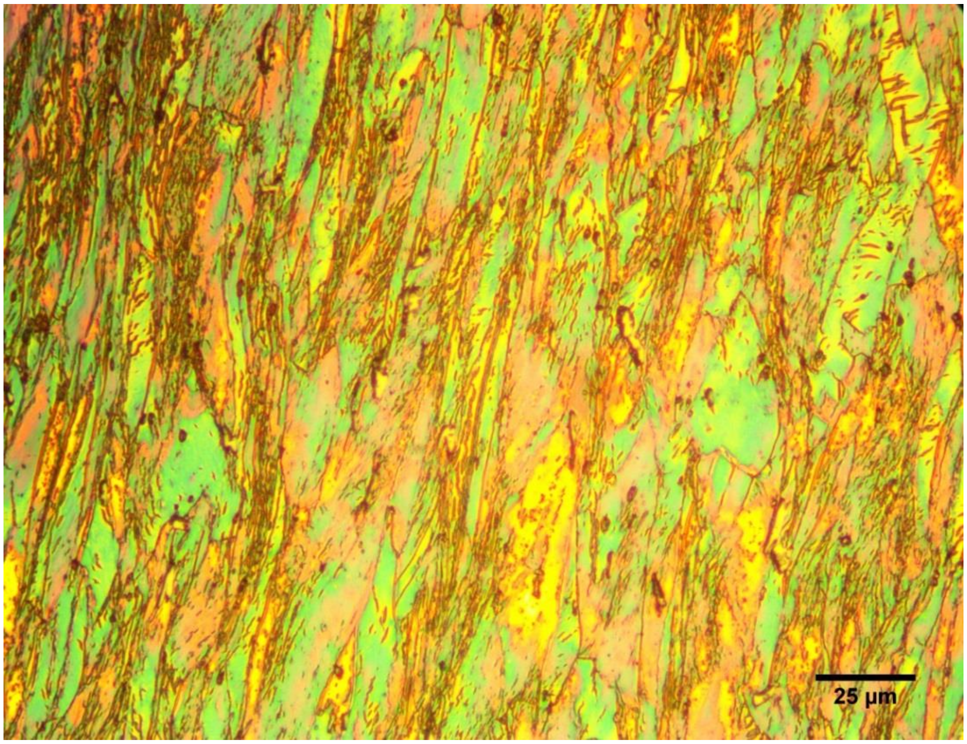

Figure III12c. Directionality of grains and strain lines near top of the head (turned)

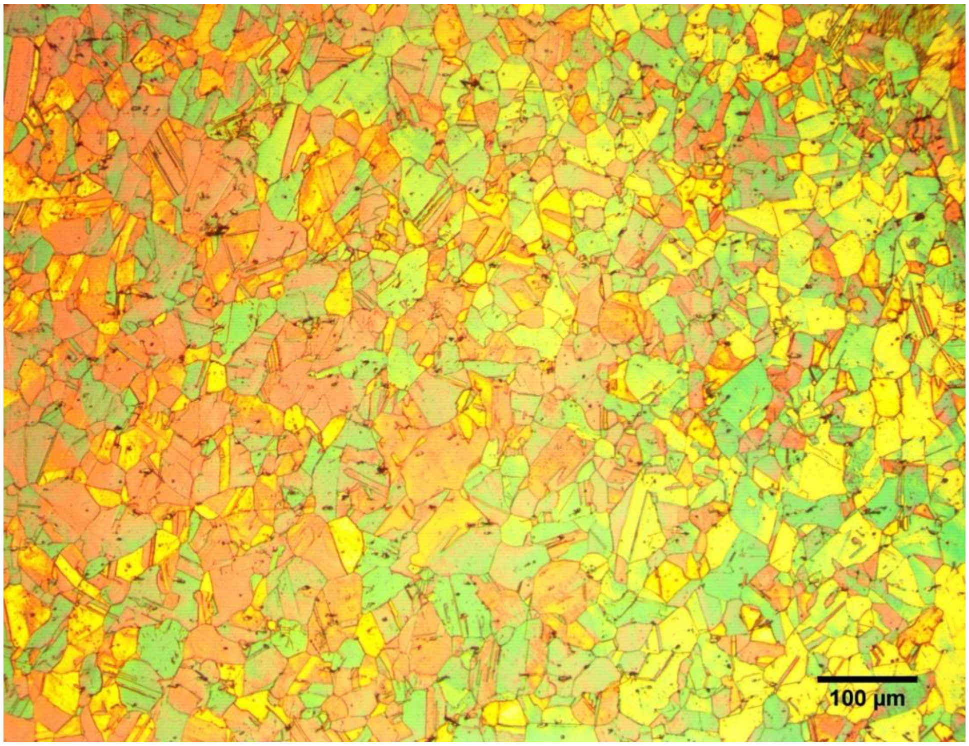

Figure III12d. Equiaxed grains toward shank – protected from heavy strains and working but still demonstrating twins

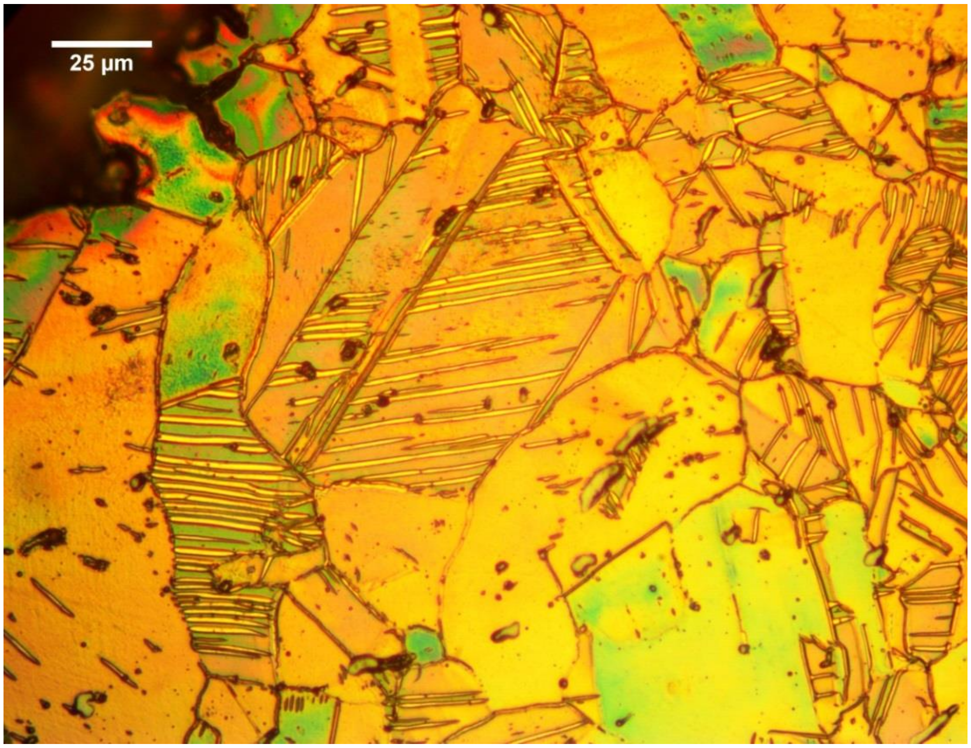

Figure III12e. Peculiar microstructure also evident from 7271 33531

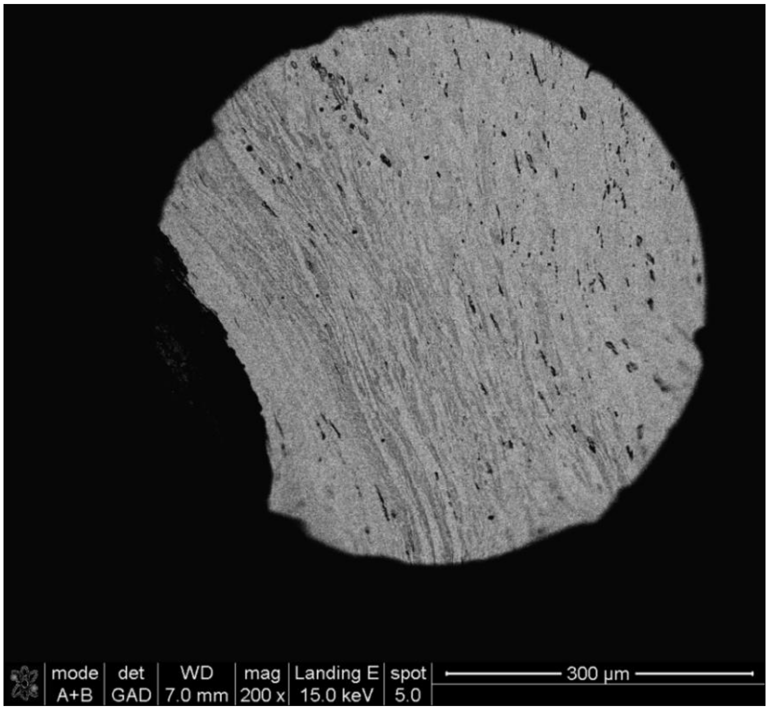

Figure III12f. “Swirling” microstructure as seen in backscattered mode

B. Cobalt

III13. Locus 1093, 10191

Context: 450-425 BC – "= (above) 1111, 1112, 1115, 1116: Compact levelling layer below floor 1068 (removal of this floor); in part same as 1074; very dirty layer with faeces; many metal (working?) finds."

Overview: It is unclear what this rare piece of a cobalt rich metalliferous object is. The cobalt content sometimes reaches upwards of 30 wt% as gathered from spot analysis. The iron content makes it highly unlikely that it is an ore. The most reasonable suppositions are that it is either slag from blue colorant for glass or specialized metal production, or that it is perhaps a type of corroded piece of jewelry like a bead. Whatever the case, it is clearly a luxury item.

Figure III13a. L. 1093 10191

Artifact	Dates	Instrument	Spots	Co	Cu	Fe	Zn	Zr	Si	Ca	Al
1093 10191	450-425	SEM-EDS	5	16.55	6.40	42.03	0.11	0.02	3.28	1.18	0.55

P	K	Cl	O	C
0.02	0.15	0.99	26.50	2.24

Table III13. SEM-EDS results

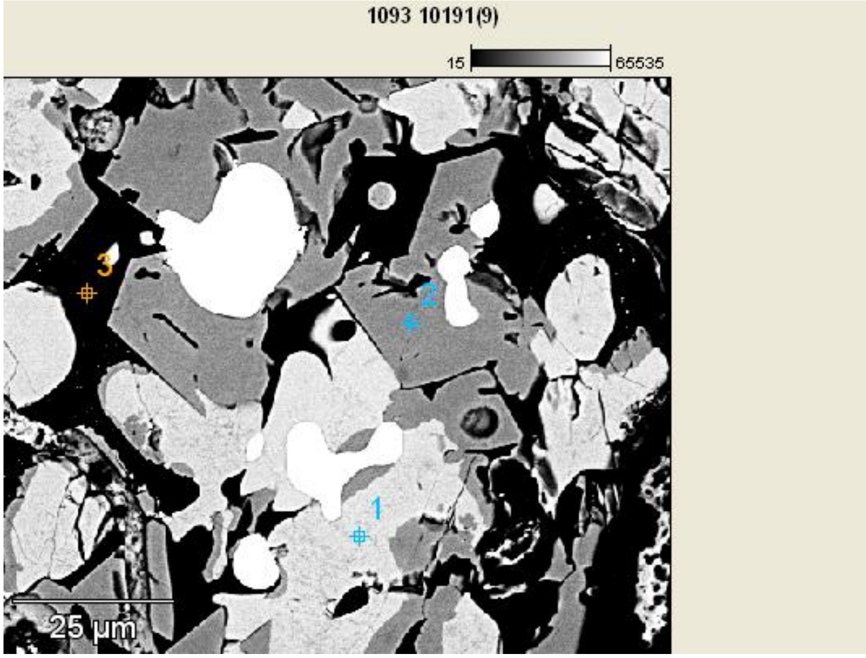

Figure III13b. Backscattered micrograph of various phases: spot 1 is 28.65 wt% cobalt; spot 2 is 12.15 wt% cobalt; spot 3 is 10.42 wt% cobalt. Brightest white phases are redeposited copper

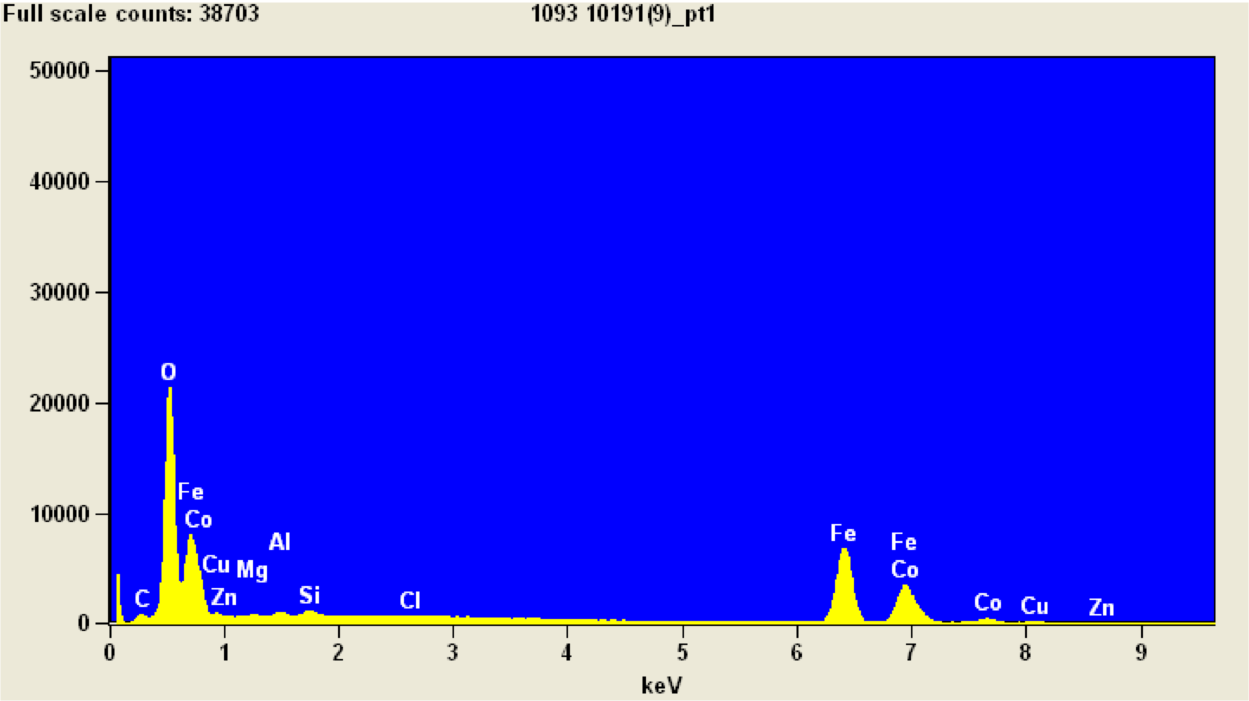

Figure III13c. Spectrum of spot 1 above from Figure III13b

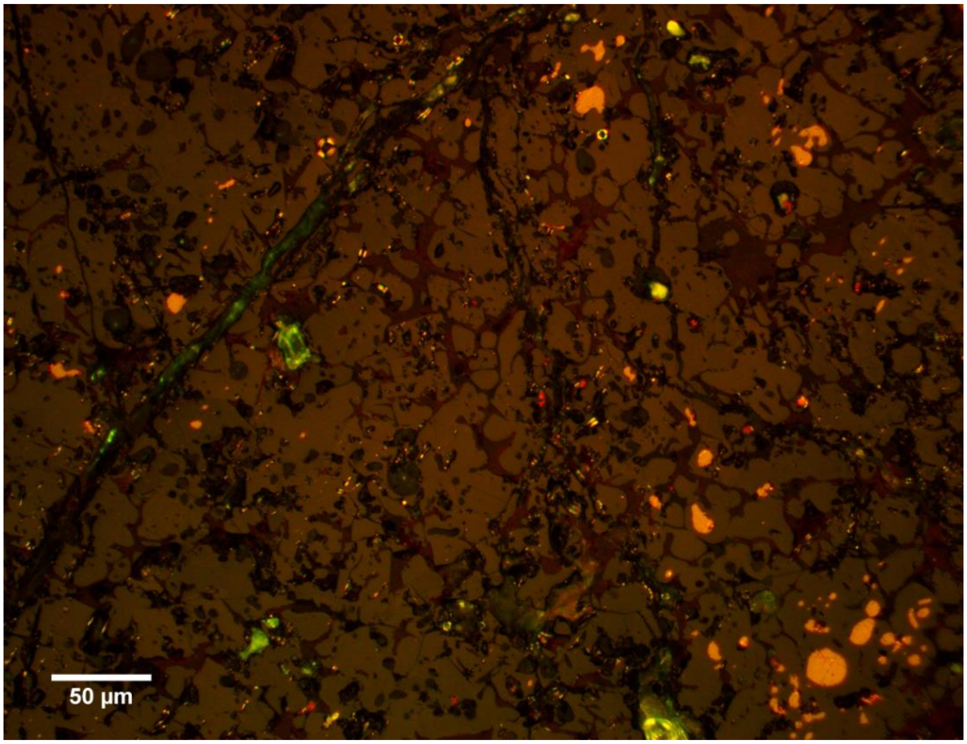

Figure III13d. Dark field micrograph of redeposited copper and what appear to be copper oxide veins

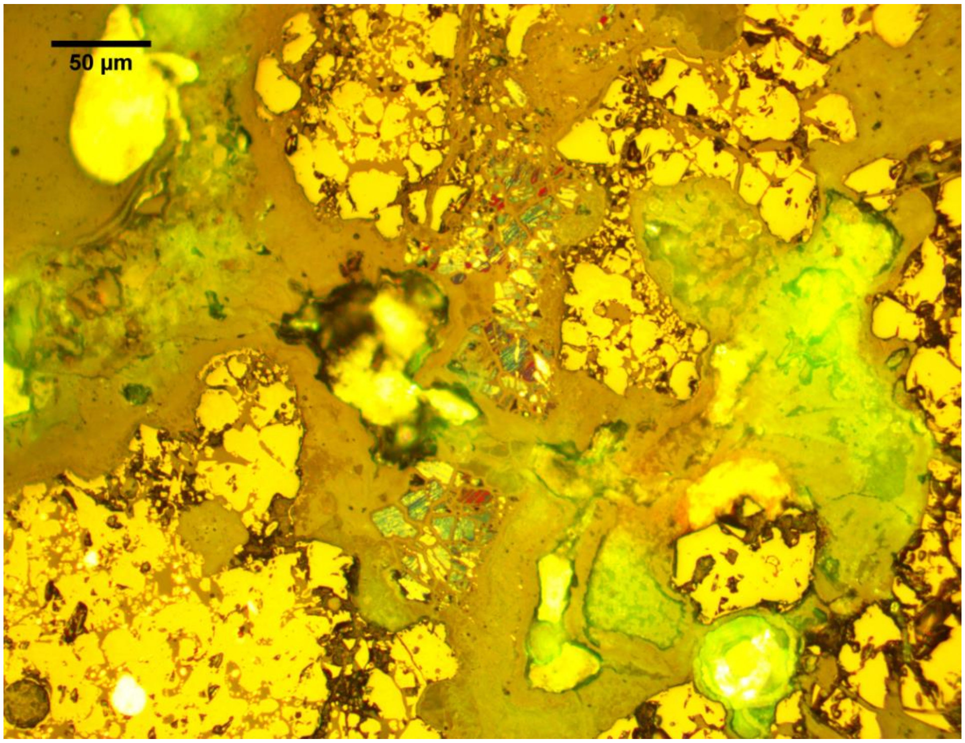

Figure III13e. Optical micrograph of various components

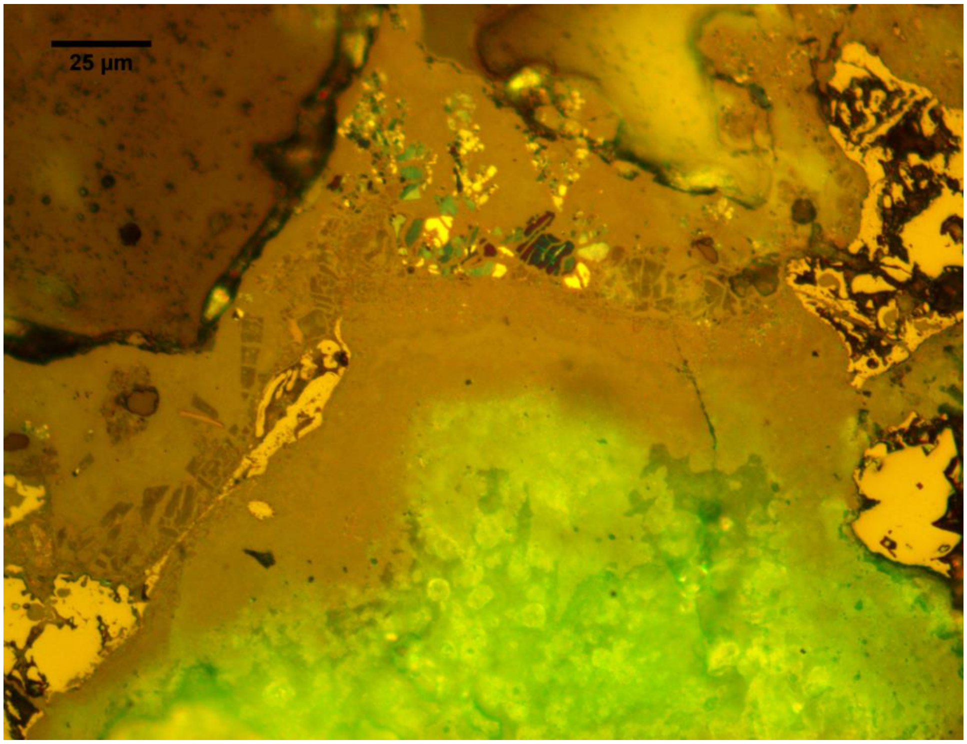

Figure III13f. Optical micrograph of various components

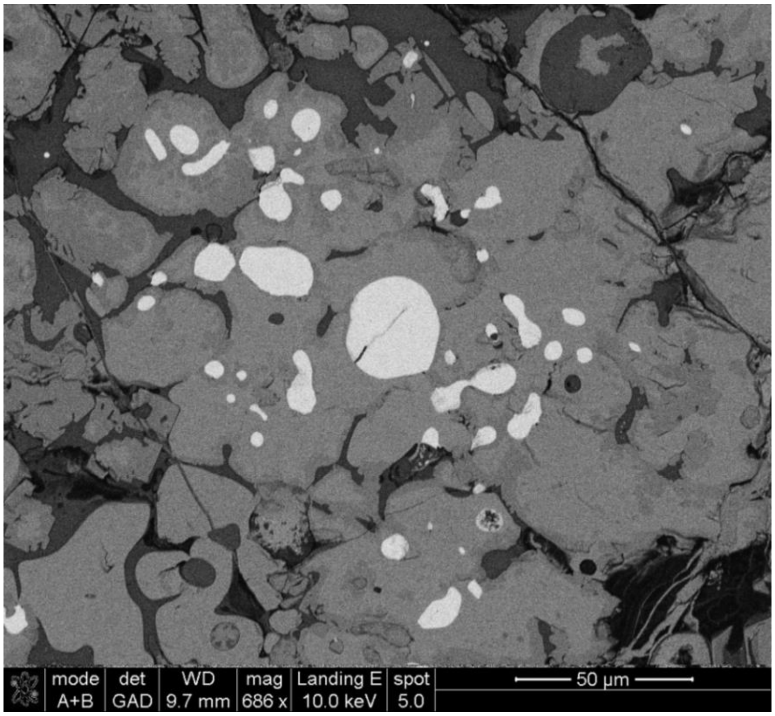

Figure III13g. Backscattered micrograph of redeposited copper

C. Leaded Bronzes

III14. Locus 4444, Artifact 38448

Context: 430-400 BC.

Overview: This leaded arsenical bronze has multiple phases which reflect varying compositions of the copper, lead, and arsenic components. It is fully corroded and has been subjected to preferential corrosion heterogenization. The laminated corrosion structure that remains would not have been intentional or present in the alloy, but rather represents the phases segregating themselves in the thousands of years of deposition. Some phases are also copper sulfides with low arsenic content. Other areas boast lead veins, and nickel impurities. Some phases have almost equal levels of copper, arsenic, and lead (a third each, see Figure 4CXIVf, spot 3). Definitive reconstruction of the original alloy is hampered by the usual changes that the composition undergoes due to corrosion, in addition to the interesting segregated nature of this particular corrosion. Still, averages were taken over all various zones in order to render an as accurate alloy determination as possible.

Figure III14a. L. 4444 38448

Artifact	Dates	Instrument	Spots	Pb	Sn	As	Fe	Cu	S
4444 38448	430-400	SEM-EDS	5	33.42	—	23.87	—	41.84	0.77

Ni	Mo	Zr	Bi	Sb
0.10		—	—	—

Table III14. SEM-EDS alloy results

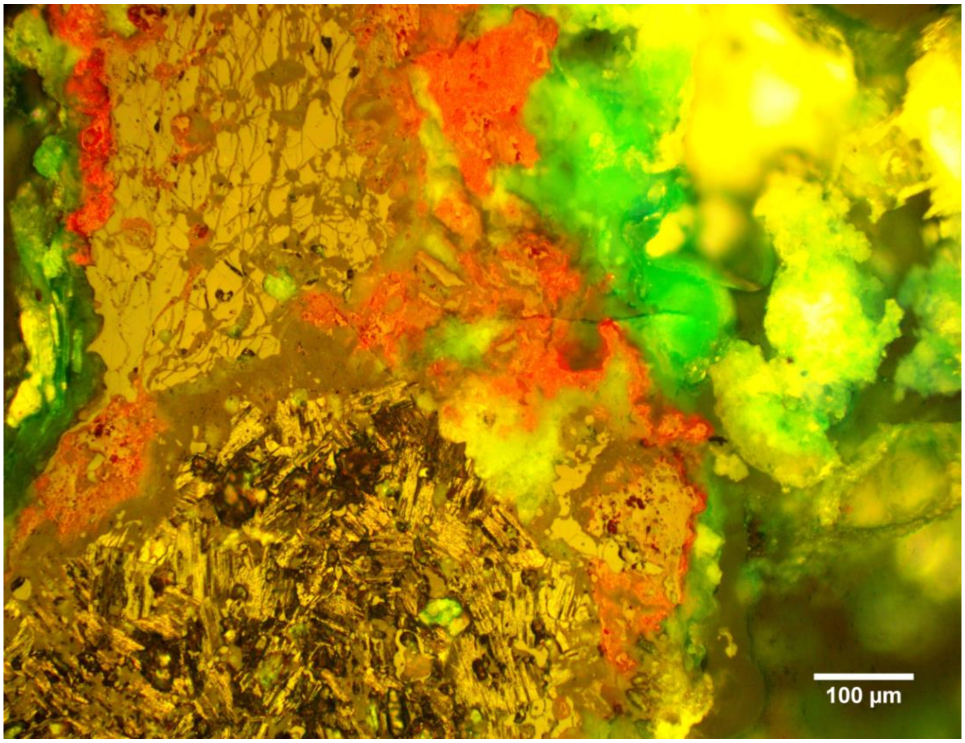

Figure III14b. Optical micrograph showing two zones: the lower left with alternating arsenic and lead rich grain-like phases; upper left with low arsenical content copper sulfides with lead veins and globes

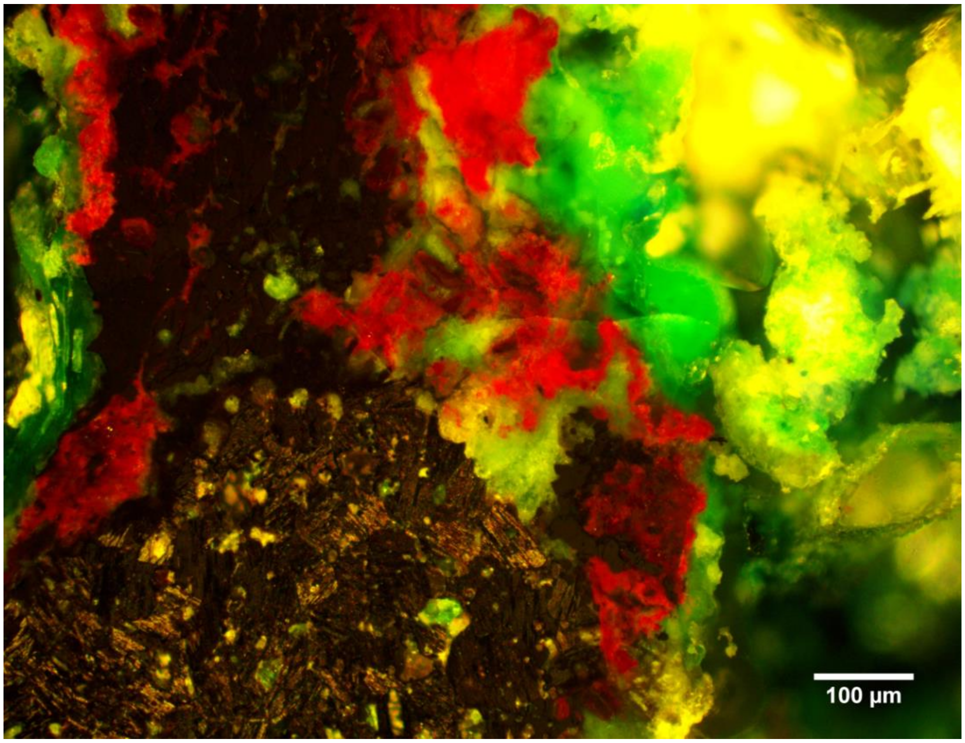

Figure III14c. Dark field micrograph of Figure 4CXIVb

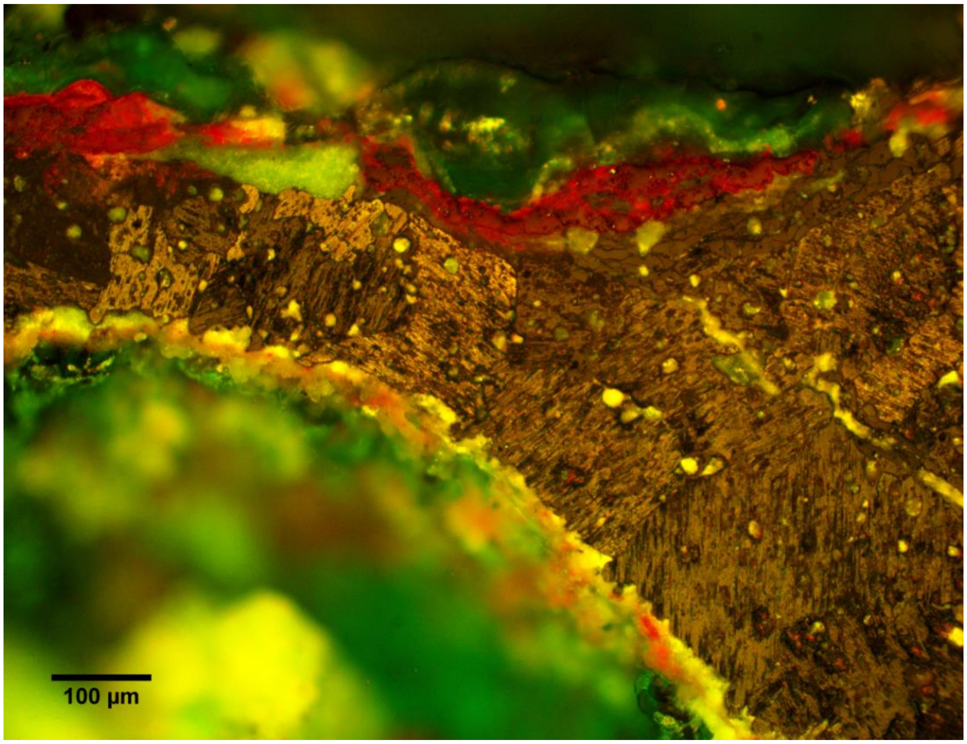

Figure III14d. Dark field micrograph of various phases of alternating arsenic or lead rich grain-like phases

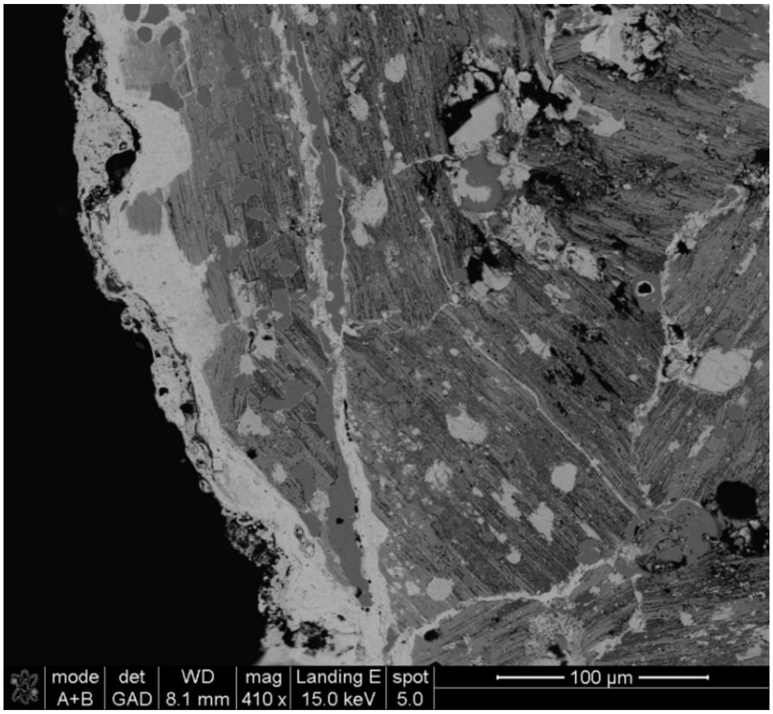

Figure III14e. Overview of zones in backscattered mode

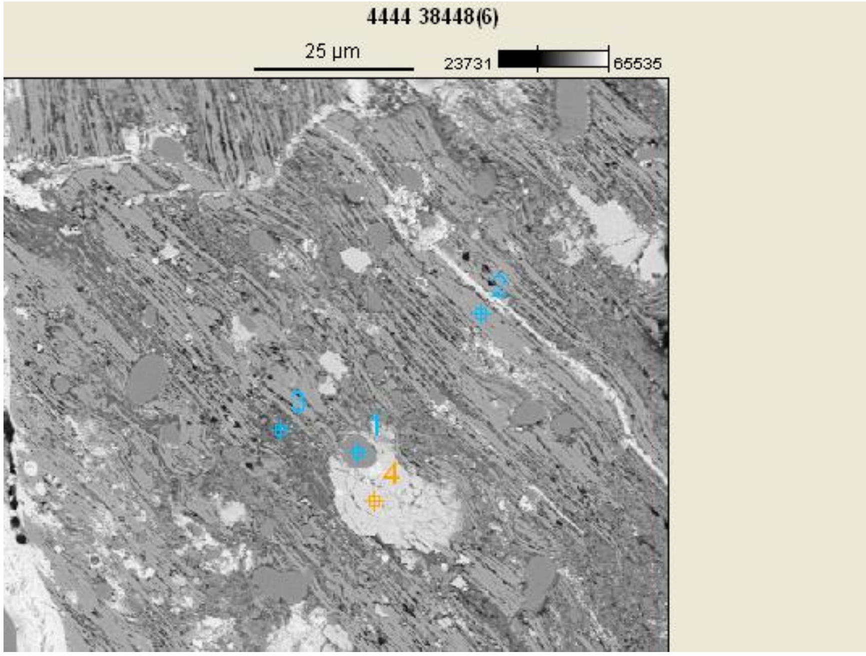

Figure III14f. Phase differentiation, in wt%, spot 1: 75.51Cu 2.77As 21.72S; spot 2: 59.54Cu 38.16As 2.14Pb 0.17S; spot 3: 31.69Cu 33.78As 34.53Pb; spot 4: 6.51Cu 1.84As 80.41Pb 11.24S

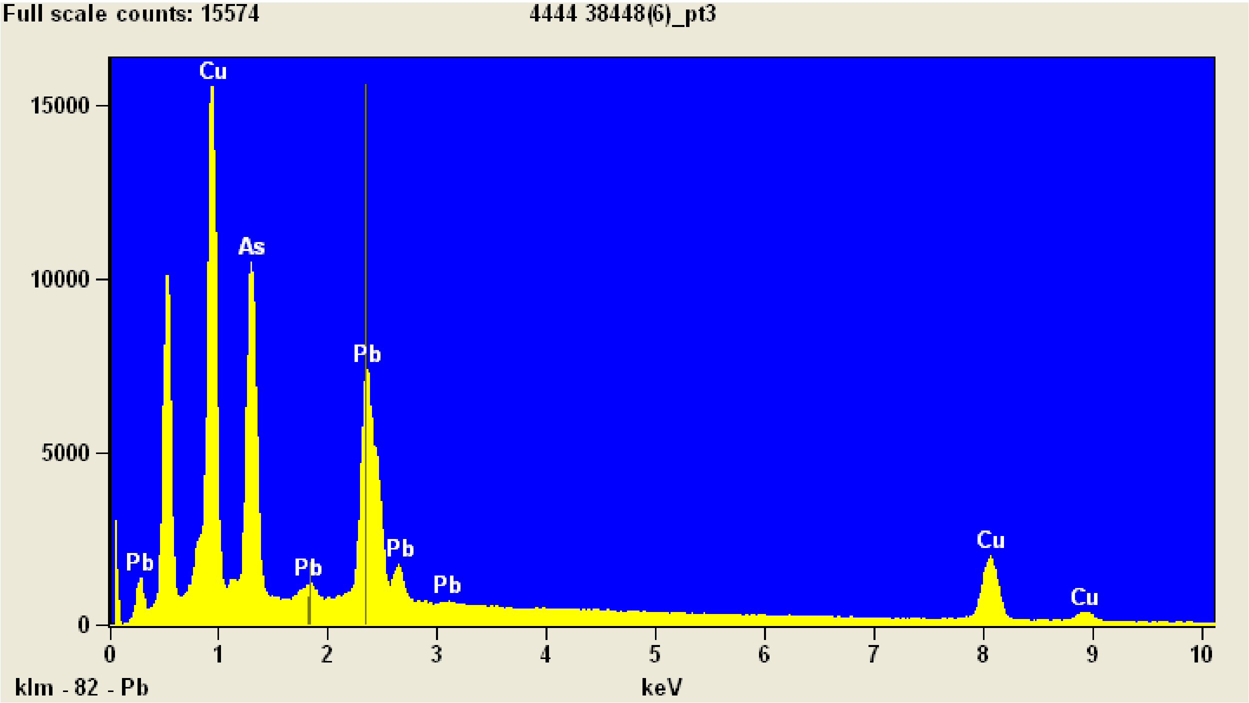

Figure III14g. Spot 3 of above, Figure 4CXIVf

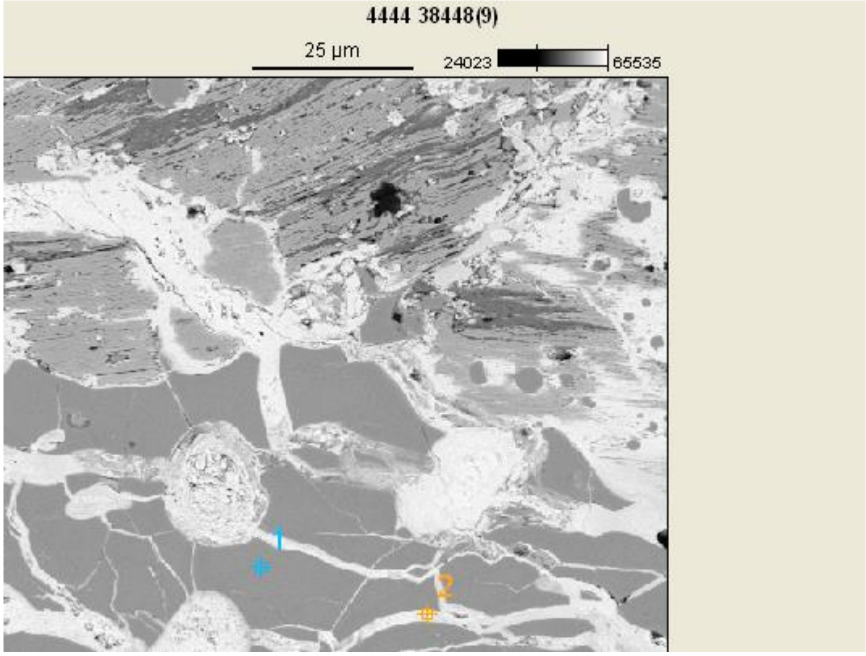

Figure III14h. Lead veins and copper sulfide matrix, in wt%, spot1: 74.91Cu 1.88As 23.22S; spot 2: 12.15Cu 20.31As 67.54Pb

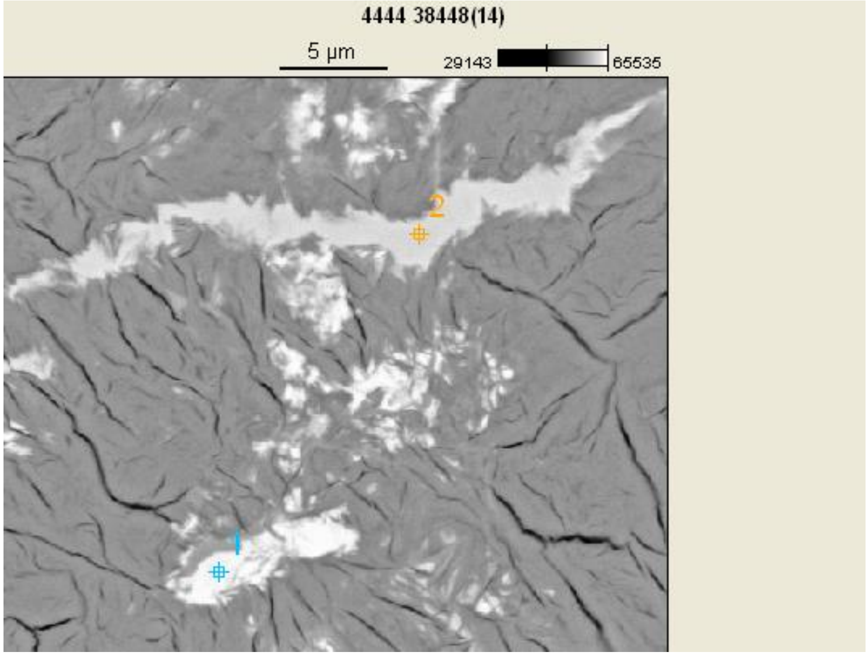

Figure III14i. Nickel impurities, in wt%, spot 1: 16.27Cu 31.45As 51.06Pb 1.22Ni; spot 2: 24.13Cu 36.91As 36.98Pb 1.99Ni

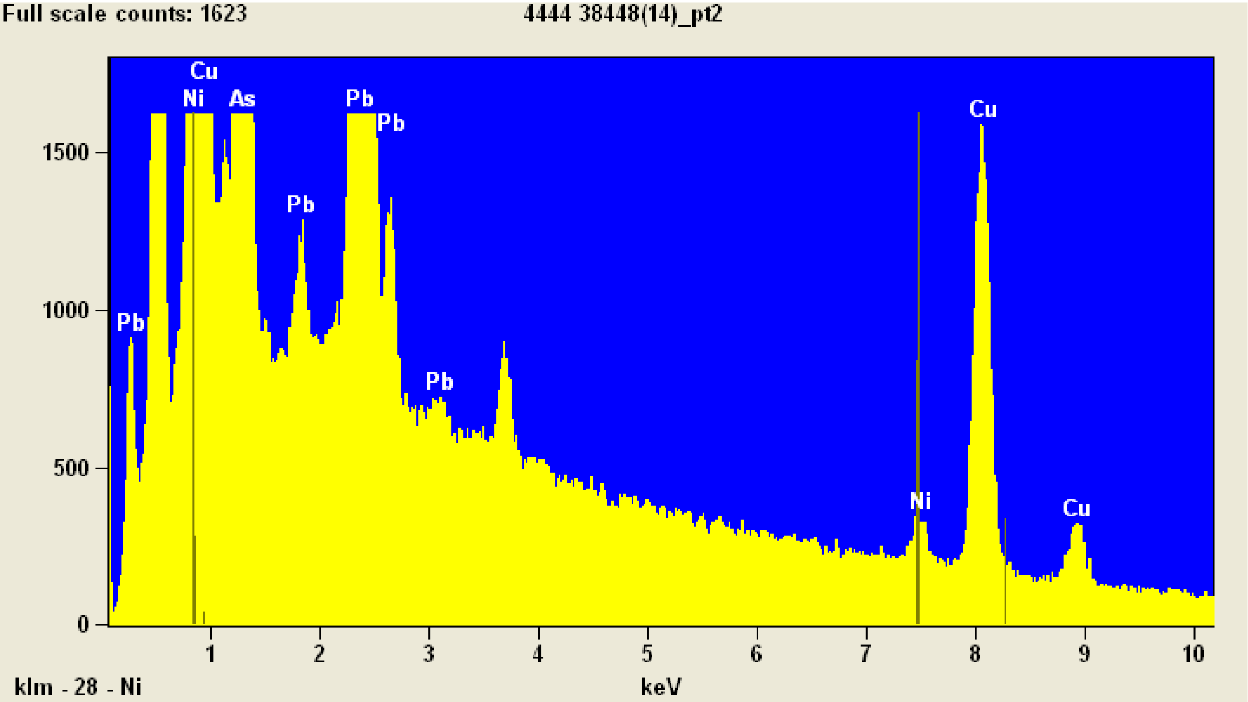

Figure III14j. Spot 2 from above, Figure III14i

III15. Locus 2504, Artifact 45010

Context: 330-300 BC – "= 2420? (=Coin (Carthage 370-340 BC); context completely sieved); 1 coin. Sandy layered level below 2503."

Overview: This leaded tin bronze was cast which resulted in a great deal of porosity. There is heavy coring, perhaps dendritic coring as well. Corrosion has attacked the alloy which is often connected to heavy working which is evident here by the strain lines. Indeed, the corrosion in some cases has stimulated grain differentiation. There are also silver impurities associated with sulfur impurities.

Figure III15a. L. 2504 45010

Artifact	Dates	Instrument	Spots	Pb	Sn	As	Fe	Cu	S
2504 45010	330-300	SEM-EDS	5	20.29	6.71	0.32	—	72.68	—

Ni	Mo	Zr	Bi	Sb
	—	—	—	—

Table III15. SEM-EDS alloy results

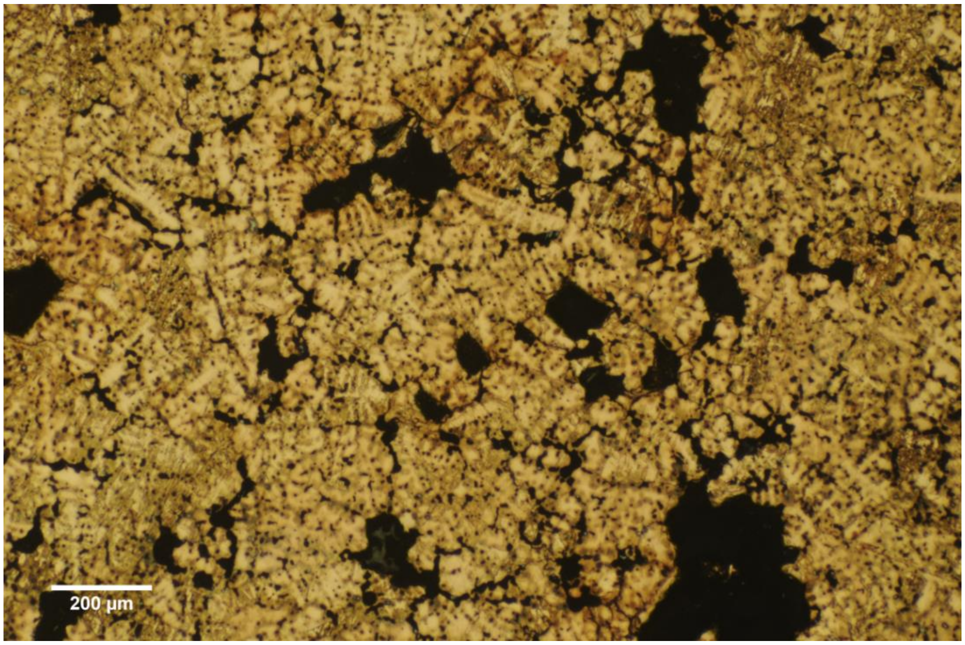

Figure III15b. Optical micrograph showing coring and grain differentiation provided by intergranular corrosion, etched with ferric chloride

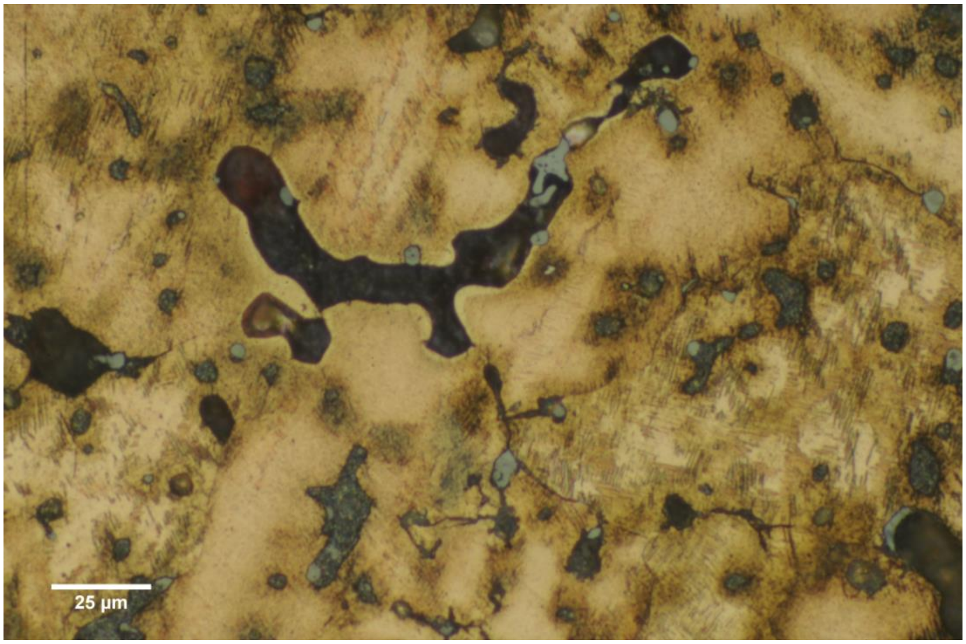

Figure III15c. Green condensed lead globules, strain lines

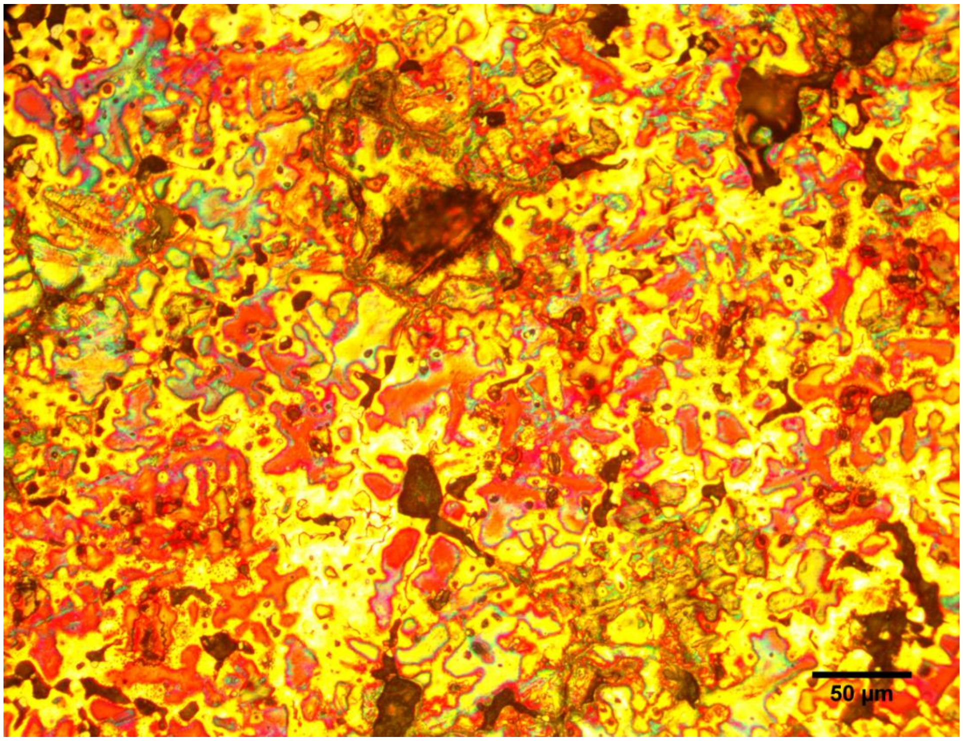

Figure III15d. Generally non-granular microstructure, color etched

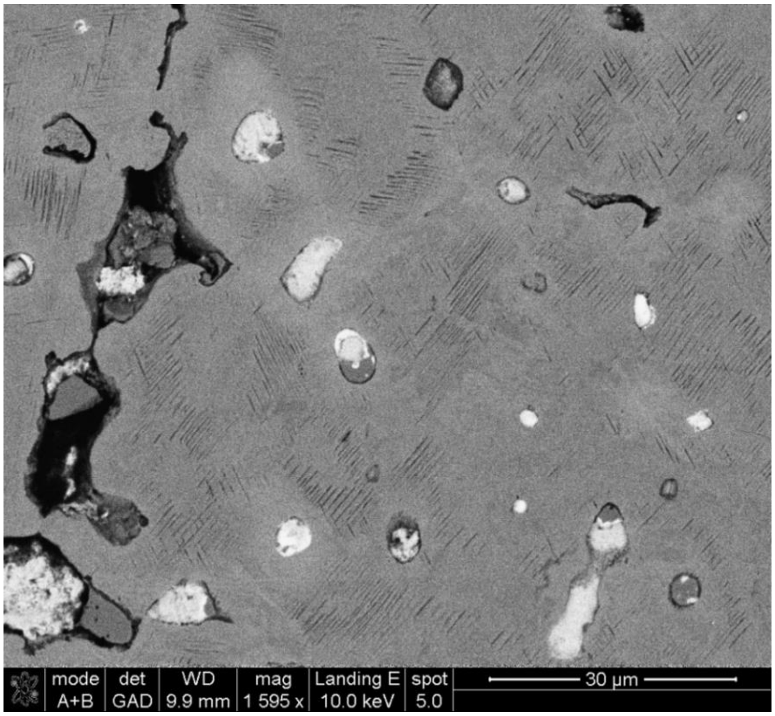

Figure III15e. Strain lines in backscattered mode

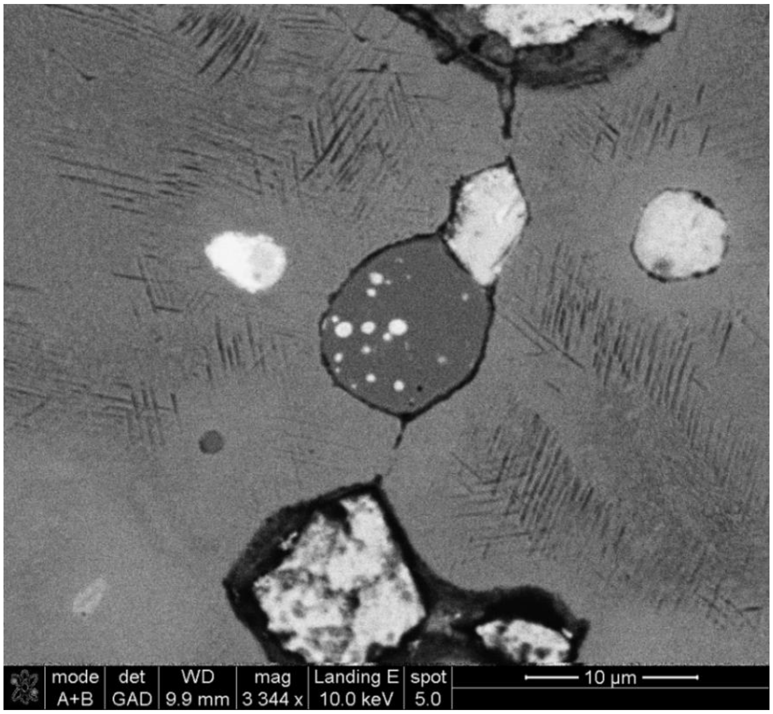

Figure III15f. Silver-rich white speckles on a sulfidic globule, possessing copper, arsenic, sulfur, and silver

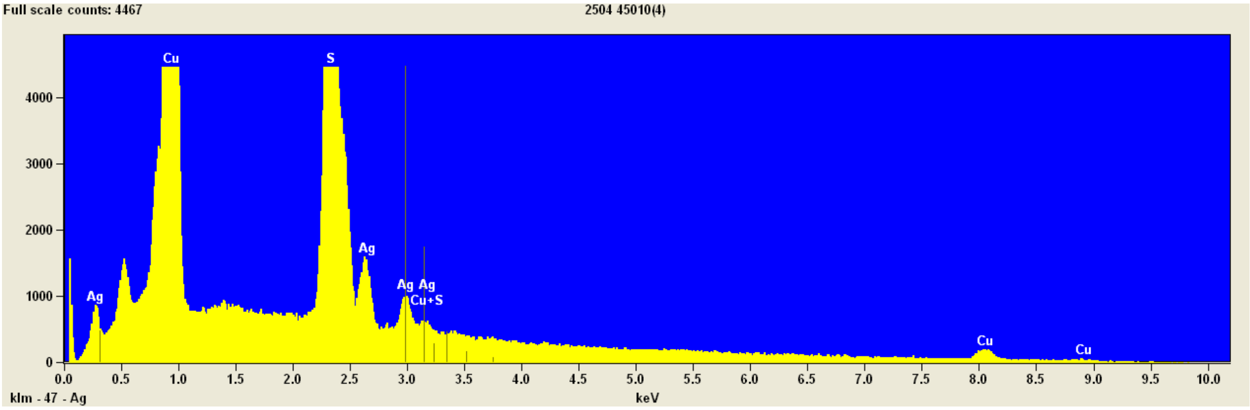

Figure III15g. Spectrum of close-up of silver-rich speckles at X191,000 magnification, in wt% 69.58Cu 8.55Ag 21.87S

D. Lead

i. *425-300 BC*

III16. Locus 1107, Artifact 38237

Context: 425-400 BC – "= 1104, 1105, (below) 1106, (above) 1108, (above) 1109, 1110, 1113, 1114, 1117, 1118, 1122: Compact levelling layer [according to PM fragm. of late I BC CBM: intrusive]."

Overview: This pure lead artifact attests to an incredibly high degree of lead refinement technology in the Middle Punic – not surprising as this metal was essentially used as the standard weighing device for commerce as seen in the lead weight of III17 below. The typology of this artifact is unknown.

Figure III16a. L. 1107 38237

Artifact	Dates	Instrument	Spots	Pb	Sn	As	Fe	Cu	S	Ni	Mo	Zr	Bi	Sb
1107 38237	425-400	pXRF	2	99.594±0.147	—	—	0.075±0.025	0.055±0.009	—	—	0.011±0.003	—	0.105±0.046	0.03±0.014

Table III16. pXRF alloy results

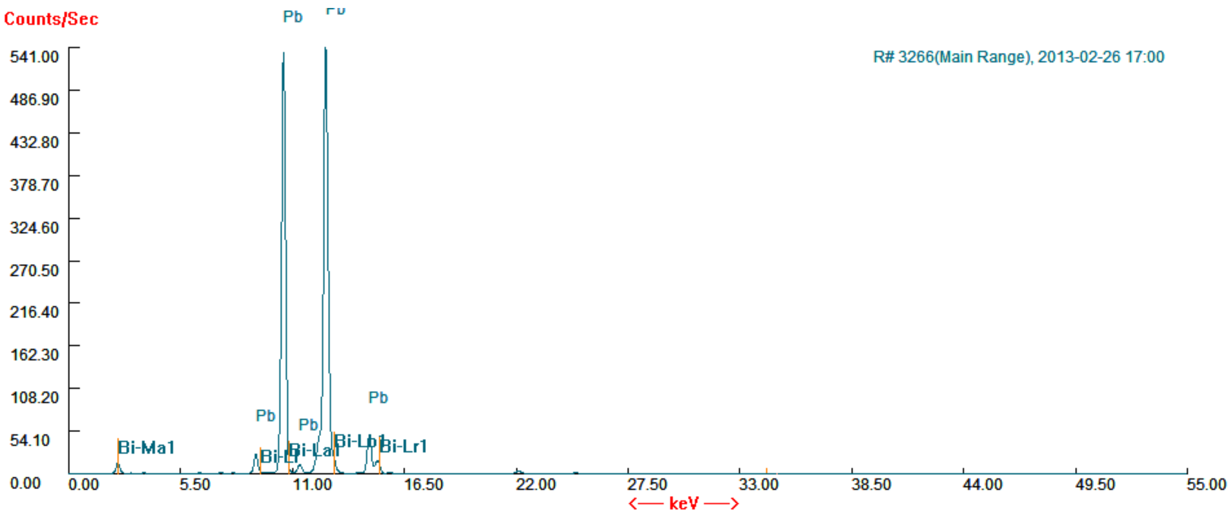

Figure III16b. pXRF spectrum

III17. Locus 2420, Artifact 42777

Context: 330-300 BC – “Coin (Carthage 370-340 BC); context completely sieved.”

Overview: This lead weight weighs 18.0 grams. Post-depositional formation processes have certainly affected the alloy, as silicon, phosphorus, and aluminum had to be excluded from the alloy reading. They were clearly additions following deposition. Only one side had these impurities, and the other six were all at least 98.5 wt%. The iron content may be attributed to this as well – but not the tin or copper content which are either intentional additions, or are the result of recycling. Either way, the pureness of the lead was comprised. It is unknown which metal had a higher price at the time between copper, tin, and lead, as this could change daily. But it is nevertheless surprising to find these impurities.

Figure III17a. L. 2420 42777

Artifact	Dates	Instrument	Spots	Pb	Sn	As	Fe	Cu	S	Ni	Mo	Zr	Bi	Sb
2420 42777	330-300	pXRF	6	96.123±0.15	0.049±0.008	—	0.576±0.019	0.023±0.005	—	—	0.082±0.003	0.039±0.004	0.119±0.022	—

Table III17. pXRF alloy results

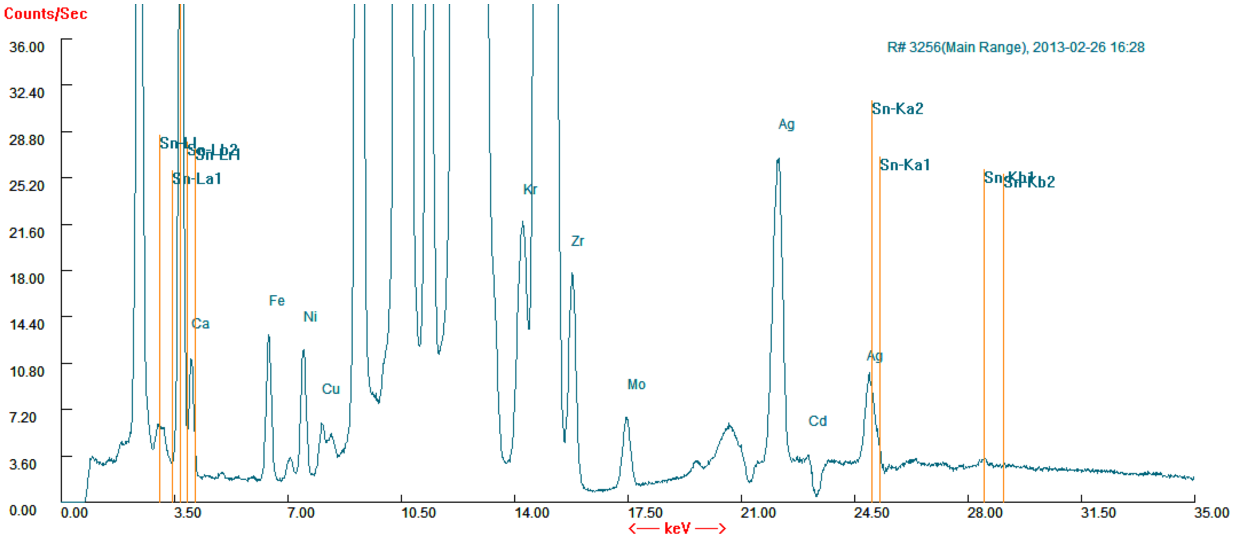

Figure III17b. pXRF spectrum showing tin and copper content

ii. *300-146 BC*

III18. Locus 1068, No artifact number

Context: 200-146 BC – “Floor at El. 11.08; below 1060; same mortar as floor 1050; floor was removed as 1074/1093.”

Overview: This lead artifact, of unidentified typology, also has tin as in impurity in amounts that are often found in the inverted situation of a bronze with lead impurities. This is also likely the result of recycling, as in the case of the weight above in 4CXVII.

Figure III18a. L. 1068

Artifact	Dates	Instrument	Spots	Pb	Sn	As	Fe
1068	300-146	pXRF	4	98.845±0.132	0.354±0.018	—	0.425±0.03

Cu	S	Ni	Mo
—	—	—	0.182±0.007

Zr	Bi	Sb
0.017±0.011	0.123±0.042	—

Table III18. pXRF alloy results

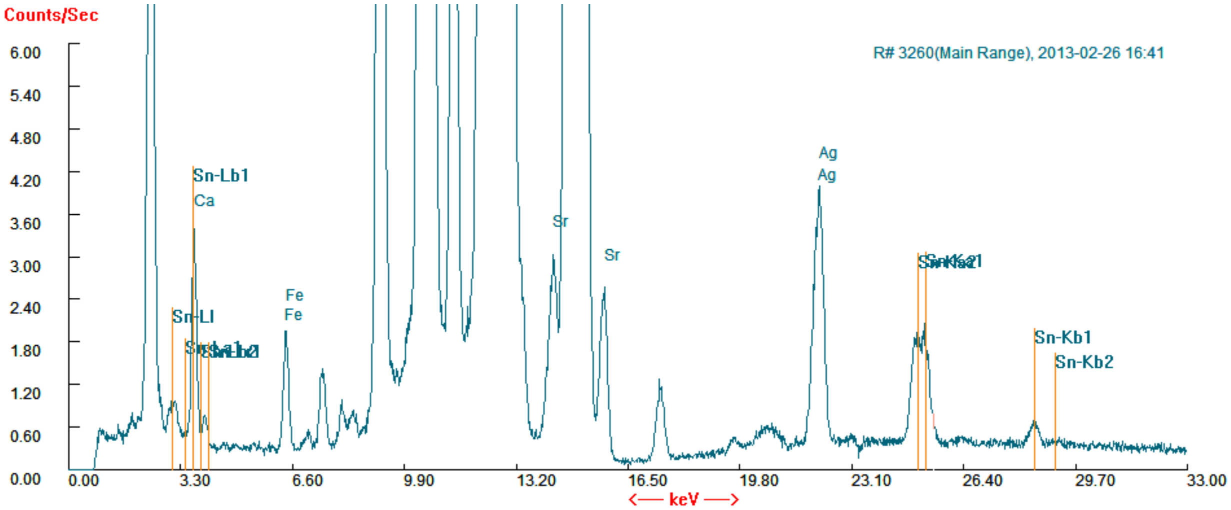

Figure III18b. pXRF spectrum

E. Iron

These two nails are the only two whole iron artifacts of the Phoenician and Punic era found in the excavations at Bir Massaouda. No quantitative analysis is available for them.

III19. Locus 7439, Artifact 40770

Context: Middle Punic, 530-300 BC – “NO POTTERY: structural sealant at the northern end of the basin 7441 (=Floor of [MP]basin (*BABesch* 2006, 49-50, fig. 21), pipeline?”

Figure III19. L. 7439 40770

III20. Locus 1281, Artifact 33569.

Context: Late Punic(?), 300-146 BC(?) – “Late Punic fill?”

Figure III20. L. 1281 33569

III21. Locus 4460, Artifact 49172

Context: Early Punic, 800-530 BC – "Ochre sandy layer with many pottery and bone fragments, below 4459 (*Beyond the homeland*, ##, figs 4–6a–d, 12; cat. 24–52)."

Overview: This iron artifact has its shaft well-preserved, indicating that it was a nail, hook, or some other small kind of implement. It appears to be a wrought iron. The corrosion pattern at places appears crystalline and even runs perpendicular to the metal and other layers of corrosion. These layers of corrosion are secondary growth from the depositional environment. One side is heavily accreted with depositional minerals. Compositional data not available due to instrument malfunction and time restrictions.

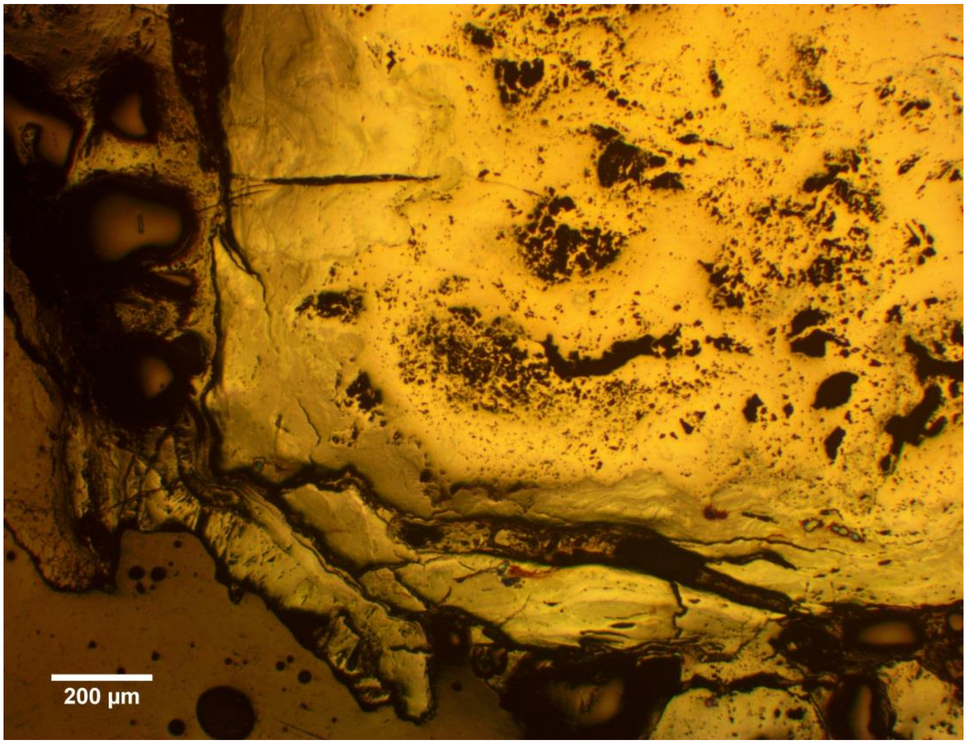

Figure III21a. Optical micrograph, iron implement rectilinear morphology

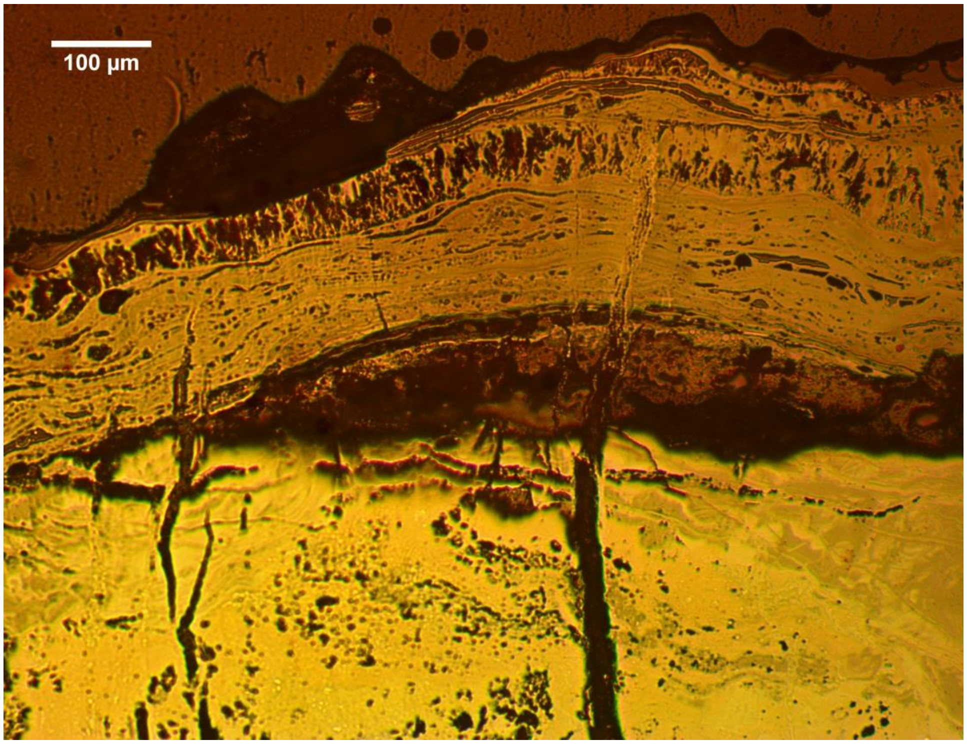

Figure III21b. Optical micrograph of corrosion crust (top) and iron oxide bulk (bottom)

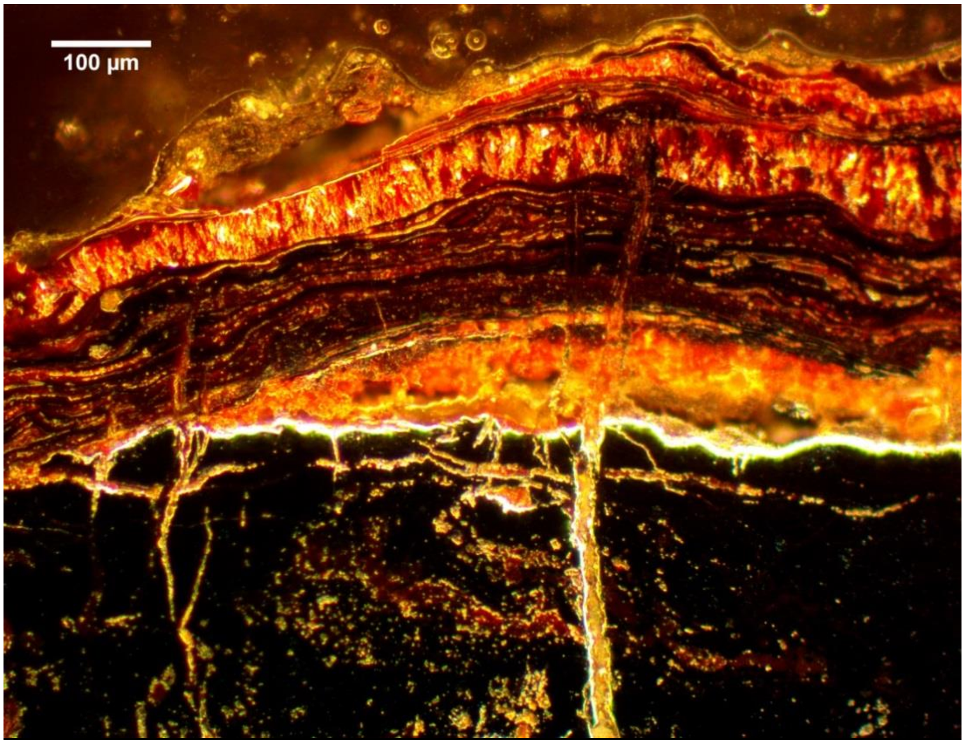

Figure III21c. Dark field micrograph of III21b, iron oxide bulk in black

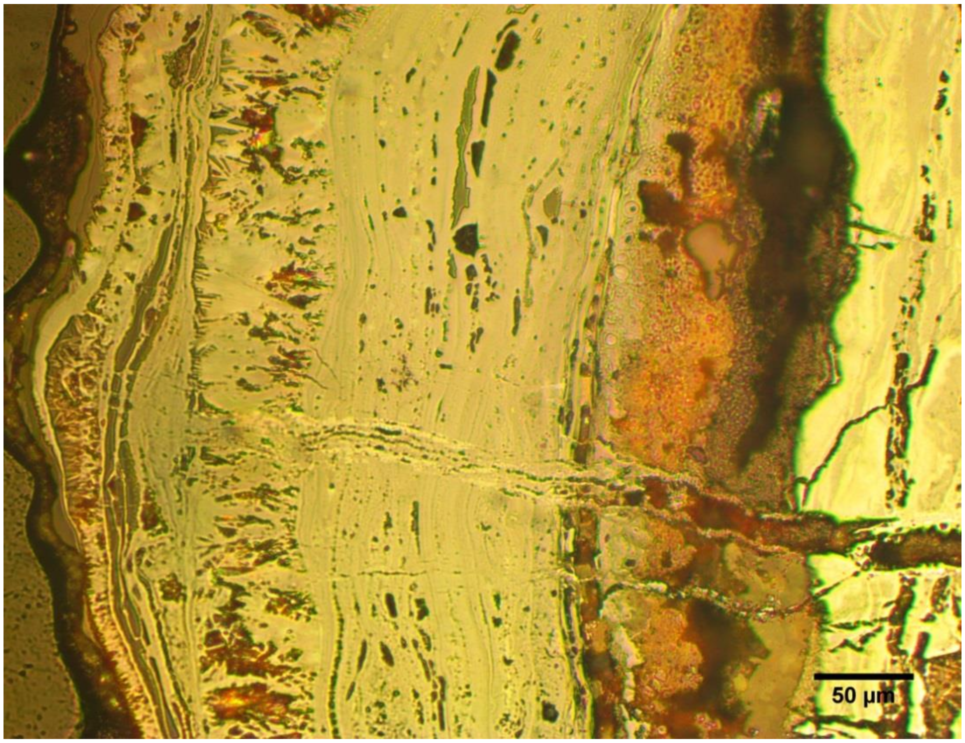

Figure III21d. Corrosion

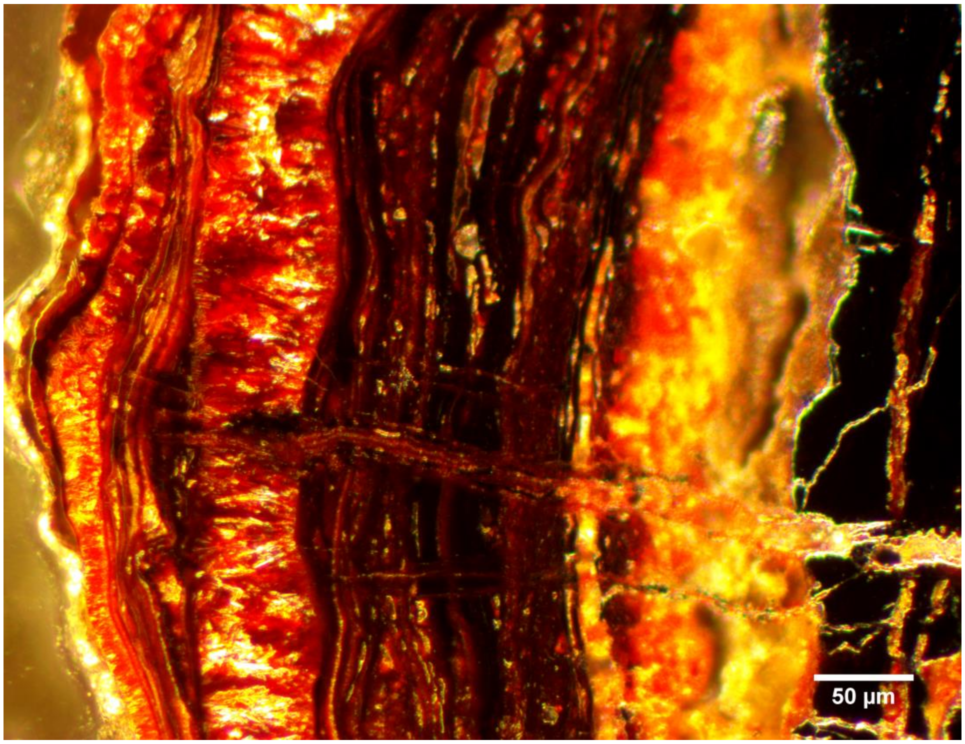

Figure III21e. Dark field micrograph of III21d, iron oxide in black on right

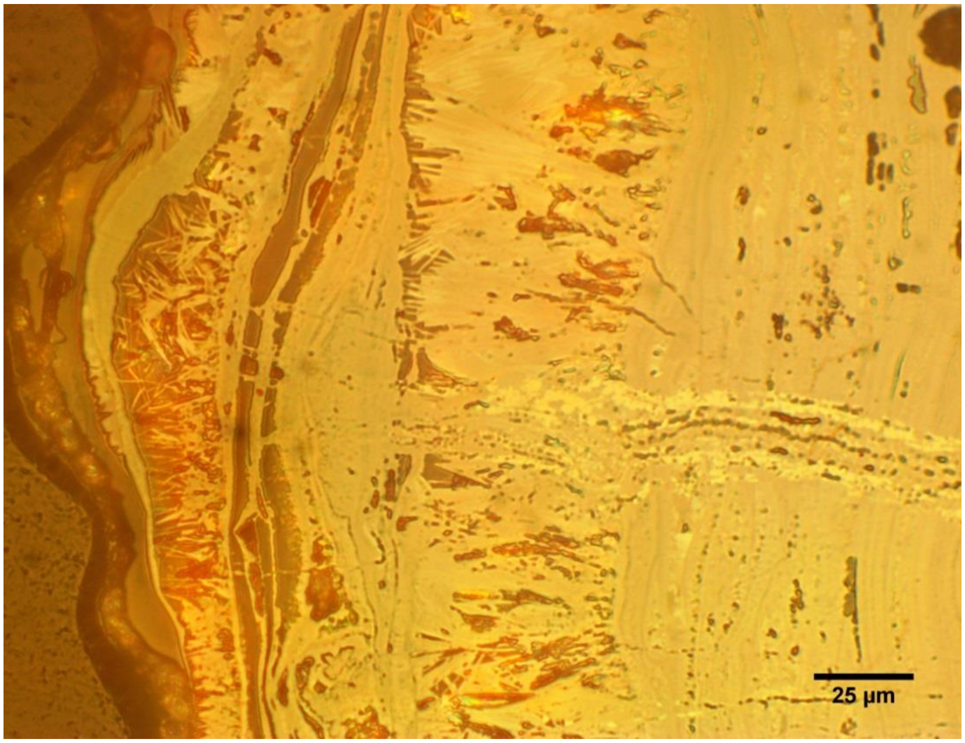

Figure III21f. Crystalline corrosion formation

III22. Locus 1246

Context: Early Punic, 550-500 BC – “Fill = (below) 1244.”

Overview: Based upon corrosion morphology this is clearly a rectangular iron artifact. The object’s shape has been affected by working, hammered into shape. There are multiple islands of metallic iron that are still preserved. It is a good quality iron, there is not a vast amount of slag in the matrix. There are however some slaggy phases throughout, with wüstite and fayalite. At the present moment the object appears to be a high quality wrought iron. Compositional and microstructural data not available due to instrument malfunction and time restrictions.

III23. Locus 1246, Artifact a

Context: Early Punic, 550-500 BC – “Fill = (below) 1244.”

Overview: This object is plausibly an actual bloom. The artifact is clearly some sort of intermediate iron production object, not a slag and not iron metal. It is quite heterogeneous, with mostly ferritic-looking grains, some iron oxides, primary wüstite in glassy phases, and finally a heavily deformed cellular wood anatomy with the arboreal cellular structure pseudomorphing into the iron phases. This latter is likely the fuel source, but due to deformation specific species identification is not possible. Compositional data not available due to instrument malfunction and time restrictions.

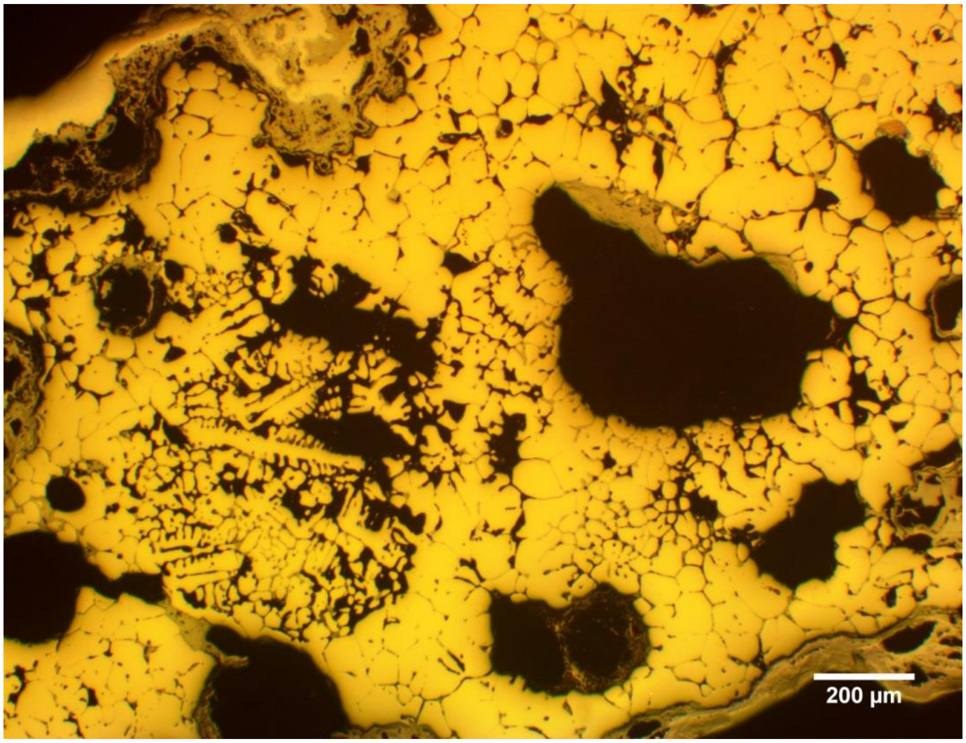

Figure III23a. Wüstite Slag and ferritic-type grains

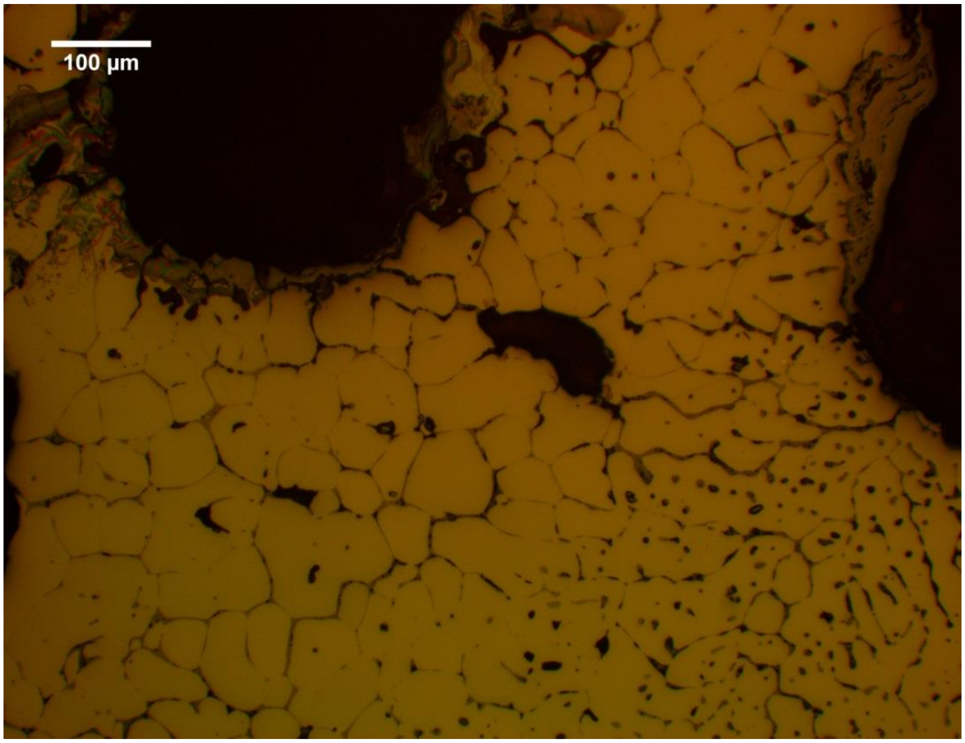

Figure III23b. Optical micrograph of ferritic-type grains

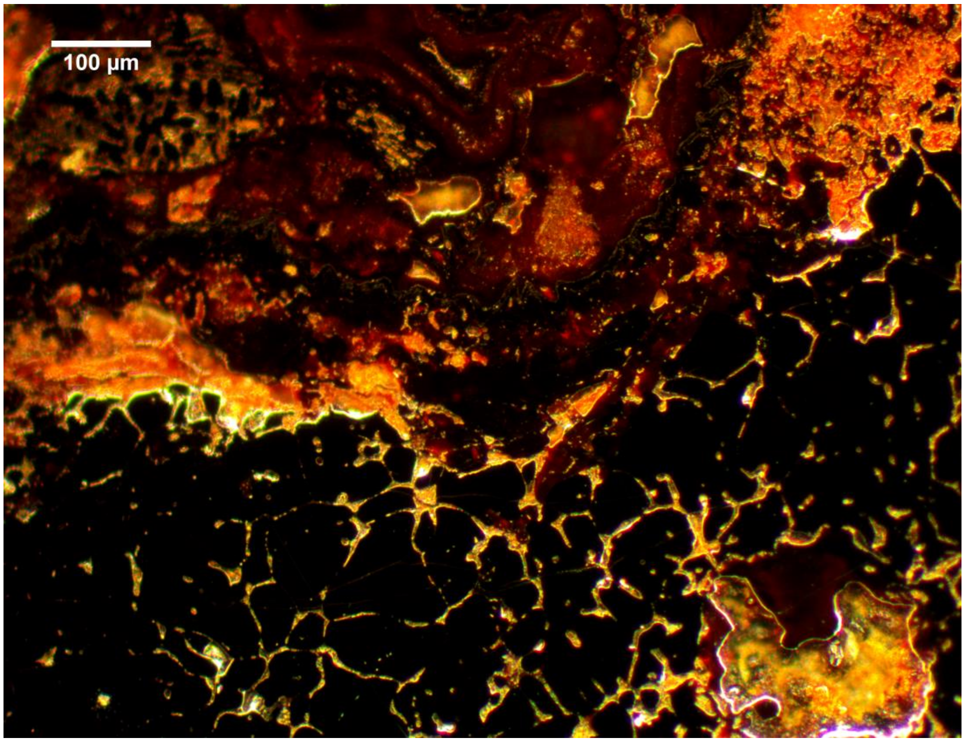

Figure III23c. Dark field micrograph of iron oxides (red) and ferritic-type grains (black)

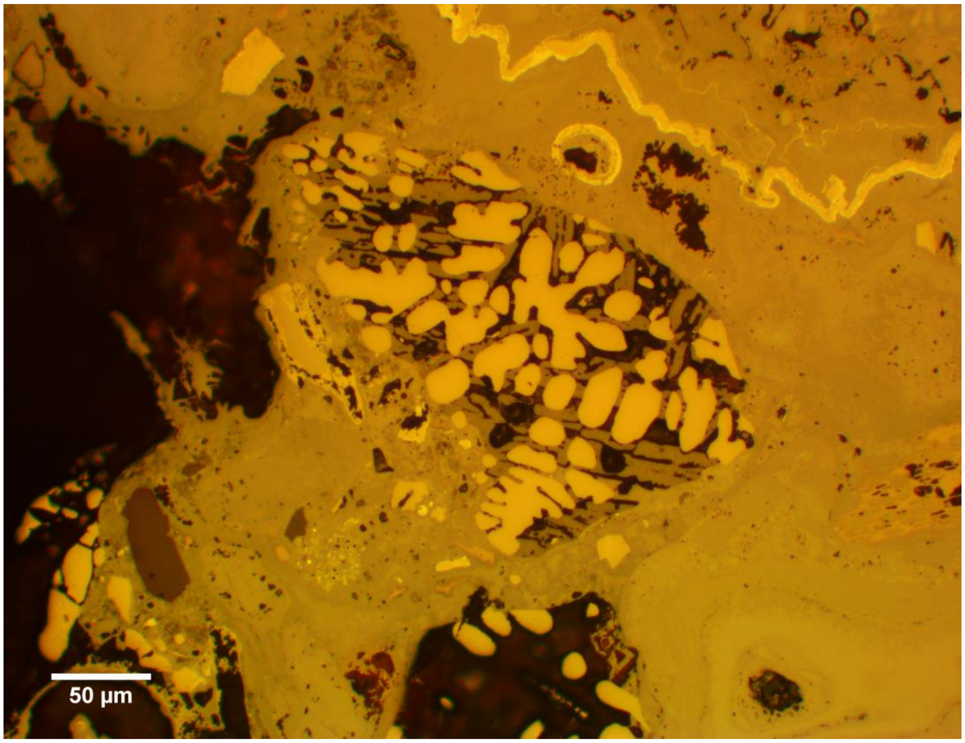

Figure III23d. Wüstite and olivine slag island

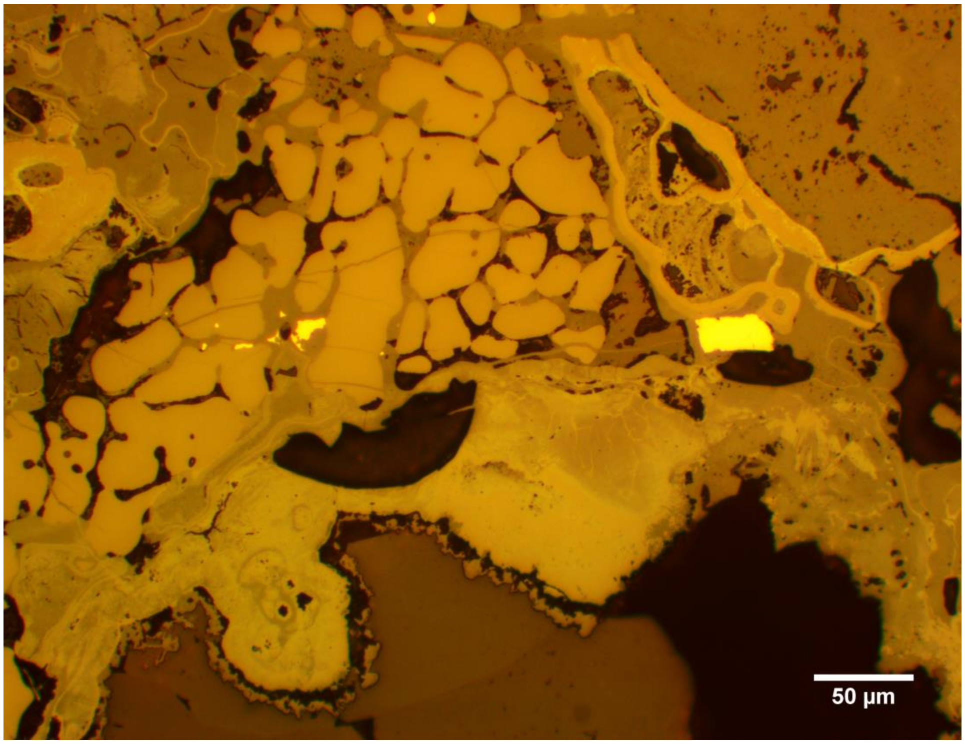

Figure III23e. Metallic iron (brightest yellow spots)

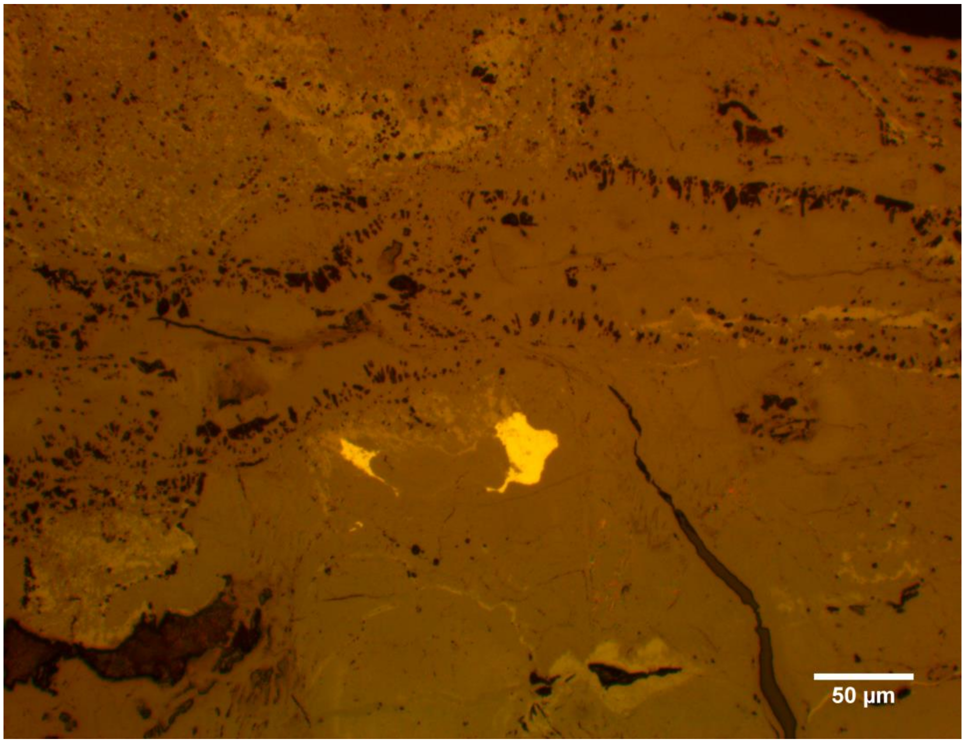

Figure III23f. Metallic iron spots

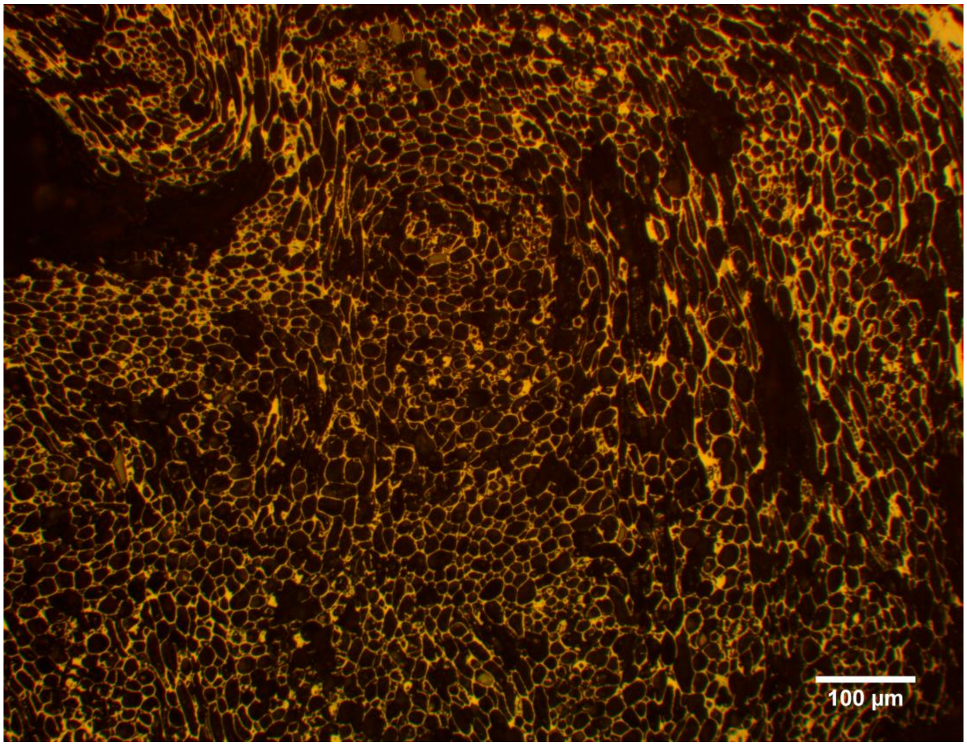

Figure III23g. Deformed wood anatomy

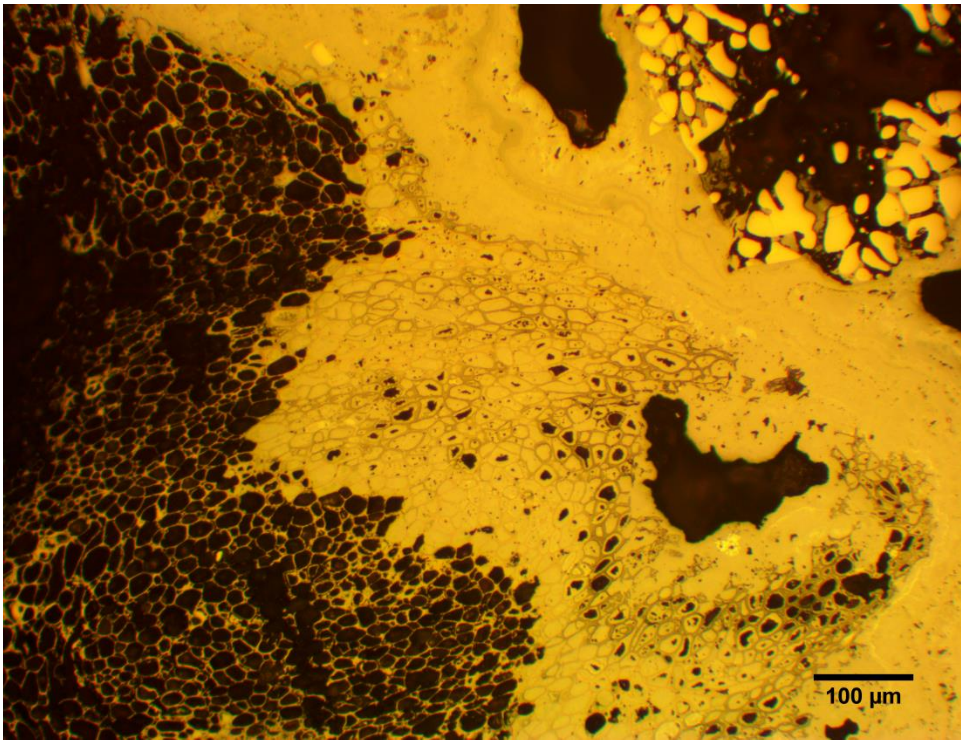

Figure III23h. Slag (upper right), wood cellular structure pseudomorphing into iron phases (center), deformed wood anatomy (left)

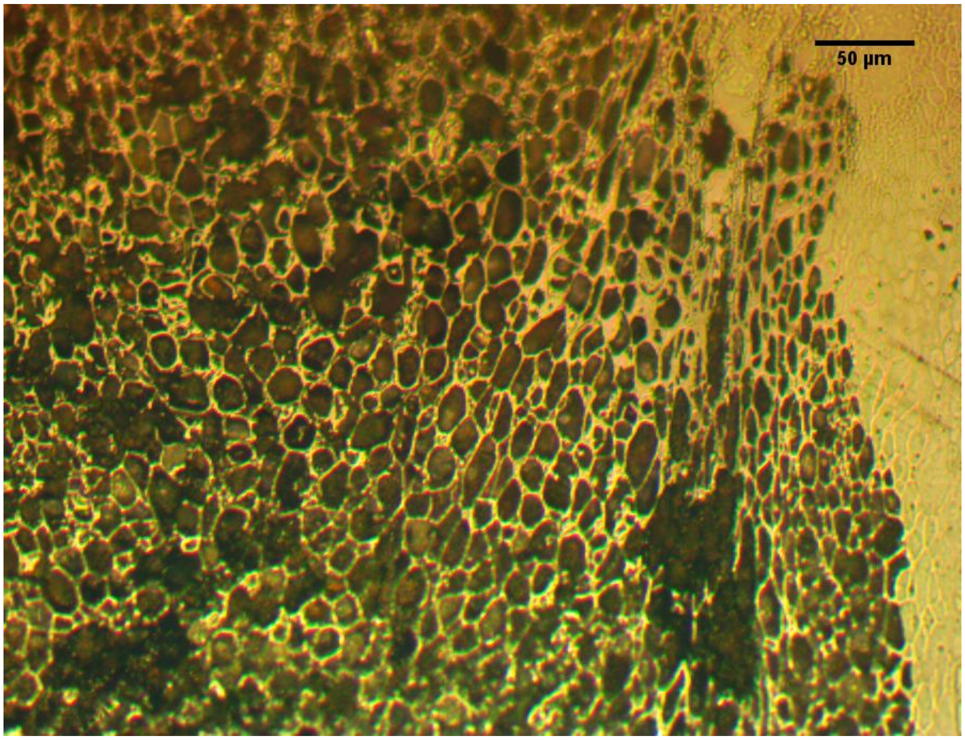

Figure III23i. Deformed wood anatomy and pseudomorph boundary

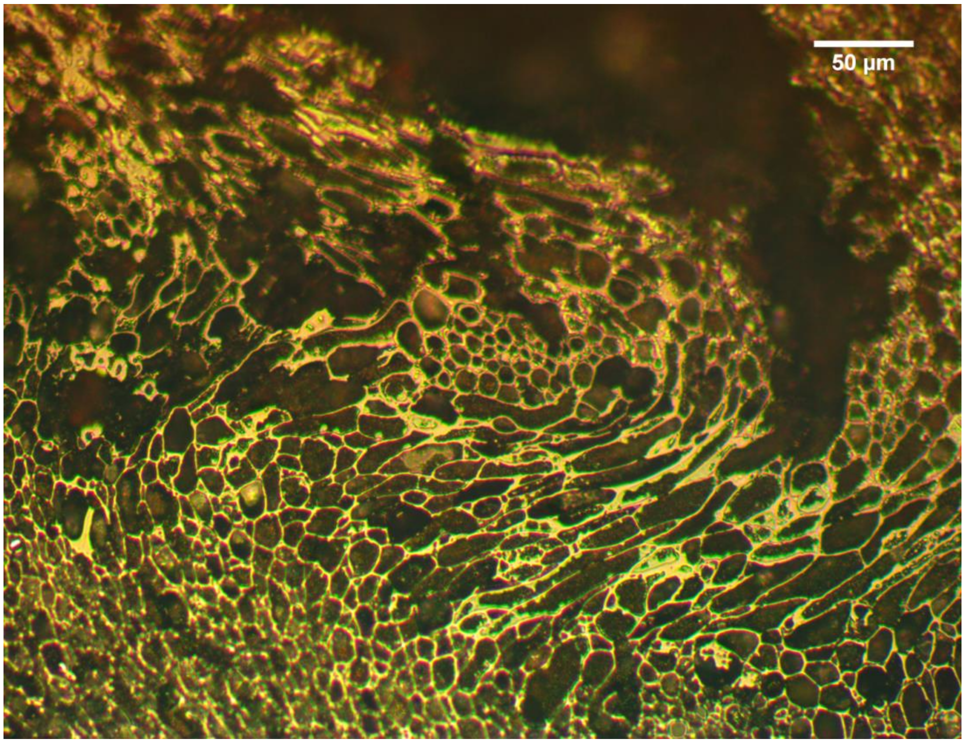

Figure III23j. Deformed wood anatomy

Appendix IV. Anvil and Grinder

Anvil

Locus 8100, Artifact 38250

Context: 700-500 BC - "= 8101 (= 8100: Levelling layer below 8094): Levelling layer."

Overview: Basalt anvil

Figure IV1a. Cross section of cracked latitudinal section of anvil, exposing internal bulk of artifact

Figure IV1b. Bird’s eye section of anvil, with iron residue

Ore Grinder

Locus 8217
Context: 800-530 BC – “Fill of metallurgical hearth (*BABesch* 2003, 45, 60-63, figs. 3, 12; *Carthage Studies* 2007, 48, No. 72).”

Overview: Flattened hard stone bloom or ore grinder with iron working residue.

Figure IV2a. Birds’ eye view of grinder with iron residue

Figure IV2a. Latitudinal flat section of grinder, covered in iron residue

Appendix V. Furnace Soil

Locus 8097, Artifact 38211
Context: 750-400 BC - “Fill of kiln 8092 (=“kiln construction”); charcoal.”

Locus 8098, Artifact 38188
Context: 750-400 BC – “Fill of kiln 8092 (E. channel); no finds but charcoal.”

Overview: The low iron content of this soil makes it unlikely that the soil recovered was effected by the furnace environment. It is more likely that this soil was the ancient fill used to decommission the furnace.

Artifact	Dates	Instrument	Spots	Ba	Sb	Sn	Mo	Th	Zr
8097 38211	750-400	pXRF ppm	2	277±33	—	19±10	—	10±3	232±6
8098 38188	750-400	pXRF ppm	2	325±36	25±10	21±10	2±3	8±4	289±7

	Sr	Rb	As	Pb	Zn	Cu
8097 38211 continued	309±12	49±3	16±4	11±5	—	97±14
8098 38188 continued	293±6	44±3	18±5	16±6	23±9	88±15

	Ni	Fe	Mn	V	Ti	Ca
8097 38211 continued	30±46	27126±226	710±63	43±59	2429±93	165798±778
8098 38188 continued	95±42	53733±339	776±73	94±55	2414±106	160336±848

	K	Cs	Te
8097 38211 continued	16927±353	30±8	—
8098 38188 continued	15430±383	45±9	66±28

Table V1. pXRF furnace soil composition in ppm

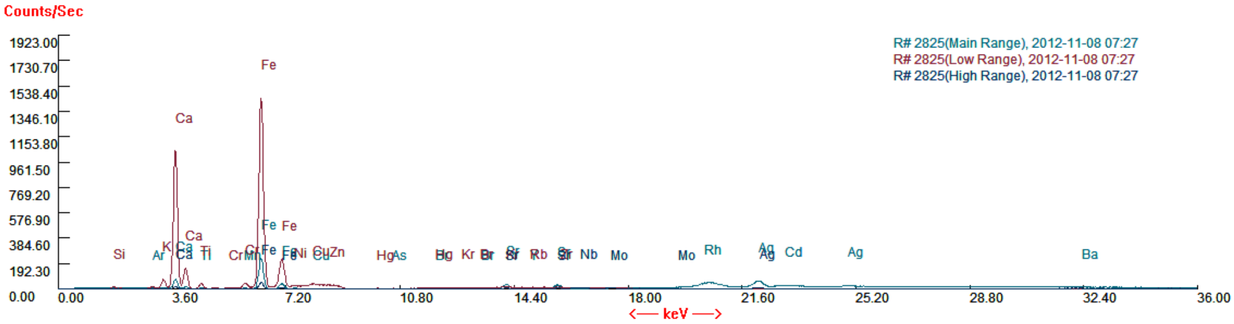

Figure V1. pXRF spectrum of one of the spots

Artifact	Dates	Instrument	Spots	Ba	Zr	Sr	Rb	Zn	Cu	Fe	Ca	Al	P	Si	Cl	Pb	K	S
8097 38211	750-400	pXRF wt%	6	0.021±0.004	0.014±0.001	0.02±0.001	0.003±0.001	0.004±0.001	0.009±0.002	4.042±0.043	9.863±0.118	2.451±0.147	0.206±0.027	13.936±0.151	0.048±0.005	—	1.109±0.029	0.06±0.011
8098 38188	750-400	pXRF wt%	6	0.02±0.004	0.018±0.001	0.021±0.001	0.003±0.001	0.006±0.001	0.008±0.002	5.813±0.054	11.02±0.137	2.633±0.165	0.253±0.029	14.003±0.156	0.047±0.005	0.002±0.002	1.104±0.032	0.086±0.013

Table V2. pXRF furnace soil composition in wt%

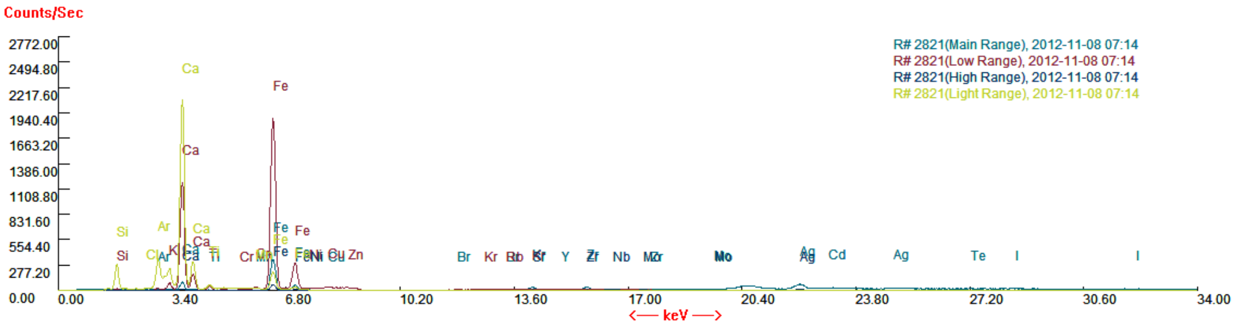

Figure V2. pXRF spectrum of one of the spots

References

Algaze, Guillermo. 1993. *The Uruk World System: The Dynamics of Expansion of Early Mesopotamian Civilization*. Chicago: University of Chicago.

Algaze, Guillermo. 2008. *Ancient Mesopotamia at the Dawn of Civilization: The Evolution of an Urban Landscape*. Chicago: University of Chicago Press.

Allan, John C. 1970. *Considerations on the Antiquity of Mining in the Iberian Peninsula*, *Royal Anthropological Institute Occasional Paper No. 27*. London: Royal Anthropological Institute of Great Britain and Ireland.

Altekamp, Stefan, and Mona Khechen. 2013. Third Carthage: Struggles and Contestations over Archaeological Space. *Journal of the World Archaeological Congress*:470-505.

Anderson, Orson L. 1986. Properties of Iron at the Earth's Core Conditions. In *The Physics of Planets: Their Origin, Evolution and Structure*, edited by S. K. Runcorn. Chichester, New York, Brisbane, Toronto, Singapore: The Royal Astronomical Society; John Wiley & Sons.

Anschuetz, Kurt F., Richard H. Wilshusen, and Cherie L. Scheick. 2001. An Archaeology of Landscapes: Perspectives and Directions. *JAR* 9 (2):157-211.

Aranegui, C., ed. 2001. *Lixus: Colonia Fenicia y Ciudad Púnico-Mauritana: Anotaciones Sobre su Ocupación Medieval. Memoria de las Excavaciones Arqueológicas Realizadas por el Equipo Hispano-Marroquí en la Ladera sur de Lixus (Larache) entre 1995 y 1999*. València: INSAP and Universitat de València.

Arvanitoyannis, Ioannis S., Aikaterini Kassaveti, and Stelios Stefanatos. 2007. Current and Potential Uses of Thermally Treated Olive Oil Waste. *International Journal of Food Science and Technology* 42:852-67.

Attanasio, D., G. Bultrini, and G.M. Ingo. 2001. The Possibility of Provenancing a Series of Bronze Punic Coins Found at Tharros (Western Sardinia) Using the Literature Lead Isotope Database. *Archaeometry* 43 (4):529-47.

Aubet, Maria Eugenia. 2001. *The Phoenicians and the West: Politics, Colonies and Trade*. Translated by M. Turton. 2nd ed. Cambridge: Cambridge University.

Aubet, Maria Eugenia. 2008. Political and Economic Implications of the New Phoenician Chronologies. In *Beyond the Homeland: Markers in Phoenician Chronology*, edited by C. Sagona. Leuven-Paris-Dudley, MA.: Peeters.

Aubet, Maria Eugenia. 2013. *Commerce and Colonization in the Ancient Near East* Cambridge University Press.

Aubet Semmler, Maria Eugenia. 2002a. Phoenician Trade in the West: Balance and Perspectives. In *The Phoenicians in Spain: An Archaeological Review of the Eighth–Sixth Centuries B.C.E.*, edited by M. R. Bierling. Winona Lake, Indiana: Eisenbrauns.

Aubet Semmler, Maria Eugenia. 2002b. The Phoenician Impact on Tartessos: Spheres of Interaction. In *The Phoenicians in Spain: An Archaeological Review of the Eighth–Sixth Centuries B.C.E.*, edited by M. R. Bierling and S. Gitin. Winona Lake, Indiana: Eisenbrauns.

Aubet Semmler, Maria Eugenia. 2002c. Some Questions Regarding the Tartessian Orientalizing Period. In *The Phoenicians in Spain: An Archaeological Review of the Eighth–Sixth Centuries B.C.E.*, edited by M. R. Bierling. Winona Lake, Indiana: Eisenbrauns.

Aubet Semmler, Maria Eugenia. 2002d. Notes on the Economy of the Phoenician Settlements in Southern Spain. In *The Phoenicians in Spain: An Archaeological Review of the Eighth–Sixth Centuries B.C.E.*, edited by M. R. Bierling. Winona Lake, Indiana: Eisenbrauns.

Bachmann, H. G. 1982. *The Identification of Slags from Archaeological Sites*, *Occasional Publication No. 6*. London: Institute of Archaeology.

Ballard, Robert D., Lawrence E. Stager, Daniel M. Master, Dana Yoerger, David Mindell, Louis L. Whitcomb, Hanumant Singh, and Dennis Piechota. 2002. Iron Age Shipwrecks in Deep Water off Ashkelon, Israel. *AJA* 106 (2):151–68.

Barkay, Gabriel. 1992. The Iron Age II–III. In *The Archaeology of Ancient Israel*, edited by A. Ben-Tor. New Haven, Connecticut: Yale University.

Bayley, Justine, and Thilo Rehren. 2007. Towards a Functional and Typological Classification of Crucibles. In *Metals and Mines: Studies in Archaeometallurgy*, edited by S. L. Niece, D. Hook and P. T. Craddock. London: Archetype/British Museum.

Bechtold, B. 2008. Observations on the Amphora Repertoire of Middle Punic Carthage. *Carthage Studies* 2:1-145.

Bechtold, Babette. 2010. The Pottery Repertoire from Late 6th-Mid 2nd Century BC Carthage: Observations Based on the Bir Messaouda Excavations. *Carthage Studies* 4:1-81.

Belén Deamos, Maria. 2009. Phoenicians in Tartessos. In *Colonial Encounters in Ancient Iberia: Phoenician, Greek, and Indigenous Relations*, edited by M. Dietler and C. López-Ruiz. Chicago: University of Chicago Press.

Ben-Yosef, Erez. 2012. Environmental Constraints on Ancient Copper Production in the Aravah Valley: Implications of the Newly Discovered Site of Khirbet Mana'iyah in Southern Jordan. *TA* 39:58-74.

Bénichou-Safar, Hélène. 2004. *Le Tophet de Salammbô à Carthage: Essai de Reconstitution*. Rome: École française de Rome.

Bernardini, P. 1986. *Precolonizzazione e Colonizzazione Fenicia in Sardegna, Egitto e Vicino Oriente 9*.

Bernardini, Paolo. 2008. Sardinia: The Chronology of the Phoenician and Punic Presence from the Ninth to Fifth Centuries BC. In *Beyond the Homeland: Markers in Phoenician Chronology*, edited by C. Sagona. Leuven-Paris-Dudley, MA.: Peeters.

Bessemer, Henry. 1905/1989. *Sir Henry Bessemer, F.R.S.: An Autobiography*. London: The Institute of Metals.

Beulé, Charles Ernest. 1861. *Fouilles à Carthage*. Paris.

Bierling, Marilyn R. 2002. Introduction. In *The Phoenicians in Spain: An Archaeological Review of the Eighth-Sixth Centuries B.C.E.*, edited by M. R. Bierling and S. Gitin. Winona Lake, Indiana: Eisenbrauns.

Binford, Lewis R. 1962. Archaeology as Anthropology. *American Antiquity* 28:217–25.

Blakelock, Eleanor, Marcos Martinón-Torres, Harald A. Veldhuijzen, and Tim Young. 2009. Slag Inclusions in Iron Objects and the Quest for Provenance: An Experiment and a Case Study. *Journal of Archaeological Science* 36:1745-57.

Blyth, P.H. 1993. Metallurgy of Two Fragmentary Archaic Greek Helmets. *Journal of the Historical Metallugy Society* 27 (1):25-36.

Bordreuil, P., and A. Ferjaoui. 1988. A Propos des ‘Fils de Tyr’ et des ‘Fils de Carthage’. In *Studia Phoenicia VI: Carthago*, edited by E. Lipinski. Leuven: Peeters.

Bordreuil, P., F. Israel, and D. Pardee. 1998. King's Command and Widow's Plea: Two New Hebrew Ostraca of the Biblical Period. *NEA* 61 (1):2-13.

Braudel, Fernand. 1972. *The Mediterranean and the Mediterranean World in the Age of Philip II*. Translated by S. Reynolds. New York: Harper & Row.

Bray, P.J., and A.M. Pollard. 2012. A new interpretive approach to the chemistry of copper-alloy objects: source, recycling and technology. *Antiquity* 86:853-67.

Brotton, Jerry. 2000. Carthage and Tunis, The Tempest and Tapestries. In *"The Tempest" and Its Travels*, edited by P. Hulme and W. H. Sherman: University of Pennsylvania Press.

Brown, Susanna Shelby. 1991. *Late Carthaginian Child Sacrifice and Sacrificial Monuments in their Mediterranean Context, JSOT/ASOR Monograph Series 3*. Sheffield: JSOT for the American Schools of Oriental Research.

Buchwald, Vagn Fabritius, and Helle Wivel. 1998. Slag Analysis as a Method for the Characterization and Provenancing of Ancient Iron Objects. *Materials Characterization* 40:73-96.

Budd, P., and B.S. Ottaway. 1991. The Properties of Arsenical Copper Alloys: Implications for the Development of Eneolithic Metallurgy. In *Archaeological Sciences 1989: Proceedings of a* *conference on the application of scientific techniques to archaeology*, edited by P. Budd, B. Chapman, C. Jackson, R. Janaway and B. Ottaway. Bradford: Oxbow Monograph.

Burke, Aaron Alexander. 2006. Tarshish in the Mountains of Lebanon: Attestations of the Biblical Place Name. *Maarav* 13 (1):125–7.

Burke, Aaron Alexander. 2008. *"Walled Up to Heaven": The Evolution of Middle Bronze Age Fortification Strategies in the Levant*. Edited by L. E. Stager, *Studies in the Archaeology and History of the Levant 4*. Winona Lake, Indiana: Eisenbrauns.

Butzer, Karl W. 1982. *Archaeology as Human Ecology: Method and Theory for a Contextual Approach*. New York: Cambridge University.

Butzer, Karl W. 2012. Collapse, Environment, and Society. *Proceedings of the National Academy of Sciences* 109 (10):3632-9.

Canales, González de, Leonardo Serrano, and Jorge Llompart. 2008. The Emporium of Huelva and Phoenician Chronology: Present and Future Possibilities. In *Beyond the Homeland: Markers in Phoenician Chronology*, edited by C. Sagona. Leuven-Paris-Dudley, MA.: Peeters.

Carter, Theresa Howard. 1965. Western Phoenicians at Lepcis Magna. *AJA* 69 (2):123-32.

Castro, José Luis López. 2008. The Iberian Peninsula: Landscapes of Tradition. In *Rural Landscapes of the Punic World*, edited by P. v. Dommelen and C. G. Bellard. London; Oakville Conn.: Equinox.

Charles-Picard, Gilbert, and Colette Charles-Picard. 1958. *Daily Life in Carthage at the time of Hannibal*. London: Ruskin House; George Allen and Unwin Ltd.

Charles, J. A. 1967. Early Arsenical Bronzes-A Metallurgical View. *AJA* 71 (1):21-6.

Charles, James A. 1980. The Coming of Copper and Copper-Base Alloys and Iron: A Metallurgical Sequence. In *The Coming of the Age of Iron*, edited by T. A. Wertime and J. D. Muhly. New Haven and London: Yale University Press.

Charlton, Michael F., Peter Crew, Thilo Rehren, and Stephen J. Shennan. 2010. Explaining the evolution of ironmaking recipes - an example from northwest Wales. *Journal of Anthropological Archaeology* 29:352-67.

Chelbi, Fethi. 2004. Tunesische Forschungen in Karthago. In *Hannibal ad portas*. Stuttgart: Theiss.

Chiarantini, L., M. Benvenuti, P. Costagliola, M.E. Fedi, S. Guideri, and A. Romualdi. 2009. Copper production at Baratti (Populonia, southern Tuscany) in the early Etruscan period (9th-8th centuries BC). *Journal of Archaeological Science* 36:1626-36.

Childe, V. Gordon. 1944. Archaeological Ages as Technological Stages. *The Journal of the Royal Anthropological Institute of Great Britain and Ireland* 74 (1/2).

Childe, V. Gordon. 1951. *Social Evolution*. London: Watts & Co.

Cintas, Pierre. 1970. *Manuel d'Archéologie Punique*. Paris: A. et J. Picard.

Cintas, Pierre. 1976. *Manuel d'Archéologie Punique 2. La Civilisation Carthaginoise*. Paris: A. et J. Picard.

Clermont-Ganneau, Charles Simon, and J.-B. Chabot, eds. 1900. *Répertoire d'Épigraphie Sémitique*. Paris: CRAI.

Cobo, Bernabé. 1653/1964. *Historia del Nuevo Mundo, Biblioteca de Autores Espanoles, tomos 91 ys 92*. Madrid: Ediciones Atlas.

Coghlan, H.H. 1956. *Notes on Prehistoric and Early Iron in the Old World*. Edited by T. K. Penniman and B. M. Blackwood, *Occasional Papers on Technology, 8*. Oxford: Pitt Rivers Museum, University of Oxford Press.

Corretti, Alessandro, and Marco Benvenuti. 2001. The Beginning of Iron Metallurgy in Tuscany, with Special Reference to *Etruria Mineraria*. *Mediterranean Archaeology* 14 (The Origins of Iron Metallurgy):127-45.

Costagliola, Pilario, Marco Benvenuti, Laura Chiarantini, Sara Bianchi, Francesco Di Benedetto, Mario Paolieri, and Luca Rossato. 2008. Impact of Ancient Metal Smelting on Arsenic Pollution in the Pecora River Valley, Southern Tuscany, Italy. *Applied Geochemistry* 23:1241-59.

Costin, Cathy L. 1996. Craft Production and Mobilization Strategies in the Inka Empire. In *Craft Specialization and Social Evolultion: In Memory of V. Gordon Childe*, edited by B. Wailes.

Philadelphia: The University Museum of Archaeology and Anthropology, University of Pennsylvania.

Craddock, P. T. 1995. *Early Metal Mining and Production*. Washington, D.C.: Smithsonian Institution Press.

Craddock, P.T., and N.D. Meeks. 1987. Iron in Ancient Copper. *Archaeometry* 29 (2):187-204.

Crew, Peter. 1991. The Iron and Copper Slags at Baratti, Populonia, Italy. *Journal of the Historical Metallugy Society* 25 (2):109-15.

Crew, Peter, and Michael Charlton. 2007. The Anatomy of a Furnace...and Some of its Ramifications. In *Metals and Mines: Studies in Archaeometallurgy*, edited by S. L. Niece, D. Hook and P. Craddock. London: Archetype/British Museum.

Cross, Frank Moore. 1968. The Phoenician Inscription from Brazil: a Nineteenth Century Forgery. *Or*:437-60.

Cross, Frank Moore. 1972. An Interpretation of the Nora Stone. *BASOR* 208:13–9.

Cross, Frank Moore. 1980. Newly Found Inscriptions in Old Canaanite and Early Phoenician Scripts. *BASOR* 238:1–20.

d'Agostino, B. 1977. La Patera Orientalizzante da Ponte Cagnano Riesaminata. *Studi Etruschi* 45:51-8.

D'Altroy, Terence. 1992. *Provincial Power in the Inka Empire*. Washington, D.C.: The Smithsonian Institution Press.

Dalfes, H. N., G. Kukla, and H. Weiss, eds. 1997. *Third Millennium BC Climate Change and Old World Collapse*. Berlin: Springer.

Davies, John K. 1977-1978. Athenian Citizenship: The Descent Group and the Alternatives. *The Classical Journal* 73 (2):105-21.

Davis, J. R., ed. 1996. *Carbon and Alloy Steels*. Materials Park, OH: ASM International.

Davis, N. 1861. *Carthage and Her Remains*. London.

Day, John. 1989. *Human Sacrifice in the Old Testament in the Light of Ancient Near Eastern Cultures, University of Cambridge Oriental Publications No. 41*: Cambridge University Press.

Dayagi-Mendels, Michal, ed. 2002. *The Akhziv Cemeteries: The Ben-Dor Excavations, 1941–1944, IAA Reports 15*. Jerusalem: Israel Antiquities Authority.

De Melo, Wolfgang. 2012. *Plautus: Poenulus, or the Little Carthaginian*. Cambridge, MA-London, England: Harvard University Press.

de Motes, J. Maluquer. 1966. Nuevos datos para el estudio del comercio prerromano en el Mediterráneo. *Pyrenae* 2:185-90.

de Onis, Harriet. 1960. *The Incas of Pedro de Cieza de León*. Norman: University of Oklahoma Press.

Deer, W.A., R.A. Howie, and J. Zussman. 1992. *An Introduction to the Rock-Forming Minerals, Second Edition*. Essex: Longman Scientific & Technical.

Delattre, Alfred-Louis. 1898. Nouvelle des Fouilles à Carthage. *CRAI Comptes-rendus des séances de l'Académie des Inscriptions et Belles-Lettres* 42 (1):96-100.

Delattre, Alfred-Louis. 1899. Fouilles Exécutées à Carthage, Pendant le Premier Semestre de 1899, dans la Nécropole Punique Située entre Bordj-Djedid et la Colline de Sainte-Monique. *CRAI Comptes-rendus des séances de l'Académie des Inscriptions et Belles-Lettres* 43 (3):308-22.

Dever, William G. 2001. *What Did the Biblical Writers Know and When Did They Know It? What Archaeology Can Tell Us about the Reality of Ancient Israel*. Grand Rapids, MI: Eerdmans.

Diakonoff, I.M. 1992. The Naval Power and Trade of Tyre. *IEJ* 42 (3/4):168-93.

Dietler, Michael. 2009. Colonial Encounters in Iberia and the Western Mediterranean: An Exploratory Framework. In *Colonial Encounters in Ancient Iberia: Phoenician, Greek, and Indigenous Relations*, edited by M. Dietler and C. López-Ruiz. Chicago: University of Chicago Press.

Dietler, Michael. 2010. *Archaeologies of Colonialism: Consumption, Entanglement, and Violence in Ancient Mediterranean France*. Berkeley: University of California Press.

Dietler, Michael, and Carolina López-Ruiz, eds. 2009. *Colonial Encounters in Ancient Iberia: Phoenician, Greek, and Indigenous Relations*. Chicago: University of Chicago Press.

Docter, R. F. 2005. Een Spectaculair Einde Carthago: 246-146. *Chr. Lampas* 38:313-29.

Docter, R. F., and B. Bechtold. 2011. Two Forgotten Amphorae from the Hamburg Excavations at Carthage (Cyprus and the Iberian Peninsula) and their Contexts. *Carthage Studies* 5:91-128.

Docter, R. F., H.G. Niemeyer, A. J. Nijboer, and J. van der Plicht, eds. 2004. *Radiocarbon dates of animal bones in the earliest levels of Carthage*, *Mediterranea: Quaderni Annuali dell'Istituto di Studi Sulle Civiltà Italiche e del Mediterraneo Antico del Consiglio Nazionale delle Ricerche*. Pisa; Rome: Istituti Editoriali e Poligrafici Internazionali.

Docter, R. F., Hans Georg Niemeyer, A. J. Nijboer, and H. van der Plicht. 2005. Radiocarbon Dates of Animal Bones in the Earliest Levels of Carthage. In *Oriente e Occidente: metodi e discipline a confronto. Riflessioni sulla cronologia dell'età del ferro in Italia, Atti dell'Incontro di studi, Roma, 30–31 ottobre 2003. Mediterranea, 1 (2004)*, edited by G. Bartoloni and F. Delpino. Pisa: Istituti Editoriali e Poligrafici Internazionali.

Docter, R.F., F. Chelbi, Bouthéina Maraoui Telmini, A.J. Nijboer, J. Van der Plicht, W. Van Neer, K. Mansel, and S. Garsallah. 2008. New Radiocarbon Dates from Carthage: Bridging the Gap between History and Archaeology? In *Beyond the Homeland: Markers in Phoenician Chronology*, edited by C. Sagona. Leuven, Paris, Dudley: Peeters.

Docter, Roald F. 2002-2003. The Topography of Archaic Carthage: Preliminary Results of Recent Excavations and Some Prospects. *TALANTA* XXXIV-XXXV:113-33.

Docter, Roald F. 2007. Carthage and its Hinterland. In *Phönizisches und punisches Städtewesen: Akten der internationalen Tagung in Rom vom 21. bis 23. Februar 2007*: Verlag Philipp Von Zabern, Mainz Am Rhein.

Docter, Roald F., ed. 2007. *Carthage Studies 1*. Gent: Department of Archaeology, Ghent University.

Docter, Roald F., ed. 2008. *Carthage Studies 2*. Gent: Department of Archaeology, Ghent University.

Docter, Roald F., ed. 2009. *Carthage Studies 3*. Gent: Department of Archaeology, Ghent University.

Docter, Roald F., ed. 2010. *Carthage Studies 4*. Gent: Department of Archaeology, Ghent University.

Docter, Roald F., Fethi Chelbi, and Boutheina Maraoui Telmini. 2002. Carthage Bir Massouda: Excavations by the Universiteit van Amsterdam (UVA) in 2000 and 2001 (1). *CEDAC Carthage* Bulletin 21:29-34.

Docter, Roald F., Fethi Chelbi, Boutheina Maraoui Telmini, Babette Bechtold, Hans Koens, Karin Schmidt, and Wim Van Neer. 2003. Carthage Bir Massouda - Preliminary Report on the First Bilateral Excavations of Ghent University and the Institut National du Patrimoine (2002-2003). *BABesch.* 78:43-70.

Docter, Roald F., Fethi Chelbi, Boutheina Maraoui Telmini, Babette Bechtold, Hamden Ben Romdhane, Vanessa Declercq, Tijs De Schacht, Eline Deweirdt, Alain De Wulf, Lamia Fersi, Suzanne Frey-Kupper, Soumaya Garsallah, Ineke Joosten, Hans Koens, Jalel Mabrouk, Taoufik Redissi, Sihem Roudesli Chebbi, Karen Ryckbosch, Karin Schmidt, Birgit Taverniers, Julie Van Kerckhove, and Lieven Verdonck. 2006. Carthage Bir Massouda: Second Preliminary Report on the Bilateral Excavations of Ghent University and the Institut National du Patrimoine (2003-2004). *BABesch* 81:37-89.

Donnan, Christopher B. 1973. A Precolumbian Smelter from Northern Peru. *Archaeology* 26 (4):289-97.

Donnan, Christopher B. 1998. Un Ceramio Moche Y La Fundicio Prehispanica de Metales. *Boletin del Museo Chileno de Arte Precolombino* 7:9-18.

Donnan, Christopher B. 2011. *Chotuna and Chornancap: Excavation an Ancient Peruvian Legend*. Los Angeles: Cotsen Institute of Archaeology Press.

Donner, H., and W. Röllig, eds. 1968. *Kanaanäische und Aramäische Inschriften*. 3 vols. Wiesbaden: Harrassowitz.

Dothan, M. 1985. A Phoenician Inscription from 'Akko. *IEJ* 35 (2/3):81-94.

Earle, Timothy. 1997. *How Chiefs Come to Power: The Political Economy in Prehistory*. Stanford: Stanford University Press.

Eaton, E.R., and H. McKerrell. 1976. Near Eastern Alloying and Some Textual Evidence for the Early Use of Arsenical Copper. *WoAr* 8 (2):169-91.

Eisenhüttenleute, Verein Deutscher, ed. 1995. *Slag Atlas, 2nd edition*. Düsseldorf: Verlag Stahleisen.

Eliyahu-Behar, A., S. Shilstein, N. Raban-Gerstel, Y. Goren, A. Gilboa, I. Sharon, and S. Weiner. 2008. An Integrated Approach to Reconstructing Primary Activities from Pit Deposits: Iron Smithing and Other Activities at Tel Dor under Neo-Assyrian Domination. *Journal of Archaeological Science* 35 (11):2895-908.

Eliyahu-Behar, Adi, Naama Yahalom-Mack, Sana Shilstein, Alexander Zukerman, Cynthia Shafer-Elliott, Aren M. Maeir, Elisabetta Boaretto, Israel Finkelstein, and Steve Weiner. 2012. Iron and Bronze Production in Iron Age IIA Philistia: New Evidence from Tell es-Safi/Gath, Israel. *Journal of Archaeological Science* 39:255-67.

Ennabli, Abdelmajid, ed. 1992. *Pour Sauver Carthage. Exploration et Conservation de la Cité Punique, Romain et Byzantine*. Paris; Tunis: UNESCO; Institut National d'Archéologie et d'Art.

Essaadi, F. 1995a. 'Recherches sur l'Histoire de l'Archéologie du Fer en Tunisie', Compte Rendu de la Communication Présentée au 3ème Congrès des Études Phéniciennes (Tunis Novembre 1991) *REPPAL* 9:217-8.

Essaadi, F. 1995b. Recherches sur l'Histoire et l'Archéologie du Fer en Tunisie. In *Actes du IIIe Congrès International des Études Phéniciennes et Puniques, Tunis, 11-16 novembre 1991*, edited by M. H. Fantar and M. Ghaki: Tunis, Institut National du Patrimoine.

Esse, Douglas L. 1989. Secondary State Formation and Collapse in Early Bronze Age Palestine. In *L'Urbanisation de la Palestine à l'âge du Bronze ancien: bilan et perspectives des recherches actuelles*, edited by P. de Miroschedji. Oxford: British Archaeological Reports.

Falbe, Christian Tuxen. 1833. *Recherches sur l'Emplacement de Carthage*. Paris.

Fantar, M.H. 1984. À Gammarth avant la Conquête Romaine. *Histoire et Archéologie de l'Afrique du Nord*.

Fariselli, Anna Chiara. 2002. *I Mercenari di Cartagine*, *Biblioteca della Rivista di Studi Punici*. La Spezia: Agorà Edizioni.

Fentress, Elizabeth. 2007. Where were North African Nundinae Held? In *Communities and Connections: Essays in Honour of Barry Cunliffe*, edited by C. Gosden. New York: Oxford University Press.

Fentress, Elizabeth, and Roald F. Docter. 2008. North Africa: Rural Settlement and Agricultural Production. In *Rural Landscapes of the Punic World*, edited by P. van Dommelen and C. Gómez Bellard. London; Oakville: Equinox.

Février, James-Germain. 1959. L'Inscription du Mausolée dit d'Aṭban (Dougga). *Karthago: Revue d'Archéologie Africaine* X:51-7.

Filigheddu, Paolo. 2008. *Die Ortsnamen des Mittelmeerraums in der Phönizischen und Punischen Überlieferung*, *Ugarit-Verlag*. Münster: Druckhaus Folberth, Pfungstadt.

Fouzai, Boutheina, Lluís Casas, Néjia Laridhi Ouazaa, and Aureli Álvarez. 2012. Archaeomagnetic Data from Four Roman Sites in Tunisia. *Journal of Archaeological Science* 39:1871-82.

Frankenstein, S. 1979. The Phoenicians in the Far West: A Function of Neo-Assyrian Imperialism. In *Power and Propaganda: A Symposium on Ancient Empires*, edited by M. T. Larsen. Copenhagen: Akademisk.

Frey-Kupper, Suzanne. 2008. A Stone-Mould for Producing Carthaginian Bronze Coins of the Second Punic War from Carthage Bir Massaouda. In *XVII International Congress of Classical Archaeology, September 22-26 2008*. British School in Rome.

Friedrich, Johannes, and Wolfgang Röllig. 1970. *Phönizisch-Punische Grammatik*. 1st ed. Vol. 46, *Analecta Orientalia*.

Frost, Honor. 1973. First Season of Excavation on the Punic Wreck in Sicily. *The International Journal of Nautical Archaeology* 2 (1):33-49.

Frost, Honor. 1974. The Punic Wreck in Sicily: Second Season of Excavation. *The International Journal of Nautical Archaeology* 3 (1):35-54.

Gadd, C.J. 1934. *The Assyrian Sculptures*. London: British Museum.

Gal, Zvi, and Yardenna Alexandre. 2000. *Horbat Rosh Zayit: An Iron Age Storage Fort and Village*, *IAA Reports 8*. Jerusalem: Israel Antiquities Authority.

Garnand, Brien K. 2006. The Use of Phoenician Human Sacrifice in the Formation of Ethnic Identities, Ph.D. dissertation, Committee on the Ancient Mediterranean World, University of Chicago, Chicago.

Gauckler, Paul. 1915. *Nécropoles Puniques de Carthage. Part 2*. Paris.

Giardino, Claudio. 1992. Nuragic Sardinia and the Mediterranean: Metallurgy and Maritime Traffic. In *Sardinia in the Mediterranean: A Footprint in the Sea. Studies in Sardinian Archaeology Presented to Miriam S. Balmuth,* edited by R. H. Tykot and T. K. Andrews. Sheffield: Monographs in Mediterranean Archaeology.

Giardino, Claudio. 1995. *The West Mediterranean between the 14th and 8th Centuries B.C.: Mining and Metallurgical Spheres*. Oxford: BAR International Series 612.

Gifford, J. A., G. Rapp, Jr., and V. Vitali. 1992. Palaeogeography of Carthage (Tunisia): Coastal Change during the First Millennium. *Journal of Archaeological Science* 19 (5):575–96.

Gilboa, Ayelet, Ilan Sharon, and Elisabetta Boaretto. 2008. Tel Dor and the Chronology of Phoenician 'Pre-Colonisation' Stages. In *Beyond the Homeland: Markers in Phoenician Chronology*, edited by C. Sagona. Leuven-Paris-Dudley, MA.: Peeters.

Giumlia-Mair, A.R. 1992. The Composition of Copper-Based Small Finds from a West Phoenician Settlement Site and from Nimrud Compared with that of Contemporary Mediterranean Small Finds. *Archaeometry* 34 (1):107-19.

Gómez Bellard, Carlos. 2008. Ibiza: The Making of New Landscapes. In *Rural Landscapes of the Punic World*, edited by P. van Dommelen and C. Gómez Bellard. London; Oakville: Equinox.

González-Ruibal, Alfredo. 2006. Past the Last Outpost: Punic Merchants in the Atlantic Ocean (5th-1st centuries BC). *JMA* 19 (1):121-50.

González Prats, Alfredo, Antonio García Menárguez, and Elisa Ruiz Segura. 2002. La Fonteta: A Phoenician City in the Far West. In *The Phoenicians in Spain: An Archaeological Review of the Eighth–Sixth Centuries B.C.E.*, edited by M. R. Bierling and S. Gitin. Winona Lake, Indiana: Eisenbrauns.

Gordon, Robert B., and David J. Killick. 1993. Adaptation of Technology to Culture and Environment: Bloomery Iron Smelting in America and Africa. *Technology and Culture* 34 (2):243-70.

Gosden, Chris. 2004. The Past and Foreign Countries: Colonial and Post-Colonial Archaeology and Anthropology. In *A Companion to Social Archaeology,* edited by L. Meskell and R. W. Preucel. Malden, MA: Blackwell.

Gottlieb, Yulia. 2010. The Advent of the Age of Iron in the Land of Israel: A Review and Reassessment. *TA* 37:89-110.

Gras, Michel, Pierre Rouillard, and Javier Teixidor. 1991. The Phoenicians and Death. *Berytus* XXXIX:127-76.

Greene, J. A., and D.P. Kehoe. 1995. Mago the Carthaginian on Agriculture: Archaeology and the Ancient Sources. Paper read at Proceedings of the Third International Conference on Phoenician/Punic Studies.

Greene, J.A. 1995. The Beginnings of Grape Cultivation and Wine Production in Phoenician/Punic North Africa. In *The Origins and Ancient History of Wine*, edited by S. Fleming, S. Katz and P. E. McGovern. New York: Gordon and Breach.

Greene, Joseph A. 1986. The Carthaginian Countryside: Archaeological Reconnaisance in the Hinterland of Ancient Carthage. Ph.D. dissertation, University of Chicago, Chicago.

Gsell, Stéphane. 1921. *Histoire ancienne de l'Afrique du Nord*. Paris: Hachette.

Hansen, Cathrine Gerner. 2002. *Carthage: Results of the Swedish excavations 1979-1983* Vol. I. Stockholm: Paul Åströms Förlag; Svenska Institutet I Rom.

Harden, Donald Benjamin. 1927. Punic Urns from the Precinct of Tanit at Carthage. *AJA* 31:297-310.

Harden, Donald Benjamin. 1937. The Pottery from the Precinct of Tanit at Salammbo, Carthage. *Iraq* 4:59-90.

Hedges, R.E.M., and C.J. Salter. 1979. Source Determination of Iron Currency Bars through Analysis of the Slag Inclusions. *Archaeometry* 21 (2):161-75.

Heginbotham, Arlen, Aniko Bezur, Michel Bouchard, Jeffrey M. Davis, Katherine Eremin, James H. Frantz, Lisha Glinsman, Lee-Ann Hayek, Duncan Hook, Vicky Kantarelou, Andreas Germanos Karydas, Lynn Lee, Jennifer Mass, Catherine Matsen, Blythe McCarthy, Molly McGath, Aaron Shugar, Jane Sirois, Dylan Smith, and Robert J. Speakman. 2010. An Evaluation of Inter-Laboratory Reproducibility for Quantitative XRF of Historic Copper Alloys. Paper read at International Conference on Metal Conservation. Interim Meeting of the International Council of Museums Committee for Conservation, Metal Working Group, at Charleston, SC.

Heltzer, Michael. 1983. A Recently Discovered Phoenician Inscription and the Problem of the Guilds of Metal-Casters. Paper read at Atti del I Congresso Internazionale di Studi Fenici e Punici, at Roma.

Hemming, John. 1970. *The Conquest of the Incas*. New York: Harcourt Brace Jovanovich, Inc.

Hendon, Julia A. 2004. Living and Working at Home: The Social Archaeology of Household Production and Social Relations. In *A Companion to Social Archaeology,* edited by L. Meskell and R. W. Preucel. Malden, MA: Blackwell.

Hermelin, Elias, Erik Tholander, and Stig Blomgren. 1979. A Prehistoric Nickel-Alloyed Iron Axe. *Journal of the Historical Metallugy Society* 13 (2):69-94.

Heskel, D., and C.C. Lamberg-Karlovsky. 1980. An Alternative Sequence for the Development of Metallurgy: Tepe Yahya, Iran. In *The Coming of the Age of Iron*, edited by Y. U. Press. New Haven.

Hodder, Ian. 1982. *The Present Past: Introduction to Anthropology for Archaeologists*. London: Batsford.

Hodder, Ian. 1999. *The Archaeological Process*. Oxford: Blackwell.

Humphris, Jane, Marcos Martinón-Torres, Thilo Rehren, and Andrew Reid. 2009. Variability in Single Smelting Episodes - A Pilot Study Using Iron Slag from Uganda. *Journal of Archaeological Science* 36:359-69.

Hurst, Henry. 1979. Excavations at Carthage, 1977-78: Fourth Interim Report. *AJ* 59 (1):19-49.

Hurst, Henry. 1999. *The Sanctuary of Tanit at Carthage in the Roman Period*, *Journal of Roman Archaeology, Supplementary Series Number 30*. Portsmouth, RI: Journal of Roman Archaeology.

Hurst, Henry R., and Steve Roskams, eds. 1984. *Excavations at Carthage: The British Mission*. Vol. I, 1. Oxford: Oxford University Press.

Hurst, Henry, and Lawrence E. Stager. 1978. A Metropolitan Landscape: The Late Punic Port of Carthage. *WoAr* 9 (3):334–46.

Hussein, Muzahim Mahmoud. 2011. Iraqi Excavations at Nimrud (Lecture). Los Angeles: Cotsen Institute of Archaeology.

Icard, F. 1923. Découverte de l'Area du Sanctuaire de Tanit. *Revue Tunisienne*.

Iles, Louise. 2009. Impressions of Banana Pseudostem in Iron Slag from Eastern Africa. *Ethnobotany Research & Applications* 7:283-91.

Ingo, G.M., S. Mazzoni, G. Bultrini, S. Fontana, G. Padeletti, G. Chiozzini, and L. Scoppio. 1994. Small-area XPS and XAES Study of the Iron Ore Smelting Process. *Surface and Interface Analysis* 22:614-9.

Johnson, Gregory A. 1980. Rank-Size Convexity and System Integration: A View from Archaeology. *Economic Geography* 56 (3):234-47.

Jones, Horace Leonard. 1997. *Strabo: Geography, Books 1 and 2*. Edited by G. P. Goold, *The Loeb Classical Library*. Cambridge, MA-London, England: Harvard University Press.

Jongeling, K. 2008. *Handbook of Neo-Punic Inscriptions*: Mohr Siebeck.

Jurado, Jesús Fernández. 2002. The Tartessian Economy: Mining and Metallurgy. In *The Phoenicians in Spain: An Archaeological Review of the Eighth–Sixth Centuries B.C.E.*, edited by M. R. Bierling. Winona Lake, Indiana: Eisenbrauns.

Kallala, Nabil, Joan Ramon Torres, Joan Sanmartí Grego, M. Carme Belarte, Bouthéina Maraoui Telmini, Thaïs Fadrique, Rafael Jornet i Niella, Daniel López Reyes, Núria Morell Cortés, and Sílvia Valenzuela Lamas. 2010. Sobre los Orígenes de la Civilización Númida y su Relación con la Colonización Fenicia. *Mainake* XXXII (I):279-99.

Kaniewski, D., E. Paulissen, Elise Van Campo, H. Weiss, T. Otto, and Karel van Lerberghe. 2010. Late Second-Early First Millennium BC Abrupt Climate Changes in Coastal Syria and their Possible Significance for the History of the Eastern Mediterranean. *Quaternary Research* 74 (2):207-15.

Karageorghis, Vassos. 1976. *Kition: Mycenaean and Phoenician Discoveries in Cyprus*. London: Thames & Hudson.

Kassianidou, V. 1992. Monte Romero, a Silver-Producing Workshop of the Seventh Century B.C in SW Spain. *Institute for Archaeo-Metallurgical Studies (IAMS) Newsletter* 18:37-47.

Kassianidou, V. 2003. Early Extraction of Silver from Complex Polymetallic Ores. In *Mining and Metal Production Through the Ages*, edited by P. Craddock and J. Lang. London: The British Museum Press.

Kassianidou, Vasiliki. 2012. The Origin and Use of Metals in Iron Age Cyprus. In *Cyprus and the Aegean in the Early Iron Age: The Legacy of Nicolas Coldstream*, edited by M. Iacovou. Nicosia: Bank of Cyprus Cultural Foundation.

Katzenstein, Hannah Jacob. 1997. *History of Tyre: From the Beginning of the Second Millennium B.C.E. until the Fall of the Neo-Babylonian Empire in 538 B.C.E.* Jerusalem: Ben-Gurion University of the Negev Press.

Kaufman, Brett. 2009. A Citizen of Tyre in Sabratha: Colonial Identity in Punic North Africa. *Maarav* 16.1:39-48.

Kaufman, Brett. 2011. Metallugy and Ecological Change in the Ancient Near East. *Backdirt Annual Review of the Cotsen Institute of Archaeology*:86-92.

Kaufman, Brett. 2013. Copper Alloys from the 'Enot Shuni Cemetery and the Origins of Bronze Metallurgy in the Levant. *Archaeometry* 55 (4):663-90.

Keesmann, I., and B. Hellermann. 1989. Mineralogische und Chemische Untersuchungen an Schlacken von Morro de Mezquitilla. *Madrider Mitteilungen* 30:92-117.

Keesmann, Ingo. 1994. In *Handwerk und Technologie im Alten Orient: ein Beitrag zur Geschichte der Technik im Altertum*, edited by R. Wartke: Ph. von Zabern.

Keesmann, Ingo. 2001. Untersuchungen Zur Metallurgie Im Archaischen Und Punischen Karthago. *Mediterranean Archaeology* 14 (The Origins of Iron Metallurgy):95-108.

Kelsey, Francis W. 1926. *Excavations at Carthage, 1925; a Preliminary Report*. New York: The Macmillan Company.

Kerr, Robert M. 2010. *Latino-Punic Epigraphy*. Tübingen: Mohr Siebeck.

Killick, David, Nikolaas J. van der Merwe, Robert B. Gordon, and Danilo Grébénart. 1988. Reassessment of the Evidence for Early Metallurgy in Niger, West Africa. *Journal of Archaeological Science* 15:367-94.

King, Philip J., and Lawrence E. Stager. 2001. *Life in Biblical Israel*, *Library of Ancient Israel*: Westminster John Knox.

Koehler, Ludwig, and Walter Baumgartner. 2001. *The Hebrew and Aramaic Lexicon of the Old Testament*. Vol. Volume One. Leiden, Boston, Köln: Brill.

Koren, Z.C. 2005. The First Optimal All-Murex All-Natural Purple Dyeing in the Eastern Mediterranean in a Millenium and a Half. In *Dyes in History and Archaeology 20*. London: Archetype Publications.

Krings, Véronique. 2008. Rereading Punic Agriculture: Representation, Analogy and Ideology in the Classical Sources. In *Rural Landscapes of the Punic World*, edited by P. van Dommelen and C. Gómez Bellard. London; Oakville: Equinox.

Kruse, Susan E., Robert D. Smith, and Katharine Starling. 1988. Experimental Casting of Silver Ingots. *Journal of the Historical Metallugy Society* 22 (2):87-92.

Kuhrt, Amélie. 1995. *The Ancient Near East c. 3000–330 BC*. 2 vols, *Routledge History of the Ancient World*. London: Routledge.

Lamb, H.F., U. Eicher, and V.R. Switsur. 1989. An 18,000-Year Record of Vegetation, Lake-Level and Climatic Change from Tigalmamine, Middle Atlas, Morocco. *Journal of Biogeography* 16 (1):65-74.

Lamberg-Karlovsky, C. C. 1972. Trade Mechanisms in Indus-Mesopotamian Interrelations. *JAOS* 92 (2):222-9.

Lancel, Serge. 1981. Fouilles Françaises à Carthage. La Colline de Byrsa et l'Occupation Punique (VIIe siècle - 146 av. J.-C.). Bilan de Sept Années de Fouilles. *CRAI Comptes-Rendus des Séances de l'Académie des Inscriptions et Belles-Lettres* 125 (2):156-93.

Lancel, Serge. 1985. La Renaissance de la Carthage Punique. Réflexions sur Quelques Enseignements de la Campagne Internationale Patronnée par l'Unesco. *CRAI Comptes-Rendus des Séances de l'Académie des Inscriptions et Belles-Lettres* 129 (4):727-51.

Lancel, Serge. 1989. L'Enceinte Périurbaine de Carthage lors de la Troisième Guerre Punique: Réalités et Hypothèses. In *Studia Phoenicia, X: Punic Wars*.

Lancel, Serge. 1995. *Carthage: A History*. Translated by A. Nevill. Oxford: Blackwell.

Lancel, Serge. 1998. *Hannibal*. Oxford, UK; Malden, Mass., USA: Blackwell.

Lancel, Serge, ed. 1979. *Byrsa I: Rapports Préliminaires des Fouilles (1974-1976)*. Rome: École française de Rome.

Lancel, Serge, ed. 1982. *Byrsa II: Rapports Préliminaires sur les Fouilles 1977-1978, Niveaux et Vestiges Puniques*. Rome: École française de Rome.

Lapeyre, Gabriel-Guillaume. 1939. Les Fouilles du Musée Lavigerie à Carthage de 1935 à 1939. *CRAI Comptes-Rendus des Séances de l'Académie des Inscriptions et Belles-Lettres*:294-304.

Lechtman, Heather. 2007. The Inka, and Andean Metallurgical Tradition. In *Variations in the Expression of Inka Power*, edited by R. L. Burger, C. Morris and R. Matos Mendieta. Washington, D. C.: Dumbarton Oaks.

Lechtman, Heather, and Sabine Klein. 1998. The Production of Copper-Arsenic Alloys (Arsenic Bronze) by Cosmelting: Modern Experiment, Ancient Practice. *Journal of Archaeological Science* 26:497-526.

Leeuw, Sander E. van der. 1984. Dust to Dust: A Transformational View of the Ceramic Cycle. In *The Many Dimensions of Pottery*, edited by S. E. v. d. Leeuw and A. C. Pritchard. Amsterdam: Universiteit van Amsterdam.

Levy, Thomas E., Erez Ben-Yosef, and Mohammad Najjar. 2012. New Perspectives on the Iron Age Copper Production and Society in the Faynan Region, Jordan. In *Eastern Mediterranean Metallurgy and Metalwork in the Second Millennium BC*, edited by V. Kassianidou and G. Papasavvas: Oxbow Books.

Linder, Elisha. 1986. The Khorsabad Wall Relief: A Mediterranean Seascape or River Transport of Timbers? *JAOS* 106 (2):273-81.

López-Ruiz, Carolina. 2009. Tarshish and Tartessos Revisited: Textual Problems and Historical Implications. In *Colonial Encounters in Ancient Iberia: Phoenician, Greek, and Indigenous Relations*, edited by M. Dietler and C. López-Ruiz. Chicago and London: University of Chicago Press.

López Castro, José Luis. 2008. The Iberian Peninsula: Landscapes of Tradition. In *Rural Landscapes of the Punic World*, edited by P. van Dommelen and C. Gómez Bellard. London; Oakville: Equinox.

López Pardo, F. 1992. Reflexiones Sobre el Origen de Lixus y su Delubrum Herculis en el Contexto de la Empresa Comercial Fenicia. Paper read at Actes de Colluque Organisé par l'Institut des Sciences de l'Archéologie et du Patrimoine de Rabat, avec le Concours de l'École Française de Rome, Larache, 8-11 de Novembre 1989, 8-11 de novembre 1989.

LoSchiavo, Fulvia. 1986. Early Metallurgy in Sardinia. Paper read at The Beginning of the Use of Metals and Alloys: Papers from the Second International Conference on the Beginning of the Use of Metals and Alloys, 21-26 October, 1986, at Zhengzhou, China.

MacCormack, Sabine. 2008. Classical Traditions in the Andes: Conversations Across Time and Space. In *Guide To Documentary Sources for Andean Studies, 1530-1900*, edited by J. Pilsbury. Norman: University Oklahoma Press.

Maddin, Robert. 1982. Early Iron Technology in Cyprus. In *Early Metallurgy in Cyprus, 4000-500 B.C.*, edited by J. D. Muhly, R. Maddin and V. Karageorghis. Larnaca: Pierides Foundation.

Manfredi, L.I. 1997. L'Archaeometria et le Monete Puniche. In *Progetto Tharros*, edited by E. Acquaro, M. T. Francisi, G. M. Ingo and L. I. Manfredi. Roma: Consiglio Nazionale delle Ricerche.

Maraoui Telmini, B., R. F. Docter, B. Bechtold, F. Chelbi, and Winfred van de Put. 2008. Defining Punic Carthage. In *XVII International Congress of Classical Archaeology, September 22-26 2008*. Bristish School in Rome.

Maraoui Telmini, Boutheina. 2012. Vestiges d'un Habitat de L'Époque Punique Moyenne À Bir Massouda (Carthage): Bilan des Fouilles le Sondage 7 et Analyse de la Céramique. *Carthage Studies* 6:1-202.

Marcus, Joyce. 2008. The Archaeological Evidence for Social Evolution. *Annual Review of Anthropology* 37:251-66.

Marcus, Joyce, and Kent Flannery. 1994. Ancient Zapotec Ritual and Religion: An Application of the Direct Historical Approach. In *The Ancient Mind*, edited by C. Renfrew and E. Zubrow. Cambridge: Cambridge University Press.

Marcus, Joyce, and Kent Flannery. 1996. *Zapotec Civilization: How Urban Society Evolved in Mexico's Oaxaca Valley*: Thames & Hudson.

Margarida Arruda, Ana. 2009. Phoenician Colonization on the Atlantic Coast of the Iberian Peninsula. In *Colonial Encounters in Ancient Iberia: Phoenician, Greek, and Indigenous Relations,* edited by M. Dietler and C. López-Ruiz. Chicago: University of Chicago Press.

Markoe, Glenn E. 1985. *Phoenician Bronze and Silver Bowls from Cyprus and the Mediterranean, University of California Publications. Classical Studies 26*. Berkeley: University of California.

Massoli-Novelli, R. 1986. The Geology and Natural Resources of Sardinia. In *Studies in Sardinian Archaeology II: Sardinia in the Mediterranean*, edited by M. S. Balmuth. Ann Arbor.

Mazar, Amihai. 1990. *Archaeology of the Land of the Bible 10,000–586 BCE*. Edited by D. N. Freedman. 1st ed, *Anchor Bible Reference Library*. New York: Doubleday.

Mazar, Eilat. 2009. *The Palace of King David: Excavations at the Summit of the City of David - Preliminary Report of Seasons 2005-2007*. Jerusalem; New York: Shoham Academic Research and Publication.

Mazar, Eilat, ed. 2001. *The Phoenicians in Achziv, The Northern Cemetery: Final Report of the Excavations 1988–1990, Cuadernos de Arqueología Mediterránea 7*. Barcelona.

Mazar, Eilat, ed. 2004. *The Phoenician Family Tomb N.1 at the Northenr Cemetery of Achziv (10th–6th Centuries BCE), Cuadernos de Arqueología Mediterránea 10*. Barcelona.

McCarty, Matthew M. 2013. Continuities and Contexts: The Tophets of Roman Imperial-Period Africa. *Studi Epigrafici e Linguistici* 29-30.

McGovern, Patrick E., and Rudolph H. Michel. 1985. Royal Purple Dye: Tracing Chemical Origins of the Industry. *Analytical Chemistry* 57 (14):1514-22A.

McKerrell, Hugh, and R.F. Tylecote. 1972. The Working of Copper-Arsenic Alloys in the Early Bronze Age and the Effect on the Determination of Provenance. *Proceedings of the Prehistoric Society* 38:209-18.

Miles, Richard. 2010. *Carthage Must Be Destroyed: The Rise and Fall of an Ancient Civilization*. London: Viking, Penguin Group.

Milik, J. T., and Frank Moore Cross. 1954. Inscribed Javelin-Heads from the Period of the Judges: A Recent Discovery in Palestine. *BASOR* 134:5–15.

Moretti Sgubini, Anna Maria, ed. 1999. *The Villa Giulia National Estruscan Museum*. Rome: "L'Erma" di Bretschneider; Ingegneria per la Cultura.

Morris, Ian. 2000. *Archaeology as Cultural History: Words and Things in Iron Age Greece*. Malden, MA: Blackwell.

Mosca, Paul G. 1975. Child Sacrifice in Canaanite and Israelite Religion. Ph.D. dissertation, Near Eastern Languages and Civilizations, Harvard University, Cambridge, Massachusetts.

Moscati, Sabatino, ed. 1988. *The Phoenicians*. New York: Abbeville.

Muhly, J.D. 2006. Texts and Technology: The Beginnings of Iron Metallurgy in the Eastern Mediterranean. In *Ancient Greek Technology, Proceedings of 2nd International Conference on Ancient Greek Technology*, edited by T. P. Tassios and C. Palyvou. Athens.

Namdar, Dvory, Ayelet Gilboa, Ronny Neumann, Israel Finkelstein, and Stever Weiner. 2013. Cinnamaldehyde in Early Iron Age Phoenician Flasks Raises Possibility of Levantine Trade with South East Asia. *Mediterranean Archaeology and Archaeometry* 12 (3):1-19.

Negueruela, I., J. Pinedo, M. Gómez, A. Miñano, I. Arellano, and J.S. Barba. 1995. Seventh-Century BC Phoenician Vessel Discovered at Playa de la Isla, Mazarron, Spain. *The International Journal of Nautical Archaeology* 24 (3):189-97.

Neville, Ann. 2007. *Mountains of Silver and Rivers of Gold: The Phoenicians in Iberia*. Edited by R. J. A. Wilson, *University of British Columbia Studies in the Ancient World 1*: Oxbow.

Niemeyer, Hans Georg. 2001. Archaeological Evidence of Early Iron Technology at Carthage and Other Phoenician Settlements. *Mediterranean Archaeology* 14 (The Origins of Iron Metallurgy):83-93.

Niemeyer, Hans Georg. 2002. The Phoenician Settlement at Toscanos: Urbanization and Function. In *The Phoenicians in Spain: An Archaeological Review of the Eighth–Sixth Centuries B.C.E.*, edited by M. R. Bierling. Winona Lake, Indiana: Eisenbrauns.

Niemeyer, Hans Georg, Roald F. Docter, and Karin Schmidt. 2007b. Die Hamburger Grabung unter dem Decumanus Maximus von Karthago. In *Phönizisches und Punisches Städtewesen: Akten der Internationalen Tagung in Rom vom 21. bis 23. Februar 2007*: Verlag Philipp Von Zabern, Mainz Am Rhein.

Niemeyer, Hans Georg, Roald F. Docter, and Karin Schmidt, eds. 2007a. *Karthago: die Ergebnisse der Hamburger Grabung unter dem Decumanus Maximus*. Mainz: Verlag Philipp Von Zabern, Mainz.

Ortega-Feliu, I., B. Gómez-Tubío, M.Á. Ontalba Salamanca, M.Á. Respaldiza, M.L. de la Bandera, and G. Ovejero Zappino. 2007. Gold and Electrum Jewellry in the Strategic Area of Gadir in Phoenician Period. *Nuclear Instruments and Methods in Physics Research* 260:329-35.

Ortega, Iván Fumadó. 2013. Colonial Representations and Carthaginian Archaeology. *Oxford Journal of Archaeology* 32 (1):53-72.

Pallary, Paul. 1922. Note sur les Débris Osseux Trouvés dans le Sanctuaire de Tanit à Salammbô, Près Carthage. *Bulletin Archéologique du Comité*.

Papadopoulos, John K. 2003. Engaging Mediterranean Archaeology: Old World and New World Perspectives. In *Theory and Practice in Mediterranean Archaeology: Old World and New World Perspectives*, edited by J. K. Papadopoulos and R. M. Leventhal. Los Angeles: Cotsen Institute of Archaeology, UCLA.

Paynter, S. 2006. Regional Variations in Bloomery Smelting Slag of the Iron Age and Romano-British periods. *Archaeometry* 48 (2):271-92.

Picard, G. 1945. Le Sanctuaire Dit de Tanit à Carthage. *CRAI Comptes-Rendus des Séances de l'Académie des Inscriptions et Belles-Lettres*:443-52.

Poinssot, Louis, and Raymond Lantier. 1923. Un Sanctuaire de Tanit à Carthage.

Polzer, Mark E., and Juan Pinedo Reyes. 2008. Phoenician Rising: Excavation of the Bajo de la Campana Site Begins. *The INA Annual*.

Polzer, Mark E., and Juan Pinedo Reyes. 2009. Bajo de la Campana 2009: Phoenician Shipwreck Excavation. *The INA Annual*.

Procelli, Rosa Maria Albanese. 2008. Sicily. In *Beyond the Homeland: Markers in Phoenician Chronology*, edited by C. Sagona. Leuven-Paris-Dudley, MA.: Peeters.

Prorok, Count Byron Khun de. 1926. *Digging for Lost African Gods: The Record of Five Years Archaeological Excavation in North Africa*. New York; London: G.P. Putnam's Sons.

Quinn, Josephine. 2011. The Cultures of the Tophet: Identification and Identity in the Phoenician Diaspora. In *Cultural Identity and the Peoples of the Ancient Mediterranean*, edited by E. Gruen. Los Angeles: Getty.

Rackham, H. 1932. *Aristotle: The Politics*. Edited by T. E. Page, E. Capps and W. H. D. Rouse, *The Loeb Classical Library*. London-New York: William Heinemann LTD-G.P. Putnam's Sons.

Radivojević, Miljana, Thilo Rehren, Ernst Pernicka, Dušan Šljivar, Michael Brauns, and Dušan Borić. 2010. On the Origins of Extractive Metallurgy: New Evidence from Europe. *Journal of Archaeological Science* 37:2775-87.

Rakob, F. 1989. Karthago. Die früühe Siedlung. Neue Forschungen. *Römische Mitteilungen* 96:155-208.

Rakob, Friedrich. 1985. Carthage Punique: Fouilles et Prospections Archeologiques de la Mission Allemande. *REPPAL*.

Ramón, Juan. 2002. The Ancient Colonization of Ibiza: Mechanisms and Process. In *The Phoenicians in Spain: An Archaeological Review of the Eighth–Sixth Centuries B.C.E.*, edited by M. R. Bierling. Winona Lake, Indiana: Eisenbrauns.

Read, Dwight W. 2012. *How Culture Makes Us Human: Primate Social Evolution and the Formation of Human Societies*. Walnut Creek, CA: Left Coast Press, Inc.

Rehren, Thilo, ed. 1991. *Selenium and Tellurium in Mediterranean Copper Ingots*. Edited by N. H. Gale, *Studies in Mediterranean Archaeology Vol. XC: Bronze Age Trade in the Mediterranean*. Rewley House, Oxford: Jonsered, Paul Åströms Förlag.

Reinach, S., and E. Babelon. 1886. Recherches Archéologiques en Tunisie. *Bulletin Archéologique CTHS (1883-1884)*:3-78.

Renfrew, Colin. 1980. The Great Tradition versus the Great Divide: Archaeology as Anthropology? *AJA* 84 (3):287-98.

Renfrew, Colin. 1982. Socio-Economic Change in Ranked Societies. In *Ranking, Resource and Exchange: Aspects of the Archaeology of Early European Society*, edited by C. Renfrew and S. Shennan. Cambridge: Cambridge University Press.

Renzi, M., and S. Rovira. 2007. Metallurgical Slags from the Phoenician Site of La Fonteta (Alicante), A Preliminary Report. In *Avances en Arqueometría 2005. Actas del VI Congreso Ibérico de Arqueometría, Universitat de Girona del 16 al 19 de noviembre de 2005*. Girona: Universitat de Girona.

Renzi, Martina, Ignacio Montero-Ruiz, and Michael Bode. 2009. Non-Ferrous Metallurgy from the Phoenician Site of La Fonteta (Alicante, Spain): A Study of Provenance. *Journal of Archaeological Science* 36:2584-96.

Rhead, E.L. 1935. *Metallurgy*. London: Longmans, Green and Co.

Roames, Jim. 2011. The Early Iron Age Metal Workshop at Tell Tayinat, Turkey. *Mater. Res. Soc. Symp. Proc.* 1319:149-55.

Robinson, E.S.G. 1956. *Punic Coins of Ancient Spain and their Bearing on the Roman Republican Series*. Chicago: Ares Publishers Inc.

Rosen, Arlene Miller. 1995. The Social Response to Environmental Change in Early Bronze Age Canaan. *Journal of Anthropological Archaeology* 14 (1):26–44.

Rostoker, William. 1986. The Ancient Heat Treatment of White Cast Iron. Paper read at The Beginning of the Use of Metals and Alloys: Papers from the Second International Conference on the Beginning of the Use of Metals and Alloys, at Zhengzhou, China.

Rothenberg, Beno, and Antonio Blanco-Freijeiro. 1981. *Studies in Ancient Mining and Metallurgy in South-West Spain: Explorations and Excavations in the Province of Huelva*. London: The Institute for Archaeo-Metallurgical Studies, University of London.

Ruiz Mata, Diego. 2002. The Ancient Phoenicians of the 8th and 7th Centuries B.C. in the Bay of Cádiz: State of the Research. In *The Phoenicians in Spain: An Archaeological Review of the Eighth–Sixth Centuries B.C.E.*, edited by M. R. Bierling and S. Gitin. Winona Lake, Indiana: Eisenbrauns.

Sagona, Claudia. 2008. Malta: Between a Rock and a Hard Place. In *Beyond the Homeland: Markers in Phoenician Chronology*, edited by C. Sagona. Leuven-Paris-Dudley, MA.: Peeters.

Said, Edward W. 1978. *Orientalism*. New York: Pantheon Books.

Sainte-Marie, Évariste de. 1884. *Mission à Carthage*. Paris: Ernst Leroux.

Salamanca, M.Á. Ontalba, B. Gómez-Tubío, I. Ortega-Feliu, M.Á. Respaldiza, M. Luisa de la Bandera, G. Ovejero Zappino, A. Bouzas, and A. Gómez Morón. 2006. External-beam PIXE Spectrometry for the Study of Punic Jewellery (SW Spain): The Geopgraphical Provenance of the Palladium-Bearing Gold. *Nuclear Instruments and Methods in Physics Research* B (249):622-7.

Salameh, Franck. 2010. *Language, Memory, and Identity in the Middle East: The Case for Lebanon*. Plymouth, United Kingdom: Lexington Books.

Sanmartí, Joan. 2009. Colonial Relations and Social Change in Iberia (Seventh to Third Centuries BC). In *Colonial Encounters in Ancient Iberia: Phoenician, Greek, and Indigenous Relations*, edited by M. Dietler and C. López-Ruiz. Chicago: University of Chicago Press.

Sanmartí, Joan Grego, Nabil Kallala, M. Carme Belarte, Joan Ramon Torres, Bouthéina Maraoui Telmini, Rafael Jornet, Souad Miniaoui, Thaïs Fadrique, Daniel López Reyes, Núria Morell, Marta Portillo, Sílvia Valenzuela, Jordi Campillo, David Montanero, Francisco Cantero, and Moufida Jenène. 2012. Filling Gaps in the Protohistory of the Eastern Maghreb: The Althiburos Archaeological Project (El Kef, Tunisia). *Journal of African Archaeology* 10 (1):21-44.

Santley, Robert, and Rani Alexander. 1992. The Political Economy of Core-Periphery Systems. In *Resources, Power, and Interregional Interaction*, edited by E. Schortman and P. Urban. New York: Plenum.

Schiffer, Michael B. 1983. Toward the Identification of Formation Processes. *American Antiquity* 48 (4):675-706.

Schmandt-Besserat, Denise. 1980. Ocher in Prehistory: 300,000 Years of the Use of Iron Ores as Pigments. In *The Coming of the Age of Iron*, edited by T. A. Wertime and J. D. Muhly. New Haven and London: Yale University Press.

Schmitz, Philip C. 1994. The Name "Agrigentum" in a Punic Inscription (CIS I 5510.10). *JNES* 53 (1):1-13.

Schmitz, Philip C. 2012. *The Phoenician Diaspora: Epigraphic and Historical Studies*. Winona Lake, Indiana: Eisenbrauns.

Schniedewind, William M. 2004. *How the Bible Became a Book: The Textualization of Ancient Israel*. Cambridge: Cambridge University.

Schubart, Hermanfrid. 2002. The Phoenician Settlement of the 8th Century B.C. in Morro de Mezquitilla (Algarrobo, Málaga). In *The Phoenicians in Spain: An Archaeological Review of the Eighth–Sixth Centuries B.C.E.*, edited by M. R. Bierling. Winona Lake, Indiana: Eisenbrauns.

Schulman, Alan R. 1979. Diplomatic Marriage in the Egyptian New Kingdom. *JNES* 38 (3):177-93.

Schwartz, J.H., F.D. Houghton, L. Bondiolo, and R. Macchiarelli. 2012. Bones, Teeth, and Estimating Age of Perinates: Carthaginian Infant Sacrifice Revisited. *Antiquity* 86:738-45.

Scott, David. 2010. *Ancient Metals: Microstructure and Metallurgy*. Vol. 1. Los Angeles: Conservation Science Press.

Scott, David. 2013. *Ancient Metals: Microstructure and Metallurgy, Vol. IV: Iron and Steel*. Los Angeles: Conservation Science Press.

Scott, David A. 1985. Periodic Corrosion Phenomena in Bronze Antiquities. *Studies in Conservation* 30 (2):49-57.

Scott, David A., and Gerhard Eggert. 2009. *Iron and steel in art: corrosion, colorants, conservation*. London: Archetype.

Shalev, S., S.Sh. Shilstein, and Yu. Yekutieli. 2006. XRF Study of Archaeological and Metallurgical Material from an Ancient Copper-Smelting Site near Ein-Yahav, Israel. *Talanta* 70:909-13.

Shaw, Joseph W. 1989. Phoenicians in Southern Crete. *AJA* 93 (2):165-83.

Silberman, Neil Asher. 1995. Power, Politics, and the Past: The Social Construction of Antiquity in the Holy Land. In *The Archaeology of Society in the Holy Land*, edited by T. E. Levy. New York: Facts on File.

Simmons, William S. 1981. Cultual Bias in the New England Puritans' Perception of Indians. *The William and Mary Quarterly* 38 (1):56-72.

Smith, Joanna S. 2008. Cyprus, the Phoenicians and Kition. In *Beyond the Homeland: Markers in Phoenician Chronology*, edited by C. Sagona. Leuven-Paris-Dudley, MA.: Peeters.

Smith, Neil, and Thomas E. Levy. 2008. The Iron Age Pottery from Khirbat en-Nahas, Jordan: A Preliminary Study. *BASOR* 352:41–91.

Smith, P., G. Avishai, J. A. Greene, and L. E. Stager. 2011. Aging Cremated Infants: The Problem of Sacrifice at the Tophet of Carthage. *Antiquity* 85 (329):859-74.

Smith, P., L.E. Stager, J.A. Greene, and G. Avishai. 2013. Age estimations attest to infant sacrifice at the Carthage Tophet. *Antiquity* 87:1191-9.

Smith, R.E. 1954. Latins and the Roman Citizenship in Roman Colonies: Livy, 34, 42, 5-6. *The Journal of Roman Studies* 44:18-20.

Snodgrass, A.M. 1987. *An Archaeology of Greece*. Berkeley.

Snodgrass, Anthony M. 1980. Iron and Early Metallurgy in the Mediterranean. In *The Coming of the Age of Iron*, edited by T. A. Wertime and J. D. Muhly. New Haven and London: Yale University Press.

Spanò Giammellaro, Antonella, Francesca Spatafora, and Peter van Dommelen. 2008. Sicily and Malta: Between Sea and Countryside. In *Rural Landscapes of the Punic World*, edited by P. van Dommelen and C. Gómez Bellard. London; Oakville: Equinox.

Stager, Jennifer M.S. 2005. 'Let No One Wonder at This Image': A Phoenician Funerary Stele at Athens. *Hesperia* 74:427-49.

Stager, Lawrence E. 1978. Excavations at Carthage 1975 - The Punic Project: First Interim Report. *AASOR* 43:151-90.

Stager, Lawrence E., and Samuel R. Wolff. 1984. Child Sacrifice at Carthage: Religious Rite or Population Control? *BAR* 10:31–51.

Stanish, Charles. 1997. Nonmarket Imperialism in the Prehispanic Americas: The Inka Occupation of the Titicaca Basin. *Latin American Antiquity* 8 (3):195-216.

Stanish, Charles. 2002. Tiwanaku Political Economy. In *Andean Archaeology I: Variations in Sociopolitical Organization*, edited by W. H. Isbell and H. Silverman. New York: Kluwer Academic/Plenum Publishers.

Stanish, Charles. 2003. *Ancient Titicaca: The Evolution of Complex Society in Southern Peru and Northern Bolivia*. Berkeley, CA: University of California.

Stein, Gil J. 1999. *Rethinking World Systems: Diasporas, Colonies and Interaction in Uruk Mesopotamia*. Tuscon, AZ: University of Arizona.

Stieglitz, Robert R. 1990. The Geopolitics of the Phoenician Littoral in the Early Iron Age. *BASOR* 279:9–12.

Stos-Gale, Z.A. 2006. Appendix A: Provenance of metals from Tell Jatt based on their lead isotope analysis. In *The Jatt metal hoard in Northern Canaanite/Phoenician and Cypriote context*, edited by M. Artzy. Barcelona: Publicaciones del Laboratoria de Arqueología, Universidad Pompeu Fabra de Barcelona.

Sznycer, Maurice. 1978. Carthage et la Civilisation Punique. In *Rome et la Conquête du Monde Méditerranéen. 2. Genèse d'un Empire (Collection 'Nouvelle Clio', 8bis)*, edited by C. Nicolet. Paris: Presses Universitaires de France.

Tatlock, Jason R. 2006. How in Ancient Times They Sacrificed People: Human Immolation in the Eastern Mediterranean Basin with Special Emphasis on Ancient Israel and the Near East, Near Eastern Studies, University of Michigan, Ann Arbor.

Thornton, C. P., and T. Rehren. 2009. A Truly Refractory Crucible from Fourth Millennium Tepe Hissar, Northeast Iran. *Journal of Archaeological Science* 36 (12):2700-12.

Thornton, C. P., Th Rehren, and V. C. Pigott. 2009. The Production of Speiss (Iron Arsenide) during the Early Bronze Age in Iran. *Journal of Archaeological Science* 36 (2):308-16.

Thornton, Christopher P., C. C. Lamberg-Karlovsky, Martin Liezers, and Suzanne M.M. Young. 2002. On Pins and Needles: Tracing the Evolution of Copper-base Alloying at Tepe Yahya, Iran, via ICP-MS Analysis of Common-place Items. *Journal of Archaeological Science* 29:1451-60.

Tilley, Christopher Y. 1994. *A Phenomenology of Landscape: Places, Paths and Monuments*. Oxford: Berg.

Treumann, Brigitte. 1997. The Role of Wood in the Rise and Decline of the Phoenician Settlements on the Iberian Peninsula. Ph.D. dissertation, University of Chicago, Chicago.

Treumann, Brigitte. 2009. Lumbermen and Shipwrights: Phoenicians on the Mediterranean Coast of Southern Spain. In *Colonial Enouncters in Ancient Iberia*, edited by M. Dietler and C. López-Ruiz. Chicago and London: The University of Chicago Press.

Trigger, Bruce G. 1996. *A History of Archaeological Thought*. Second ed. Cambridge: Cambridge University.

Trigger, Bruce G. 2003. *Understanding Early Civilizations*. Cambridge: Cambridge University Press.

Tringham, Ruth. 2003. (Re)-Digging the Site at the End of the Twentieth Century: Large-Scale Archaeological Fieldwork in a New Millennium. In *Theory and Practice in Mediterranean Archaeology: Old World and New World Perspectives*, edited by J. K. Papadopoulos and R. M. Leventhal. Los Angeles: Cotsen Institute of Archaeology, UCLA.

Tronchetti, Carlo, and Peter van Dommelen. 2005. Entangled Objects and Hybrd Practices: Colonial Contacts and Elite Connections at Monte Prama, Sardinia. *JMA* 18 (2):183-208.

Tylecote, R. F. 1962. *Metallurgy in Archaeology: A Prehistory of Metallurgy in the British Isles*. London: Edward Arnold (Publishers) Ltd.

Tylecote, R. F., and Brian J. J. Gilmour. 1986. *The metallography of early ferrous edge tools and edged weapons*. Oxford, England: B.A.R.

Tylecote, R.F. 1982a. Metallurgy in Punic and Roman Carthage. In *Mines et Fonderies Antiques de la Gaule*. Paris: Centre National de la Recherche Scientifique.

Tylecote, R.F. 1982b. Metallurgical Crucibles and Crucible Slags. In *Archaeological Ceramics*, edited by J. S. Olin and A. D. Franklin. Washington: Smithsonian Institution Press.

Tylecote, R.F. 1992. *A History of Metallurgy*. Second ed. London: The Institute of Materials.

Tylecote, R.F., and B.J.J. Gilmour. 1986. *The Metallography of Early Ferrous Edge Tools and Edged Weapons*. Vol. 155. Oxford: B.A.R. British Series.

Valério, Pedro, Rui J.C. Silva, António M. Monge Soares, Maria F. Araújo, Francisco M. Braz Fernandes, António C. Silva, and Luis Berrocal-Rangel. 2010. Technological Continuity in Early Iron Age Bronze Metallurgy at the South-Western Iberian Peninsula - A Sight from Castro dos Ratinhos. *Journal of Archaeological Science* 37:1811-9.

Valério, Pedro, António M. Monge Soares, Rui J.C. Silva, Maria Fátima Araújo, Paulo Rebelo, Nuno Neto, Raquel Santos, and Tiago Fontes. 2013. Bronze Production in Southwestern Iberian Peninsula: The Late Bronze Age Metallurgical Workshop from Entre Águas 5 (Portugal). *Journal of Archaeological Science* 40:439-51.

van Dommelen, Peter. 1997. Colonial Constructs: Colonialism and Archaeology in the Mediterranean. *WoAr* 28:3:305-23.

van Dommelen, Peter. 1998. On Colonial Grounds: A Comparative Study of Colonisalism and Rural Settlement in 1st Milennium BC in West Central Sardinia. Leiden: University of Leiden.

van Dommelen, Peter. 2002. Ambiguous Matters: Colonialism and Local Identities in Punic Sardinia. In *The Archaeology of Colonialism*, edited by C. L. Lyons and J. K. Papadopoulos. Los Angeles, California: Getty Research Institute.

van Dommelen, Peter. 2005. Colonial Interactions and Hybrid Practices: Phoenician and Carthaginian Settlement in the Ancient Mediterranean. In *The Archaeology of Colonial Encounters*, edited by G. J. Stein. Sante Fe: School of American Research Press.

van Dommelen, Peter. 2006. Punic farms and Carthaginian colonists: surveying Punic rural settlement in the central Mediterranean. *Journal of Roman Archaeology* 19:7-28.

van Dommelen, Peter, and Stefano Finocchi. 2008. Sardinia: Diverging Landscapes. In *Rural Landscapes of the Punic World*, edited by P. van Dommelen and C. Gómez Bellard. London; Oakville: Equinox.

van Dommelen, Peter, and Carlos Gómez Bellard. 2008. *Rural Landscapes of the Punic World*. London; Oakville, CT: Equinox.

van Zeist, Willem, Sytze Bottema, and Mirjke van der Veen. 2001. *Diet and Vegetation at Ancient Carthage: The Archaeobotanical Evidence*. Groningen.

Veldhuijzen, H.A. 2003. 'Slag_Fun' - A New Tool for Archaeometallurgy: Development of an Analytical (P)ED-XRF Method for Iron-Rich Materials. *Papers from the Institute of Archaeology* 14:102-18.

Veldhuijzen, Harald Alexander, and Thilo Rehren. 2007. Slag and the city: early iron production at Tell Hammeh, Jordan, and Tel Beth-Shemesh, Israel. In *Metals and Mines: Studies in Archaeometallurgy*, edited by S. L. Niece, D. Hook and P. Craddock. London: Archetype/British Museum.

Vella, Nicholas. 2005. Phoenician and Punic Malta. *Journal of Roman Archaeology* 18 (2):436–50.

Vives-Ferrándiz, Jaime. 2008. Negotiating Colonial Encounters: Hybrid Practices and Consumption in Eastern Iberia (8th-6th centuries BC). *JMA* 21 (2):241-72.

Waggoner, Ben. 2009. *The Sagas of Ragnar Lodbrok*. New Haven: Troth.

Wagner, Donald B. 1996. *Iron and Steel in Ancient China*. Leiden-New York-Köln: E.J. Brill.

Wagner, Donald B. 2001. *The State and the Iron Industry in Han China*. Copenhagen: Nordic Institute of Asian Studies.

Walbank, F.W. 1972. Nationality as a Factor in Roman History. *Harvard Studies in Classical Philology* 76:145-68.

Waldbaum, J.C. 1989. Copper, Iron, Tin, Wood: the Start of the Iron Age in the Eastern Mediterranean. *Archeomaterials* 3 (2):111-22.

Waldbaum, Jane C. 1980. The First Archaeological Appearance of Iron and the Transition to the Iron Age. In *The Coming of the Age of Iron*, edited by T. A. Wertime and J. D. Muhly. New Haven and London: Yale University Press.

Warmington, B.H. 1969. *Carthage: A History*. New York: Barnes & Noble Books.

Weiss, H., M. A. Courty, W. Wetterstrom, F. Guichard, L. Senior, R. Meadow, and A. Curnow. 1993. The Genesis and Collapse of Third Millennium North Mesopotamian Civilization. *Science* 261 (5124):995-1004.

Weiss, Harvey. 2000. Beyond the Younger Dryas: Collapse as Adaptation to Abrupt Climate Change in Ancient West Asia and the Eastern Mediterranean. In *Environmental Disaster and the Archaeology of Human Response*, edited by G. Bawden and R. M. Reycraft. Albuquerque, NM: Maxwell Museum of Anthropology.

Wertime, Theodore A. 1980. The Pyrotechnological Background. In *The Coming of the Age of Iron*, edited by T. A. Wertime and J. D. Muhly. New Haven: Yale University Press.

Wheeler, T.S., and R. Maddin. 1980. Metallurgy and Ancient Man. In *The Coming of the Age of Iron*, edited by T. A. Wertime and J. D. Muhly. New Haven: Yale University Press.

Whitaker, Joseph I. S. 1921. *Motya: A Phoenician Colony in Sicily*. London: G. Bell.

Wilson, D.S., and E. Sober. 1994. Re-Introducing Group Selection to the Human Behavorial Sciences. *Behavorial and Brain Sciences* 17 (4):585-654.

Wilson, V. 1975. 'Punic Stelae', Appendix to Hurst 1975. *Antiquaries Journal* 55:38-9.

Winter, Irene J. 1976. Phoenician and North Syrian Ivory Carving in Historical Context: Questions of Style and Distribution. *Iraq* 38:1–22.

Wolff, Samuel R. 1986. Maritime Trade at Punic Carthage. Ph.D. dissertation, Near Eastern Languages and Civilizations, University of Chicago, Chicago.

Wright, Henry T. 1977. Recent Research on the Origins of the State. *Annual Review of Anthropology* 6:379-97.

Xella, Paolo, Josephine Quinn, Valentina Melchiorri, and Peter Van Dommelen. 2013. Phoenician Bones of Contention. *Antiquity* 87 (338):1199-207.

Yon, Marguerite, and William A.P. Childs. 1997. Kition in the Tenth to Fourth Centuries B.C. *BASOR* 308 (The City-Kingdoms of Early Iron Age Cyprus in Their Eastern Mediterranean Context):9-17.