The Development of Iron Technology in the Mediterranean Bronze Age

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1 Introduction

In the eastern Mediterranean region in the Bronze Age there were a number of societies that through cultural activities and trade and international agreements, participated in a regional exchange economy. This was based on the highly preferential metal bronze, which, with the other metals copper and tin (the components of bronze), gold, silver and lead were important exchange components for the whole economic system. This thesis assumes a bias to archaeometallurgy, and seeks to demonstrate the significance of the development of iron technology to the societies and the regional economy in the transition from the Bronze Age to the time when iron became the most used metal.

The eastern Mediterranean regional economy grew during the Late Bronze Age and seemed to function well, until its sudden collapse in about 1200 BC. The reciprocal impact of metallurgical developments are sought demonstrated by examining the societies and other factors in the region. Some of the more significant societies were the Hittites, Mycenae (Greece), Cyprus and states in Syria and the Levant, as well as Egypt. Most of the complex societies were ruled by elites, and had centralised control of their growing economies by 1500 BC. This control included commercial and religious affairs, as well as those which we today would call industrial. These latter included mining and production of metals and metal products. Since the elites controlled the absolute majority of the wealth of the society, it is probable that their control also extended into other spheres of the activities in which the population actively engaged.

From an early part of the BA, the elites acquired desired luxury goods through gift exchange, trade, looting or war. Thus the trade in luxuries benefited mainly the elites, who were connected in a "peer-polity" regional network. After a time of high and increasing prosperity, this ultimately led to a systems collapse in the region, perhaps assisted by a dissatisfied populace (van de Mieroop, 2010).

1.1 Background

Here the abbreviations used are **IA**= Iron Age, **LBA**=Late Bronze Age, **BA**=Bronze Age, and where used alone the term "**bronze**" means the copper-tin alloy. The pan regional collapse in about 1200 BC is hereafter called the **PRC**.

The region was plagued with unrest and war in the last 100 years of LBA, especially just before and during the PRC (Knapp, a, b,1992; Muhly, 1984; Sandars, 1978; Artzy, 1987;

among others). The Egypt - Hittite war at Kadesh in northern Syria of about 1270 is an example. The Egyptians and Hittites vied for power over a base in the Levant/Syria. The Egyptians moved against the Hittites, but the result of the war was controversial, with neither Egypt nor Hytta being universally seen as a decisive victor (Bryce, 1998:251; McMahon, 1989; Santosuosso, 1996; Goedicke, 1966; among others). In this struggle the Hittites used some iron weapons at a time when bronze was paramount. This demonstrates that iron was developed and accepted as weapon material, at least in the Hittite Kingdom at that time. A particularly important question in this respect is whether iron was a better material than bronze, or simply "good enough" for some uses, while still inferior to bronze in others. Could perhaps the Hittites not afford to use only bronze, or did they find iron to be of better quality for weapons than bronze, or some other reason? This indicates the changes taking place in metallurgy at that time.

The Hittite Empire collapsed less than 100 years after the battle of Kadesh, as did the important city state of Ugarit, which was an important node in the network of ports and trading routes, both inland and maritime (Knapp, 1992(a):63). Both the Hittite Empire and state of Ugarit were important parts of the regional economy and elite network and control structure. Troubles were brewing in the region, and even the Egyptian Empire was struggling (van der Steen, 1996), though it was still a major power. There was widespread migration, and also the exploits of the "Sea Peoples" in LBA (figure 1), who are said by some to be at least one of the reasons for the PRC (Karageorghis, 2002; Muhly, 1984; Sandars, 1978). These factors all point in the direction of social changes. The regional economy was under the control of the region's elites, and so these developments must raise the question of whether their control was slipping.

In times of social change it is possible that <u>development</u> of iron technology could have gained ground. It may be that it had failed to do so at an earlier period, solely because bronze was so solidly established as the metal of preference. But there might also be other reasons, e.g. connected to decay of the elite power. Possibly, the disturbances in the region might have caused greater <u>spreading</u> of iron technology. Among other effects are migration (Anthony, 1990), the phenomenon of the "Sea Peoples" (Sanders, 1978) and related elements such as the development of commerce through history (Manning, 2005:77-90). It is not difficult to imagine that people on the move would have had increased need of metals for tools and weapons. It is perhaps reasonable in these circumstances to expect a growth of interest in the use of iron, especially if bronze was more difficult to obtain.

The LBA ended with collapse. Some people believe that the IA started in about 1000 BC, although others differ. Nevertheless, it seems unlikely that the new IA could start only about 200 years after a regional collapse, given present understanding of developments and knowledge of the production of iron. In short, to assess iron's popularity at that time it is not sufficient to solely examine metallurgical development but ignore social development.

The societies in the focus region in BA traded with other societies in the Near East, as well as neighbouring regions, from Afghanistan to Europe. In about 1300 BC growth in culture and economy in the eastern Mediterranean was rapid, culminating before 1200 BC . In its heyday the culture was an advanced and complex exchange economy (Negbi, 2005), but not much is known about the centuries after the collapse. The scribes disappeared with the palaces. The PRC was abrupt for most societies in the region, but Egypt fared better than most. It preceded the start of IA which was about the late eleventh century BC, by 100-200 years. An <u>early</u> date for the start of IA is 1050 BC (Gilboa and Sharon, 2003).

Any kind of metallurgical activity in this period, either before or during the PRC, based on either archaeological material or texts, is relevant. Thus, both developments in smelting of copper for production purposes, and attempts to smelt iron or use meteorological iron for production will also be relevant. The important question is how developments in metallurgy affected societies in LBA or in the transition to IA

1.2 Chronology, stages in Iron Age definition and scope

The chronological start and ending of BA and IA in the various regions of the continent are not necessarily synchronous. For example, in northern Europe BA started later than in the Mediterranean (Eskildsen, 2012; Wertime and Muhly, 1980:xiii; Trigger, 1996:62-71; Waldbaum, 1978:19).

There is still some controversy about chronology, and this is potentially significant because of the dating of the Ulu Burun shipwreck, south of Kaş in Turkey. This was set to 1305 BC in the conventional chronology by dendrochronological dating (see Pulak, 1998: 213-214). The controversy centres on a book (James et al, 1991) claiming that the conventional chronology is wrong. See Trigger (1994), Snodgrass (1991), Ray (1992) and Kohl (1995), among others. In this thesis the conventional chronology is followed.

For the relative development chronology for iron, specifically regarding the transition to iron from bronze, and in answer to the question: “What actually defines the Iron Age?”, the suggestion by Snodgrass, (1980:336-7) is to use a stage system which (simplified) states:

- the **first** stage is when “working iron” is produced, i.e. the cutting edge of a tool is made of iron.
- the **second** stage is when working iron is present and used, but less frequently than bronze.
- the **third** stage is when iron is used more often than bronze, although bronze is still present. This is the Iron Age proper.

Based on this “stage” system, I would prefer in this thesis to put up an operational definition of the otherwise slightly vague definition of the first stage: i.e. stage 1 is when smiths have the knowledge to produce iron from its mined ores. This to differentiate between iron objects produced from meteoric iron, and those produced from iron ores excavated from the earth by mankind. This definition excludes many of the earliest iron objects. Stages 2 and 3 remain as above.

The scope of this thesis is defined as exclusively the developments in LBA in the eastern Mediterranean region, and chronologically, specifically the period 1700 to 1000 BC.

1.3 Metallurgy and society

In the early phases of metallurgy, metalworkers were faced with highly complex chemical problems. Ores of high or low-grade metal content had to be treated differently, and to extract the metal one wanted, in as pure a condition as possible, was not easy. The first metals they came into contact with were various forms of lead, copper, occasionally tin and iron. The latter, iron, was not the first ore that they came to work, because the early techniques with pyrotechnics could not melt iron to liquid state. All in all, the early metallurgists were faced with a staggering amount of metallic ores, and had to proceed by trial and error, in attempts to produce a product from them (Wertime, 1964; Muhly, 2006; Yalçın, 1999).

Technological development is closely coupled to a society's general development. As technology advances, so does the possibility of exploitation of new tools, materials and ideas expand (Dobres, 1995; Dobres and Hoffman, 1994; Geselowitz, 1993). This is only one side of the matter, the other being the means of the spreading of technology to other people. In LBA, ideas and technological development were spread by the mobility of specialists in times of war, by royal gift exchange and by the general movement of people (Moorey, 2001; Zaccagnini, 1983).

Furthermore, the importance of economic matters or commercial matters are to be emphasised. The commercial arena was not as in present day commerce. Flow of high value materials such as metals and products made from them did also generate product innovation, wealth and capital investment. But all matters about the storage, development or exchange of high value materials were the prerogative of the palaces alone (Sherratt & Sherratt, 2001).

The development of iron through ascending stages (Snodgrass, 1980:336-7) to a more popular and utilitarian metal can only be properly understood if the culture that develops it is understood, or at least described. Also, at the same time as the complex societies of the eastern Mediterranean began to disappear in this period, iron itself began to appear more frequently in the archaeological record (or in written sources). But any connection between the two cannot be assumed without question. It is necessary to examine the spread of types of iron objects as well as the events in society at the same time (McConchie, 2004:12). Therefore some of the most relevant societies in the region are discussed in the following sections.

The period 1200 to 900 BC in the region is often referred to in a general fashion as the "Early Iron Age". But the entire region was not synchronously attuned with the spread of iron technology. Different areas had reached different stages in development, but there was a significant spread of iron technology and types of objects. It is a period generally with much social disturbance and migration, and the activities of the "Sea Peoples" that spread confusion. The effect of the failure of major BA civilisations in the region and migrations from some parts to other parts heralded major changes in cultural, economic and political aspects of the region (Waldbaum, 1978:10-11).

2 The eastern Mediterranean region - Cultures and societies in BA - LBA.

Metallurgy is an affair of mankind. It is done to generate the development and production of tools and objects that promote more effective service to people, for their activities, and also for their deities. It is not for human consumption (feeding). It is therefore closely linked to society, because a congregation of humans can make decisions to initiate metallurgical projects, and assign to them certain common resources such as the labour (work in man-days) of some people, and food and life support for the participants. Human creativity is a part of the process. Therefore, a broader, more inclusive view must be taken of the development of metallurgy in the region, especially as it concerns some of the societies and their contributions to metallurgy. The question of why the people in the Mediterranean in BA chose to develop iron at the same time that bronze was the most common and well established metal must be posed.

2.1. The societies in Anatolia

Some of the societies in the northern and eastern parts were among the earliest users of iron in the region. Some hypotheses about why this is so have been given by Wertime (1973:885).

- Anatolia was the first known organised production site of copper and silver, and of penetration of the sulphide zone.
- There are few other parts of the world with such resources of copper, lead, iron and other important metals/minerals. For example the south coast of the Black Sea has sands with high amounts of magnetite.
- Iron is difficult to process and the earliest methods were heating and hammering. Only the tribal societies of Anatolia had the necessary experience over time with experimentation, and processing of iron. A thousand years elapsed between the first experiments with iron and its full acceptance in society.

The cultures in this part of the region may also have been at the centre of the PRC, which might also be connected to the development of iron technology and the subsequent start of the Iron Age in about 1050-950.

The region of Anatolia has little or no tin deposits, and has been importing tin as long as they have needed it (Muhly, 1993). The mineral deposits and need for tin were important factors in the development of trade with lands far away, especially in the south east. By the middle of the third millenium BC wealthy elites and important centres of civilization existed in Anatolia including Troy and Poliochnii in the north west (Bryce, 1998:8) as well as many others. Around 2300 BC there were some major upheavals in Anatolia, thought by some to be the result of indo-european newcomers. The matter of the origin of these newcomers and their entry points to Anatolia is controversial, but few if any compass directions have been excluded. In addition there is controversy about the time or times that they arrived.

2.2. The Assyrian Colonies

These merchant colonies preceded the Hittite Kingdom, and controlled or traded with some iron-producing pre-Hittite societies. They probably set the stage for iron development in the region. They established and maintained contacts with Mesopotamia which were probably important for the development of later iron technology (Bryce, 1998:21-43).

The Assyrian Colony period in Anatolia began very early in the second millennium, also marking the start of the written record, some 1.000 years after record keeping is known to have started in Mesopotamia. The Assyrian merchants produced tablets profusely. More than 15,000 had been discovered by about 1999. The Assyrian activity indicates a strong connection between Anatolia and Assyria, and thence to other areas of the near east. It may be deduced that the political climate in the region was fairly stable, since the Assyrians were essentially interested in trading, and were sensitive about political and societal stability. If there was too much instability, they would pull out of mercantile activity in that area. They built up colonies and an administration, including an arbitration system to settle disputes (Bryce, 1998:21-25). Deposits of copper, lead, arsenic, nickel and other minerals were many, but tin was imported from south west Iran, Mesopotamia or Syria (Bryce, 1998:21-43). But nevertheless there is also the possibility of some import of tin and other metals by boat, possibly through Cyprus.

It is probable that the Assyrian trading connection was responsible for the import of tin, probably from SW Iran. But they were traders, so there were other goods they were bringing to merchants in Anatolia, e.g. textiles. These goods were exchanged for others including metals and minerals from Anatolia for transport to other parts on the trading route to Assyria and Mesopotamia. The Assyrians were interested in acquiring the copper, silver and gold that was to be found (mined) in Anatolia (Bryce, 1998:27). Their interests included iron, and they participated in manufacture of iron products in Anatolia (Wertime, 1973).

The trading system included forms of transaction such as payment, debt and interest. In itself a complex part of any commercial exercise. There were taxes levied on caravans crossing the different territories. Although these might be seen as prohibitive, it must have been possible to turn a profit on these commercial enterprises, or they would have dried up. The palaces and kings that ruled the different territories had also to ensure safe passage for the caravans. But all the risks from brigands, disasters and other unforeseeable problems nevertheless had to be covered by the merchants themselves, as well as all levies and taxes that had to be paid en route. So the total result was that the trading continued as long as the profits were good and the risks and costs acceptable. As soon as this changed, then the traffic would probably have dried up (Bryce, 1998:21-43).

This traffic overland by caravan was from the region of Mesopotamia through northern Syria and to Anatolia, ending at the Black Sea coast. The areas neighbouring the routes were probably also able to participate in trade to various ports in the region, on the Black Sea and Mediterranean. By this means, the flow of information, new ideas, cultural developments and new products was probably also effective.

It also led to the development of relations between the various rulers of the territories it passed through. Agreements were reached between these rulers and cooperation to keep the roads and routes free of brigands etc. Unfortunately, there were also occasions when the local ruler (or vassal ruler) came himself in conflict with a neighbouring territory's ruler, or his own king, and this could lead to outright war. This tendency accelerated as time went on. Cities were destroyed, rebuilt and resettled, but the caravan routes continued for a long time, thus laying the basis for the commercial and cultural network that extended from the Black Sea coast to Mesopotamia, and probably further afield (Bryce, 1998:28-62).

However, the increasing conflicts and wars led to the withdrawal of the Assyrian mercantile initiative. The merchants, their families, contacts and network of agreements and contract all ended shortly before the Hittite realm was founded in c.1620 BC. The situation in the region was dramatically changed with total disruption in Anatolia, following the termination of the Assyrian colony period. The relatively enlightened period of the Assyrian Colonies was replaced by several decades of darkness when written records cease, and of which little is known (Bryce, 1998:16, 42-64).

2.3 The Hittite Empire

The Hittite Empire, after its foundation, became a power in the region with a high king on a par with Egypt. There were several languages spoken in Anatolia, and several were of indo-european origin, as was the written language of the Hittite court indo-european. It was also the language used for communication with the king of Ahhiyawa (Bryce, 1998:17). The Hittites controlled the polity of Ugarit (probably as a vassal state), which had a port with coastal marine traffic from many ports in the Mediterranean, as well as being a node for land transport to various other countries such as Hittite towns, Syria and the Levant. The Hittites also had other vassal states, some of which were occasionally a source of trouble. Other problematic relationships existed also, with the Ahhiyawa, to their west, and the kingdom of Assyria, to their east. They were at times hard pressed in retaining control over their own domains (Bryce, 1998).

The first proper state to develop iron was the Hittite Empire. It was a major complex society in the eastern Mediterranean, and traded domestic production of minerals and metals for other goods including textiles, produced abroad. Tin was important for the production of bronze, and came mostly along the same routes as the Assyrians had used previously. Written sources indicate 80 tons of tin import in a 50 year period, which would give about 800 tons of bronze.

This was a trading route that was important throughout the existence of the kingdom, and an access route that had high priority and strategic importance. If this route had been closed by another state, that alone would have caused major, perhaps insurmountable, problems. They had viceroy seats in 2 vassal states strategically placed to represent Hittite political and military power in the area of the trading routes. The Hittites were also frequently in the field in arms, in many parts of Anatolia, putting down insurrections in vassal states or other states' attempts to encroach upon their territory. The cover of Macqueen's book is iconic, showing a Hittite warrior with sword in one hand and the other clenched in a fist. This image is something that springs to mind when the Hittites are discussed (Macqueen, 1976).

The Hittite Empire was born in a time of struggle, and existed throughout its history with constant challenges to the leadership of its kings. There was only ever the one royal house in the kingdom, but there was internal intrigue and factional trouble making by persons wishing to gain more power or replace the ruling king. Syria was also a constant worry, and a country both Egypt and other neighbouring territories tried to gain control over. After the battle of Kadesh against Egypt (where the Hittites used some iron weapons), both sides claimed victory, but it was the Hittites who secured control over Syria. However, after some years, Egypt tightened its grip on others of their vassal states in that region, and the threat of a renewed conflict was ever prevalent. Other states or cultures which were potentially significant enemies were Babylonia, Assyria, Ahhiyawa, Kaska, Lukka and the Hurrians.

However, the king Tudhaliya gained the throne in 1227, and in the course of his reign regained control of Cyprus and imposed a tributary regime. It seems that Tudhaliya's reign was relatively successful, with more accomplished than some of his better known ancestors. He was successful in limiting the power of the Ahhiyawa in western Anatolia, and rebuffed some attempts by Assyria to impinge on the Hittite domains. It is not easy to see in his reign any signs of the collapse that was to follow shortly afterwards (Bryce, 1998).

The next Regent was a son of Tudhaliya, Arnuwanda (III), died after a year, so that the reign was passed to another son of Tudhaliya, named Suppiluliuma (II). He faced unrest both internally, perhaps brought on by food shortage, and externally. The task he was confronted with was enormous. One of Suppiluliuma's big problems was the Ahhiyawa, situated in western Anatolia but with a base in Greece (see next section).

The Hittite Empire was more or less in the central part of Anatolia with access to surrounding sea areas through their vassal states, although they had no navy. There were at least two military campaigns to put down unrest on Cyprus, and make the king of Cyprus submit to Hittite authority. These included tribute to be paid to the Hittite king. Probably the Hittites considered Cyprus as a vassal state (Knapp, 1980).

Nevertheless the Hittites were good at diplomacy, first trying to persuade or coerce vassal states to comply with Hittite wishes, and only going into the field against them when the situation was deadlocked, and they felt they had to have a solution to a critical problem. The area controlled by the Hittites in the 2nd millenium BC, either themselves directly, or through vassal states was most of Anatolia except the area near the sea of Marmara in the north-west (where there is a land connection to modern Istanbul), and excepting the area controlled by the Ahhiyawa. On the eastern side from the south coast of the Black Sea down to Assyria and circumscribing the Syrian desert as it was then, and down to about Kadesh.

2.4 The Ahhiyawa

The Ahhiyawa are still something of a mystery. However, it is currently believed that they were centred near Corinth, in Greece. The Ahhiyawa were almost certainly Mycenaean, although that doesn't necessarily mean all Mycenaeans. The Mycenaean people were possibly divided into several kingdoms, such that the Ahhiyawa were only one such kingdom. The current understanding is that the core of the Ahhiyawa was at Mycenae, the main port was at Tiryns, and a large population in the area near Corinth, centred on Mycenae. The rest of the scattered kingdom was the Dodecanese islands and part of western Anatolia (Bryce, 1998:60-61; Mountjoy, 1998:51). The Ahhiyawa were active in western Anatolia, although it wasn't to the advantage of the Hittites, whose vassal states were raided by them. These raiding activities were also carried out in Anatolia and the Levant (Macqueen, 1996) by the Mycenaeans, something made possible by their marine capabilities.

There is a controversy about whether the Ahhiyawa were actually Mycenaean (a theory supported by some, e.g. Bryce (1998:60-61), Mountjoy (1998:51), but rejected by others e.g. Macqueen (1996:40-41). Mountjoy (1998) believes the Ahhiyawa was either a culture on mainland Greece, or it was possibly a maritime kingdom that stretched from Miletos to Rhodes, and included parts of coastal Anatolia. Also that the Ahhiyawa were acculturated to some degree as Mycenaeans (based on similarities in pottery). Mountjoy is also open to the idea that the boundaries of Ahhiyawa changed through time. It is easy to understand that this could be the case, since the boundaries of what is in fact an archipelago might well change as naval supremacy and aggression changed in the region. In this thesis the hypothesis that Ahhiyawa = Mycenaean is accepted.

The Mycenaean colonies on the Anatolian mainland were nearest the coast in the south west. Musgebi, near ancient Halikarnassos (Bodrum) is one, Miletos, on the coast, is another. At both sites, Mycenaean pottery and burial practices were used. This was a kingdom with many people, overseas trade, a naval force and a king respected as a Great King on a par with the King of the Hittites (Simpson, 2003; Mountjoy, 1998; Rose, 2008).

However, regarding the fortunes of the Ahhiyawa, the so-called “Milawata letter” is of importance. By the time Tudhaliya IV became king (he reigned 1227-1209) the Ahhiyawa had a position of authority over the ruler of Milawata. The “Milawata letter” is not entirely understood, since it refers to other documents which have not yet been recovered. However, the understanding is that Milawata, formerly leaning toward Ahhiyawa interests to the disadvantage of the Hittites, had been forced to declare loyalty to the Hittites by king Tudhaliya. The letter makes it clear that the Hittites had authority over Milawata. In addition, Milawata is also granted a larger degree of freedom, as well as a degree of power over a neighbouring Hittite vassal state. This was most unusual, since all vassal states reported directly to Hattusa, not to other states (Bryce, 1998; Rose, 2008).

This was extremely important because it created huge problems for the Ahhiyawa in west Anatolia. Their trade and political activities were probably significantly reduced, if not wiped out. The King of Ahhiyawa would have lost his most powerful base on the Anatolian mainland because the activities of Ahhiyawa were detrimental to Hittite policies in the west. Tudhaliya also drew up a treaty with Sausgamuwa, ruler of the Syrian state of Amurru, that there should be no Ahhiyawa traffic to Assyria, through ports in Amurru (Hytta was currently at war with Assyria). Since Amurru is on the coast, from the south border of the Hittite kingdom near Ugarit, down to some point south of Beirut, it was an effective way to cripple Ahhiyawa commercial and political activity because they were basically shut out of affairs in that end of the Mediterranean.

This had a rebound effect on the Hittites, because the Ahhiyawa had had a stabilising effect on the local population, and the Hittites had a similar effect on their vassal states in the west, so the general effect was a reasonable stability most of the time. When the troubles began it was possibly the Ahhiyawa that were affected first. When the crisis had worsened sufficiently, it also brought down the Hittites. So had the two cooperated, maybe the course of the collapse would have been affected, so that one or both might not have been drowned in the ensuing chaos.

As it was, the developments seem to have been increased unrest in the outer vassal states of Anatolia, termination of Ahhiyawa control in the west as well as possible unrest in some of the states along the trading routes to the south east. Many of the people in the vassal states of Anatolia were either displaced or without means to maintain their families or themselves, so their only alternative was to migrate. The Hittites had also practised the method of moving people en masse for various reasons (e.g. to solve problems of unrest in an area, they moved people to another state), so that they had to travel to return to their original homes. People were probably travelling in different directions, but the main direction on the whole seems to have been southwards (Bryce, 1998).

Another thing that is relevant for the matter of the decline of the Ahhiyawa is the draft of a letter found on one or more clay tablets, in which the king of Ahhiyawa was included, then in retrospect removed, as a Great King on par with the Hittite king. This indicates a reversal of fortunes for Ahhiyawa, for the status of Great King is not just removed because one is somewhat piqued with the blighter. Seen in conjunction with the changes at

Milawata, it seems highly possible that the Ahhiyawa was already declining at that time, and no longer could their king be considered a Great King.

2.5 The Sea Peoples

The Sea Peoples were not a homogeneous society or culture, but a loose number of various groups, including more radicalised, disparate or aggressive elements of some societies. They operated together from time to time, but at other times not. For many of these people it was a matter of fleeing or migrating from their homelands after extreme social disturbances (Voskos and Knapp, 2008:659; Bryce, 1998). These people were probably not active in metallurgical production for commercial purposes, but it is possible that they included people with a metallurgical knowledge. Their activities might have been symptomatic of the state of affairs, but they could also have been a part of the problems that put pressure on the elites' control of various cultures in the region (Muhly, 1984; Sandars, 1978; Wainwright, 1939, 1961).

There had long been various maritime raids and attacks on the coast of Egypt, Cyprus and other parts of the region. Well known are the attacks on Egypt from Libya, but other agents were also active in that respect. For some other groups there was a strategy to attack and colonise or pillage parts of the fertile Egyptian delta, as well as various polity. These people, some from Libya but possibly also from such widespread places as Anatolia, the Levant, Greece, Sardinia, Sicily and others, were in several cases known to Ramesses III as pirates with a history of making attacks on the east Mediterranean coast.

These known groups included the Peleset (the Philistines, who later settled in Palestine), Sherden, Shekelesh, Tjekker, Lukka (from south west Anatolia), the Ekwesh (also known as Akaiwasha or Ahhiyawa), Denyen (Danuna, associated with Cilicia) and others. Some of these groups later settled in various parts of the region. However, the name “Sea Peoples” is taken from the Pharaoh's description of them.

On the walls of the funerary monument to the Pharaoh Ramesses III at Medinet Habu, is depicted: *“the foreign countries made a conspiracy in their islands”,* and described the Sea People's frontal attack that had apparently devastated many of the cultures and lands they traversed on the way toward Egypt, including the Hittites and the polity of Ugarit. They had wrought havoc everywhere until they reached Egypt, where the Pharaoh stopped them. This inscription contributed also to support the theory that the Hittite Empire collapsed and was swept away in the Sea People's attacks. There was then mass migration southwards through Anatolia, the Levant and parts of Palestine as well as inland through Syria, to more southerly regions, both inland and along the coast towards Egypt (Muhly, 1984; Sandars, 1978; Wainwright, 1939, 1961).

There are 2 main sources of information on these attacks against Egypt. One was the script at Medinet Habu, but the other was the Great Harris Papyrus of Ramesses IV, son of Ramesses III. This scroll is over 1500 lines long and describes the whole of Ramesses III's reign. Both of these are written with some political acumen designed to portray the Pharaoh as a formidable personage, well able to deflect the attacks of the pirates and maintain domestic security. They may have been angled in such a way as to maximise the external threat, as well as the defence and potency of the Pharaoh. In other words the attacks may have been more coincidental, uncoordinated, limited and sporadic, with smaller groups than is portrayed in the scripts. Nevertheless it is apparent that the Pharaoh stopped the land side advances of the migrant peoples and then sank the raiders' ships, thereby securing the Egyptian domains intact (Bryce, 1998: 370).

The reliefs and inscriptions on the mortuary temple of Ramesses III at Medinet Habu are part of a long history of such monuments to Egyptian Pharaohs, where the principal part is the Pharaoh and his view is paramount. Since the venture turned out well for the Pharaoh, the number of the enemy could easily be vastly overstated, thereby showing that the Pharaoh had done his job heroically and repulsed a very threatening invader (Roberts, 2009).

But the question of the origin of these people is not satisfactorily answered in any of the sources mentioned, so from which islands did the Sea Peoples come? Here there may be a translation problem, for Bryce (1998:367, see footnote) states that there is no equivalent word in Egyptian script for “islands”. There is however, a word for “lands bordering the sea”, which might be called “sealands” or simply coastal regions, or perhaps even “littoral”. So the Sea Peoples were simply groups of people who were to be found near the sea or travelling on it. But they also included migrating populations from various parts of Anatolia whose mode of transport was probably the most frequently used mode of the period, boats, but many of whom also moved inland (Bryce, 1998: 367-368).

These groups were in part people who had been cast on hard times following the collapse of Hittite domains in central Anatolia, and Ahhiyawa domains in west Anatolia (both of which had offered security and stability). This became a movement of people seeking southwards for new lands and new opportunities. Bryce (1998) rejects the notion of barbaric northerners moving down from parts of Europe and probably Caucasus, driving people in front of them.

However, these people could certainly not have formed a military operation in any ordered manner against the remaining states in the region, especially Egypt. Bryce thinks this movement could have been combined with an opportunistic raiding and pillaging, but they could not have threatened the military power of Egypt. They could possibly have had trouble obtaining food and shelter, and thus caused problems. Other participants must have been the traditional raiders of the region, such as the Lukka (who the Pharaoh Akhenaten had complained of in the 14th century) and perhaps Libyans, making the most of their opportunity. They were also looking for places they could take control of, and they had military strength. Bryce (1998:367-373)

The “Sea Peoples” were in large part a consequence of the collapses in the states of Ahhiyawa as well as Anatolia, and the Ahhiyawa had naval power. Once the Mycenaeans lost their former hold on power, and the Great King was reduced to ordinary king near Corinth, the various islands and communities of the Greek mainland as well as those in west Anatolia would have to find new ways to maintain themselves. It's not a far cry to imagine Ahhiyawa ships taking part in operations planned by Libyans or others, against cities in the region or even Egypt, in their new and poorer circumstances.

2.6 Cyprus

Cyprus was little involved in international affairs in the eastern Mediterranean until just before the LBA. In fact the island was initially mostly isolated until the migration of people, especially from Anatolia, occurred in the prehistoric BA. By about 1700 BC the island was in the process of establishing contacts and trading with other parts of the region. Part of this activity was based on the ongoing and increasing exploitation of mineral resources around the foothills of the Troudos mountains. Copper was the most important resource that was extracted. This helped feed the demand in many parts of the region for copper, and later for bronze (Steel, 2004:149-160). In the period 14th – 13th centuries BC, the commercial and cultural affairs came under the control of elites, with one king (Steel, 2004:149:160; Manning, 1998:54; Knapp, 1996:22-23). Muhly (1989) however, states that Cyprus retained a regional structure with each region having a local ruler. This structure prevented a total economic failure in Cyprus at the end of the LBA, and Cyprus was well placed to move into the new economic structures in the early IA.

Cyprus' role in the region appears also to have been important in LBA, being a major supplier of copper, other raw materials and products of copper and bronze. Most of the exchange concerning copper was done with “ox-hide” shaped ingots (Muhly, 1977), which often weighed about 30-40 kg each. This continued after the collapse, although its own economy suffered, albeit to a lesser extent than most cultures in the region. Migrations and invasions also had an impact. Steel (2004:150-155) in discussing Cyprus states that there is evidence of population resettlement from inland to coastal regions, building of forts inland, destruction horizons, and mass burials. The inland fortifications could indicate internal unrest, since they are situated on routes across the island, indicating internal instability.

Possibly the changes in settlement patterns and destruction horizons indicate the same. It seems likely that movement of populations may have taken place, probably with some conflicts. It does seem probable that Cyprus would have been affected by events in the region, because of its position as well as any affiliations (figure 1). The situation seems to bear witness to the sort of social unrest that accompanies migration from external places, as well as internal. The relocation movements from internal settlements to coastal areas could, in LBA, also be a consequence of the booming bronze industry, with establishment of more industrial sites along the coastal region Steel (2004).

Cyprus played a central role in metallurgy in the Mediterranean, and produced and exported bronze artefacts well into the iron age. So it seems that bronze was still available in Cyprus. There are also indications of some type of "blockade" which prevented east-west trade after the LBA collapse, whereby sufficient amounts of copper and tin might have been prevented from delivery in several parts of the region Zaccagnini (1990). This is supported indirectly by Meyer (2008:58-61) who proposes that bronze age societies are very vulnerable to disturbances in their commercial region, based on his analysis of the failed Sumerian culture.

At this point it might be well to remember the ancient trade routes to Mesopotamia and its environs, from which civilisations the Hittites and Assyrian Traders acquired tin. This seems likely to have still been possible after the collapse, and even if there were maritime blockades to Cyprus' western seas. It's not far eastwards from Cyprus to the Levantine coastal ports, and caravans from there to Mesopotamia might still have been operating (McConchie, 2004:16-17). At any rate, from Waldbaum (1978:36) we see that the finds of metals from Cyprus indicate a more affluent society than many others after the collapse. Especially gold which is at constant high levels throughout the transition 1200 – 900 BC.

A further element introduced into the discussion is that the development of iron production might have become so advanced that people willingly adopted iron technology, and that there was a very rapid change from LBA to IA (Zaccagnini, 1990). There is also clear evidence that there was ample opportunity for the LBA metallurgy craftsmen to experiment at their leisure with high iron content copper, for example those who produced the copper that was on board the Cape Gelidonya shipwreck (Snodgrass, 1980:340). In Cyprus the bronze industry remained conservative until there was a strong wave of newcomers into Cyprus about 1200 BC.

At this point metallurgists started experimenting intensively with iron, culminating in a full Iron Age before the end of LCIIIB (about 1050 BC). One of several finds of LBA iron knives from excavations on Cyprus, excavated from Room 19 LCIIIB context at Enkomi by P. Dikaos, was shown to be carbonized, quench-hardened and tempered, on examination by the metallurgist E. Tholander. It had the qualities of a modern high-carbon steel. There is no evidence of similar developments anywhere else in the region until some time later (Snodgrass, 1980:341). This means that Cyprus was poised to lead the region on entry to the Iron Age. At this point, it should be said, as Doonan (1994:84) does so eloquently "*.....technology, which is seen not as an external phenomenon to society but as a total social phenomenon wholly embedded within society*".

Cyprus probably experienced a movement of people to the island in the 12th -11th centuries BC. Mycenaean immigrants to Cyprus arrived in a gradual fashion and probably continued with their trades on the island. As discussed later in this thesis, Mycenaeans were also (at least partly) otherwise known as the Ahhiyawa, and were a people with maritime traditions. This would have strengthened Cyprus in commercial ventures from the island to other parts of the Mediterranean. In short the Aegean contribution to development in Cyprus was significant in this period of about 200-300 years, before and after the transition from LBA to IA (Voskos and Knapp , 2008:678-679). This might well be a key to understanding why the Iron Age did get off to a fairly quick start. Cyprus was ready to lead on into the IA, and as said before, probably had the resources to do so.

2.7 Trade network in the eastern Mediterranean

The city of Ugarit was an important node in the traffic of the region, since it was a port for maritime trade as well as centrally placed for land based trade to Hytta, Syria and other inland destinations. Most of the inland goods transport was done by caravan. These trade routes existed between Ugarit and Egypt, Hittite Asia Minor, parts of the southern Euphrates region, Kadesh in Syria, and Babylonia . Ugarit was also forced to pay tribute to the Hittite king (Helzer, 1977:206-207; Negbi, 2005:18). The maritime routes were of course by sea, but the distance to Cyprus was short.

There is evidence of contact between Cyprus and other parts of the region. For example the similarity in town planning layout and architecture between Ugarit and Enkomi (Cyprus) in the period LC IIC, where ashlar masonry was used for similar purposes (Negbi, 2005:7). That this is so is hardly surprising since both Enkomi and Ugarit are ports, about 200 km apart, and Cyprus supplied large amounts of copper to the region. A huge amount of metal trading was through the port of Ugarit (Heltzer, 1977).

There are 2 shipwrecks of special interest in the Mediterranean. Both are near the cape at the south west part of Turkey, south of Kaş. The one at Ulu Burun went down at the end of the 14th century BC (Bass, 1986; Pulak, 1988; Bass et al, 1989; Pulak, 1998), and the one at Cape Gelidonya went down end of 13th century BC (Bass et al 1967; Muhly et al, 1977). The Ulu Burun wreck was a “rich” find with several metals including massive amounts of copper, and lead and silver. The Cape Gelidonya wreck was more a cargo of metal scrap and various metal smithing equipment, suitable for a travelling bronze smith (Sherratt, 2000:83-88). The Ulu Burun wreck correlates with LBA expansion up to 1300 BC, based on the value of the cargo, and that was a period of strong economic growth.

The ship wrecks off Cape Gelidonya and Ulu Burun demonstrate that trade was extensive (Pulak, 1998; Bass, 1986), and one of the ships was thought to have Cyprus as its last cargo port. These wrecks confirm such maritime traffic at least in the last phase of LBA, but the possibility must also have been present in the earlier LBA. In addition, the Ulu Burun shipwreck was a trader of the times and carried organic cargoes for off-loading in other ports or their hinterlands (Haldane, 1993). This supports the view that ships such as that at Ulu Burun were normal modes of transport in the eastern Mediterranean, between Egypt, the Levant, Anatolia as well as more westerly destinations.

The wreck at Cape Gelidonya

The ship was a 9-10 metres long merchant vessel, sailing toward Cape Gelidonya from its last port of call in Cyprus, and had a large cargo embarked. The ship was likely to have been hired or owned by a metal smith (there was only one personal seal on board), and had ingots of copper (ox-hide), tin and bronze, as well as scrap metals, various stones used in metallurgy as anvils, a weight system for commercial use etc. and diverse other objects typically used in metallurgic operations. The ship probably sank about 1200 BC in about 30 metres of water. It is believed that the merchant was Syrian and the ship sailed originally from a Syro-Palestinian port. Pictures of the ingots show that they all are slightly dissimilar in shape, showing that they were not part of any “industrialised” technological production process, but produced in the standard fashion and each looked distinct (Bass et al, 1967).

However, Muhly et al (1977) dispute the home port of the ship, and the port of lading of the ingots, posing that it is not possible to ascertain these details from the contents of the wreck. But one interesting position by Muhly et al is that some of the Bronze Age trade must have been in the hands of private entrepreneurs. This strengthens the line of reasoning that the elites did not control the entire trading system in about 1200 BC. Looking at the details of the ingots, Muhly et al point out that some ingots distributed by centralised organisations could have been sold to private commercial agents for shipping and sale internationally at some time probably before 1200 BC.

The wreck at Ulu Burun

This ship carried a rich cargo and was seemingly plying the same route as the Cape Gelidonya wreck. The waters in this area must be treacherous, because there are reports of oh-hide ingots either being recovered, or identified by sponge divers, who can descend to fairly deep coastal water (Bass, 1986). This wreck differs from the Cape Gelidonya wreck in a number of ways, especially in the composition of the cargo. The artefacts present on the Gelidonya were indicative of an entrepreneur metal-smith, plying ports along the coast and looking for goods and markets, whereas the cargo on the Ulu Burun carried major resources and also luxury items. This shipment may well be direct evidence for international elite gift exchange. The types included copper ox-hide ingots and tin in the same form (Pulak, 1988).

Pottery of Syrian, Mycenaean, Cypriot and Canaanite types were included in the cargo, and indicate that trade between the various parts of the eastern Mediterranean was extensive. The cargo also included bronze tools and weapons, weights, gold and silver jewellery, a gold ring inscribed with Egyptian hieroglyphs and much more (Pulak, 1988). There was also a gold scarab of Nefertiti, who may have been co-regent in Egypt in the reign of Akhenaten. This is a most important find, of Egyptian origin, ever made in the eastern Mediterranean. There was also more of the luxury items of gold previously mentioned as well as tools, and more seals (Bass et al, 1989). This wreck had an extraordinarily rich cargo.

The Ulu Burun ship contained 354 ox-hide ingots (often with a weight of about 30-40 kg). In addition, there were about 130 other ingots, about 150 Canaanite jars with wine, at about 25 litres each (Pulak, 1998). This cargo could in total could have been in excess of about 30 tons, and a 10 meter sailing vessel (beam to length ratio 1:3). This seems to be quite heavy, almost unmanageable. So it could be that the risks are high, but the chances of extra earnings are also high, by taking on extra cargo. Perhaps the chances of earning really big amounts were enough to encourage some captains to go in for private commercialism in goods transport by ship in the LBA. Apparently, this did not always go well.

2.8 Summary – cultures and societies

The foregoing sections have treated the societies in the eastern Mediterranean in LBA, up to the PRC. This is necessary because the development of iron at that time was very dependant on social conditions and changes in them, as well as developments in metallurgy. It is clear that Anatolia, especially the Hittite Realm, was the centre of iron technological development at its earliest time in the eastern Mediterranean region. The societies in Anatolia had good connections with Mesopotamia, Babylon and neighbouring parts, and possibly gained their knowledge of iron metallurgy from those regions. Even if this was not the case, their own insight was probably enforced by comparison with developments there.

The Hittites were also the first society to succumb to the PRC. The Hittites' ruling dynasty were from one family, and there was considerable trouble within that family. There were several occasions when that ruling dynasty looked as though it could fall, because of internal disagreement. That it did fall in the end should be no surprise, but that it should have vanished completely practically overnight is somewhat surprising. There is no information to be gleaned on the last days of the Hittite Realm, even though the Neo Hittite kingdom in Carchemish claimed to be descended from the Hittite realm, with direct line of descent from the Hittite Great King. Even if they knew what had happened, they certainly weren't telling (Bryce, 2012: 9-32; 1998). Neither did they make a significant profile in the sphere of iron technology and development. So where did this insight go? Who, after the fall of the Hittite dynasty, possessed the necessary knowledge of the extraction and production of from ores?

For Cyprus there was a slow start to their activities, being isolated until ~1800 BC, and then slowly supplying more and more copper (for making bronze) and getting into a position of almost impervious stability. It is possible that the powerful societies around might have preferred a neutral Cyprus, since it was such an important provider to all. Or maybe the Hittites who were the nearest, powerful, and likely to think themselves feudal masters of Cyprus, deterred potential invaders from trying to conquer it. The Hittites had no navy, and Cyprus is pretty big, so that it wouldn't be worth the effort for them to rule it themselves. With regard to iron, any other development politically on Cyprus might well have delayed the IA by a very long time.

The other societies, the Ahhiyawa and the mixed group the “Sea Peoples” all contributed to the developments of iron at that period, contributing knowledge, cultures, communication, colonies and political change, all necessary for the development of iron technology..

3 Aspects of metallurgy and production in parts of the region

Metallurgy is the use of knowledge, experience and practice for mining, processing and forming metals. It is also the creative process of shaping metal objects into tools or other objects that can be effectively used by humans, and which make their traditional work easier and more effective, in relation to wood and stone based tools. In addition, new tools can probably make possible new methods of doing work, including tasks not previously undertaken. The transition from LBA to early IA happened in the project's focus period, and metallurgy is a major interest to this project. The transition process was an effect of the increase in use of iron in relation to bronze, until iron reached the third stage described by Snodgrass in section 1.3. So in this section metallurgy will be discusses with emphasis on the processes involved, both for copper and iron. The alloying of copper and tin to produce bronze is also mentioned.

For the Aegean, metallurgy is not present in the archaeological record before ca. 5500 BC. But there was some connection with the Balkans, which demonstrates a wide spread of early metallurgy (Muhly, 2006:156-160). Muhly also states that developments in the Balkans was on a larger scale and some centuries earlier than similar developments in the Aegean. In Crete, there was a later start to metallurgy. Finds there were from in the area from Mesara and Phaistos in the west to Palaikastro in the east. This is more than half the area of Crete, and included settlements in the Final Neolithic, ca. 4500 to 3500 BC (Muhly, 2006: 155-156).

3.1 Production of copper and bronze

Bronze is an alloy made principally of copper and tin (although other types were also used by the ancients, e.g. arsenic bronze). Ancient artefacts often contain amounts of other constituents also, all of which can affect the qualities of the bronze. This metal alloy was important for human development. It was used by the ancients for making tools, armaments, equipment of all sorts and jewellery (Waldbaum, 1978).

Production of bronze is in principle a fairly simple process to understand, but it does require a high level of organisation to keep the production system as a whole continuously operational, and especially with maintenance of the market. See for example the Amarna letters (Moran, 1992), which also refer to Egypt's acquisition of bronze (Knapp et al, 1994:427, among others). It is also probable that it required a long period of development, since the process involves one or more chemical reactions , a pyrotechnical proficiency, a very large and consistent supply of energy and significant competency in mining metal ores (Tylecote, 1980). It could hardly be seen as an intuitive development process. Given that people did in fact produce a reasonably consistent production of fairly good to high quality bronze alloy, after perhaps hundreds of years of development, and continued to do so, means that they were metallurgically competent. They were probably also familiar with development aspects, using alternative production methods and learning how to adapt methods from the resulting products.

To investigate the metallurgical processes involved in producing iron, we have to start by looking at the forgoing metallurgical practices and traditions in bronze production, because they were the precursors. After the copper ores have been mined and the wood has been converted to charcoal, the ores have to be crushed to a suitable size for the furnace. The furnace (figure 2) was purpose-built, of stones and/or clay, and is equipped with an air supply by manual pumping of air through some form of bellows. The air is led straight to the heart of the furnace through one or more *tuyères* which are attached to the bellows with a hose or pipe. The combination of ores, pumped air and charcoal yielding temperatures over 1200 degrees C (energy) leads to reduction of the ores and the formation of relatively high grade copper in the furnace, which then moves down by gravity to the furnace bottom. The slag, a non-usable bi-product of the reaction, also forms at a higher point and moves down, but "floats" on top of the liquid copper, which has a melting point of 1083 degrees C (Hough, 1916)). There are tapping holes at the suitable levels to drain off slag and copper as separate products (Tylecote, 1980).

The reactions which take place in these conditions vary somewhat. The central principle is the reduction of ores containing a high percentage of copper (but also other substances, some including iron) to copper of greater purity and other products. This is expressed very generally by: $CuO + CO \rightarrow Cu + CO_2$, but is much more complex (see later in text). As said already, other substances such as silica are present, and these run off as slag (and other gases in addition to CO_2). These other substances vary with the method selected for producing the copper. Some substances are part of the ore itself, but others were in fact added as "fluxes", to aid in the copper extraction process. It is also probable that the metallurgists of the ancient world often smelted the copper in 2 or more "runs". This would have depended on factors such as available ores and fuels, human and natural resources and locality dependant characteristics (Charles, 1980; Tylecote, 1980; Doonan 1994).

Some of the processes (e.g. roasting plus smelting) require a minimum of 2 separate operations. Some produced heavy sulphuric fumes, and would have been significantly polluting. This could have been best to have done near the mine, and not near the settlement. Transportation was also a factor, requiring a train of donkeys or asses to move the product to the "end user", the harbour for shipping, or the next processing. It might also have been advantageous to do the first smelt near the mine, to reduce the amount of material that needed to be transported to the final processing plant, i.e. leave the slag on site. The product could have been a partially processed low grade copper, a high grade copper, a bronze ingot or a final product, e.g. bronze tools, armaments, equipment or jewellery.

Pre-processing of ores is also an important step in effective use of resources. From the viewpoint of the BA metallurgist, and taking account of the methods and choices they had then, the procedure is as follows. The ore which has been mined goes firstly through a process of beneficiation. There are several choices in this process, and it leads to a more effective smelt in later stages. The ore is first crushed, then ore-rich nodules selected and gangue discarded (saving time and energy later). This is a manual task, making use of colour and density. Other methods, such as winnowing (throwing upwards and into the wind), panning and sluicing with water can also have been used. The total mass of extracted, mined material can be reduced while higher grade ore can be retained (Doonan, 1994:85-87).

The next step is crushing lumps of chalcopyrite. The best method is using a “pebble hammer”, or a normal stone pebble from e.g. a pebble beach. This in hand, the ore is placed on a large stone, on the ground, and crushed with blows from the hand held pebble. This is a better method than the use of a lump hammer because of lower impact velocity and larger surface for striking the ore. In trial, this process produced more crushed ore per unit time than use of a lump hammer.

After crushing, the sulphidic copper ore can be roasted. There are a number of ways to do this and there are many equations to suit them. In the main, there is a dead roast or a partial roast. A dead roast means that all sulphur is driven off and a partial roast means that some sulphur is driven off. An example of each chemical equation is shown below (more reactions and equations exist). Note that the partial roast does not remove all sulphur:

$\mathbf{4CuFeS_2 + 13O_2 \rightarrow 4CuO + 2Fe_2O_3 + 8SO_2}$ Dead roast

$\mathbf{4CuFeS_2 + 7O_2 \rightarrow 4CuS + 2Fe_2O_3 + 4SO_2}$ Partial roast (remaining copper sulphide)

From the above equations, we can see that there is parity in numbers of copper and iron atoms. The copper melts first, and forms a matte, which needs a secondary processing to obtain pure copper. In general partial roasts seem to have been slightly more popular. The roasting can be done by arranging baulks of wood in a pit, under and between the copper ore, and then the wood is fired. Once the wood has burnt out, the ore is collected. The process generates a lot of greasy smoke and sulphurous gasses, so that the area around the site is affected (Doonan, 1994:88-96) This would have been an environmental factor in BA.

It is clear from Doonan's experiments that there is considerable expertise involved in choice of materials, wood stacking and management, and a host of other considerations. Nevertheless, this gives a realistic impression of what the BA metallurgists were doing to produce copper (Doonan, 1994).

The industrial pollution component of the entire project must have had considerable impact on the area. Clearing forests, burning wood for charcoal, smelting, roasting and co-smelting producing in all probability vast quantities of smoke and pollution. It brings to mind descriptions of the “dark satanic mills” first mentioned in poems by William Blake (1808), later put to music by Sir Hubert Parry (1916), which did conceptually depict grimmer times and heavy pollution in early industrial England.

3.2 The structure and function of BA Furnaces

As part of this project the author took part in an experimental smelting of copper, under the auspices of the Archaeological Research Unit of the University of Cyprus in Nicosia. The experimental work was done at the mine of Skouriotissa, Cyprus. This experiment was to explore just one smelting process for copper. There was no co-smelting or roasting, just the central process of extracting copper in an open furnace of the simplest type, and a slightly bigger one. This was extremely useful, because it effectively showed to the participants that this was a simple process that could quite believably have been used by the ancients.

The general procedure is as follows: The ore is crushed manually and placed in the clay “heat resistant” crucible. The crucible is placed in the open furnace, and charcoal heaped over it. The charcoal is then ignited, and the bellows are pumped assiduously. This can be exhausting work, so the “bellowers” change over as necessary.

Once the temperature rises to near 1200 C the copper smelts and trickles down into the crucible, along with the slag. The slag floats on top of the copper in the crucible, and is a bi-product not collected under normal circumstances. In theory the copper then is collected from the crucible and can go on to the next stage of the process, re-smelting or whatever is necessary. There are 2 basic types of furnace, the bowl (open) furnace (figure 2) and the shaft furnace (figure 3).

The practical problems seen during the experiment were:

1. There must be enough ore and it should be crushed (as described above). It's not necessary to produce a fine powder to get a result, but that's more effective.
2. Reaching the required temperature of about 1200 C should be done rapidly. This requires assiduous bellowing, and not least, enough charcoal. Better results are obtained with several sets of bellows. For this experiment, less than 50 % success might possibly have been a result of less than optimum bellowing (usually 2 bellows and only 1 bellower, or person operating them).
3. The emphasis should be on covering the crucible amply with charcoal, and then some. Having to add charcoal can cause delays and cooling, which causes problems. In addition, part of the chemical reaction is the addition of carbon, so there should be only charcoal, lots of it, and heaped in contact with the ore!
4. The “heat resistant” crucible (figure 4) melts at a temperature slightly above that of copper. The distribution of heat in such open furnaces is affected by wind, bellowing, and other events caused by the operators and weather. In some circumstances the crucible can melt, and the smelted copper (matte) “sinks into” the mass of the crucible and slag lies on top, and appears to mix somewhat with the upper half of the crucible.

One of the important things that early metallurgists became aware of was the procedure of “fluxing”, whereby other metal ores could be added to the smelt in order to extract more copper than would otherwise be possible, and sometimes faster (using less fuel).

3.3 Other types of furnace

We know that early cultures made ceramic artefacts by firing clay. These must have been fired in early furnaces, which are unsuitable for smelting of metals. Some reasons could have been a lack of reductive charcoal in contact with the ore in such furnaces, and the problem with furnaces that were big enough to fire ceramics, of achieving high enough temperatures to smelt metals. As seen in the previous section, a reducing furnace for some metals is at its simplest, quite small, in need of heavy blowing (bellowing), although easy to build (even if you have to destroy it after each use). Chalcolithic period furnaces could tackle the complexity of producing copper from various substrates containing iron, lead, arsenic and a multitude of other elements as well as copper (Tylecote, 1980:183-188). A point to note here is that metallurgists from even the earliest times must have been accustomed to dealing with complexes of iron, among others.

The majority of known LBA furnaces were found in places in Israel, possibly because research projects have been more frequent and investigative there. These can be described as embedded in the ground, with a sloping slag pit and mortared or cemented sides. The slag weighed about 30 kg and the ingots calculated to be about 2-4 kg. The bottom of the furnace was formed as a small pit, or bowl, and when the process was at the right stage, the slag was tapped off, leaving the copper in the bottom pit. This process, however, does not lead to the best known ingot of LBA, which are the so-called ox-hide ingots. These are named for their shape, reminiscent of the hides of oxen (Tylecote, 1980:190-192). Such ingots as these have been found in ship wrecks such as that at Ulu Burun (Pulak, 1988), in some Egyptian tombs (as images painted in scenes), and in some excavation sites.

Ox-hide ingots weigh a good deal more, and probably need 4 furnaces producing (or most probably re-smelting) copper at the same time. They often weigh a little more than 30 kg, so each furnace would have to produce at least twice as much as described above. This would be difficult, according to Tylecote (1980), without a substantial improvement in furnace construction. Furnaces became a little more developed later in LBA . Ox-hide ingots were traded widely in the eastern Mediterranean, and images of them have been found in Egyptian tombs ca 1450 BC (Tylecote, 1980:194). These ingots can probably be made by using some smaller ingots in a secondary remelting operation. It is possible that many ox-hide ingots were cast this way.

The normal design for an LBA <u>ingot type</u> furnace is a furnace wall, either circular or rectangular in plan, and made of clay or brick. It is sunk into the ground far enough for the surface of the slag (which floats on the smelted metal) to be slightly below ground level. The *tuyeres* (air tubes for blowing air into the charcoal in the furnace) go through the wall just above ground level. The bellows are not part of the furnace, but are also required. Under the clay/brick furnace wall there is a clay foundation with an inner rounded bottom (a bowl, not quite hemispheric in section) to collect the metal. There are 2 tap holes, the high one in the lower wall (for slag) and low one in the foundation bottom (for copper). The upper tap hole leads to the slag pit and the lower to the mould in the casting pit (from the diagram in Tylecote, 1980:195). In building a furnace to this design the intention is probably to use it more than once.

The brazier type furnace is somewhat similar to the ingot type, but does not tap slag or metal, because it doesn't smelt the ore. These were probably used to melt scraps of metal and pour them into a mould. There are no *tuyeres*, and the temperature probably didn't go far over temperatures of 950 C, which is sufficient to melt bronze. The furnace stands on the ground with openings under and through the walls so air can be drawn into the furnace, through a grating of clay, and up through the charcoal or wood. The metal is in the crucible, where it is melted. A hole in the wall is used to access the crucible. This type of furnace is probably reusable. Only the crucibles are at risk in normal circumstances. The earliest example of this type is from Abu Matar near Beersheba, 3300 – 3000 BC, (Tylecote, 1980:197).

4 Iron: what is it and what potential had it in the ancient world?

Iron is a metal, and an abundant element in the Universe, as well as on Earth. The earliest iron artefacts (from the 4th millennia BC) were very often of meteoric origin (i.e. matter from the collision of a meteor with the Earth), highly regarded, and more commonly associated with sovereignty and power. One example of how this aspect has survived to modern times is a gift by a foreign emissary to Queen Elizabeth II of England, of a sword of meteoric iron.

4.1 The Entrance of Iron

Meteoric iron is in principle found where meteorites that survive the passage through the atmosphere have struck down on the earth's surface. The main characteristic of meteoric iron is its content of nickel. We know that meteoric iron contains more nickel than does terrestrial iron, and that makes the iron a better quality (Waldbaum, 1980).

The scarcity of meteoric iron and sometimes its superior qualities would have made it more attractive as a "collector's item". This state of affairs was probably continued until bronze smelting craftsmen recognised the presence of terrestrial iron in their ores, slags and matte, and began to experiment with that metal for further processing. Their most immediate problem would have been to process the metal complex to a more pure state (van der Merwe & Avery, 1982). This was not done early, but their achievements in some cases later on were exceptional, and the quality of their iron close to that of modern times. Iron technology was improved in the LBA but production of really high grade iron (steel) had to wait until much later (Wheeler and Maddin, 1980).

The discovery of iron was the inevitable end product of technological development in BA. That there were developments in pyrotechnology throughout thousands of years, developments in construction of metallurgic furnaces and exclusive use of charcoal in contact with metals, and of course the penetration of previously unused zones of gossan in search for new metallurgical ores, all led the ancients to a final discovery of iron's potential. Just as impressive is the revelation that it about 4,000 BP there was a centre in northern Anatolia of culture, metals and trade that introduced the concepts of banking and credit and their practice (Wertime & Muhly, 1980:xiii-xv; Bryce, 1998:26-29).

There was a connection between cultural development and development of iron technology. Some cultures, e.g. the New World, chose not to pursue that path, but e.g. Asia and the Near East chose did do so (Wertime & Muhly, 1980:xv-xix). It is from this work also evident that iron's technological development was linked to the work done with production of terracotta, glass and cement. This was also done in BA (Wertime & Muhly, 1980:1-11).

4.2 Early iron finds

4000 BC: Various small objects and utensils for daily use were found in grave contexts from 4000 BC, in Egypt. Some examples are iron beads, a plate, picks and a dagger, all from Egypt and dated about 4000, 2800 and 2200 BC respectively(Richardson, 1934:555). But there do not seem to be very many other artefacts of iron from this early period. Could there have been more, that have since simply rusted away? It is however, thought that terrestrial (not meteoric) iron was being worked in Anatolia in the early bronze age (Waldbaum, 1978;20).

The Assyrian Colonies in Anatolia were established and active early in the second millennium BC (Bryce, 1998:21). Iron was known at that time and was regarded as a precious metal. It was known in Anatolia in Sumerian text as **KU.AN** about 2000-1500 BC, and as **AN.BAR** about 1500-1000 BC. In Hittite texts it seems that only **AN.BAR** is used throughout the Hittite Kingdom's existence. **KU.AN** was traded in Anatolia at more than 8 parts gold to 1 part iron (Maxwell-Hyslop, 1972). Iron was used in this period in many parts of the region at this time. For example in Mesopotamia (Muhly et al, 1985:68) and in Anatolia (Yalçın, 1999).

An other text source mentions iron, stating that there existed 400 iron *šukur* weapons (maybe spearheads) in the 18th century BC, in Hatay (Yalçın, 1999:182). He also states that iron at this time was an extremely valuable material, most commonly associated with sovereignty and power. Since his source in this case was a text, and it didn't give the origin of iron material, we can't know whether it was meteoric iron or not, because we don't have the artefacts. The obvious advantage of meteoric iron is that it can be simpler to produce objects from it, since part of the work with smelting and smithing is unnecessary (Wadsworth, 1883).

In a recent excavation at Kaman-Kalehöyük by Japanese researchers, the finds included pieces of iron slag, as well as copper sulphide ores. There is reason to believe that copper was produced using a copper-iron sulphide mix there. This was dated to the Assyrian Colony Period (Akanuma, 2008:a). From the same excavation a sample was collected from Stratum IVa, which was, or had been, part of an object of steeled iron. Its carbon content was thought to be 0.1 – 0.3 % of mass. The general conclusion, based on the observations on site, was that the production of steel had begun there in the 3rd millennium BC. The general conclusions of this project put forward the hypothesis that there had been connections between the proto- Hittites and the Assyrians (or other people) from the Mesopotamian region, which had led to the development of iron (and steel) in central Anatolia at that time (Akanuma, 2008:b).

1400 BC: An important artefact in this respect is the Ugarit battle axe; from about 1450-1350 BC, with a nickel content of 3.25 % and a carbon content of 0.41 %, which puts it in the range of mild steel (Waldbaum, 1978;17). There is some discussion as to whether the axe is of meteoric iron, but the point is made that the piece was forged. No further conclusions are given, and it seems that this particular discussion on meteoric origin was not decided. This artefact shows that the knowledge of methods to produce steeled iron may have existed prior to 1200 BC.

In Anatolia, copper and tin were not easy to acquire, bronze was considered a luxury material, but iron ore deposits were readily available and items of everyday use were worked in iron. There was development of iron technology in early 2nd millennium BC and the Hittites used iron weapons at the battle of Kadesh in 1285 BC (Muhly et al, 1985:68). Mention is also made there that in Ugarit iron was considered a precious metal, worth much more than copper and twice as much as silver.

1200 BC: Presumably there was a continuous development in those parts and those times. The intentional extraction of iron took place in the Hittite domains north of Assyria in 13th. century BC (Pleiner and Bjorkman, 1974:307-308).

In the 12th century BC further evidence of iron technology is the find of a primitive iron smelting installation in Israel (lower Galilee) dated to the 12th century BC (Liebowitz and Folk, 1984:264). Thus had iron as a metal grown from the scarce (and therefore precious) little known metal arriving on the earth

4.3 Number and types of artefacts found in the region

From about 1400 BC complex societies of the eastern Mediterranean began to disappear, while for the same period, objects of iron appear more frequently in the archaeological record (figure 5). Nevertheless, the amount of iron finds is not as extensive as one would like, and certainly not as extensive as comparable finds of bronze. This makes all quantitative research on iron technological development more difficult (McConchie, 2004:12; Waldbaum, 1978).

The amount of iron artefacts does not reflect the popularity of iron at that time. Iron is much more likely to corrode and generally deteriorate than other metals that were used then (Waldbaum, 1978:57-Fig. Iv.l4 .) Iron which endures soil or moisture will rapidly revert to a substance quite similar to iron ore. It will rapidly decompose until it looks like a useless unformed piece of ore. Then the way is short to the scrap heap when excavated in later times, such as 13th century Timna, where more than 700 iron fragments were excavated, but only 7-8 were published afterwards (McConchie, 2004:13).

The importance of whether iron is found in burial contexts or some other environment is pivotal. Burial contexts have often conditions with less moisture and stable air circulation, such that iron objects deposited there have a better chance of retaining their condition for some time. Other factors which might affect the quantitative analysis of iron in archaeological projects are the geographic coverage of excavations. If excavations are being conducted somewhere other than Anatolia (e.g. Cyprus) then the results will not necessarily reflect what otherwise might have been deposited in Anatolia (McConchie 2004; Sandars, 1978:177).

Archaeological reporting might also be flawed for objects which are not easily identifiable or perceived as not suitable for publication. There is very often a bias in perception of ancient iron's utilitarian value. The basis for this has been a view of the technological superiority of hardened and tempered steel over bronze. This also encompasses the view that iron would never have surpassed bronze in popularity unless it was in fact harder than bronze. From this basis it has often been presumed that the popularity of iron increased from the time it was possible to produce iron (or steel) that was harder than bronze. However, this has not been proven by the vast majority of iron objects recovered from that period. In fact, the opposite, or at least divergent situation may be the case (McConchie, 2004:13-21; Muhly et al, 1985:82; Waldbaum, 1978).

Recognition of iron in excavation projects can follow this rough layout (McConchie, 2004:89-90):

1. A magnet is used to see if the object responds. This is important to exclude other types of metal, or stone, that look similar to iron in one of its many guises.
2. Objects are then tested to see if it has a realistic build up of corrosion. This can be aimed at accretion, robustness and density loss.
3. Statistics of the iron finds, i.e. find-location, dimensions and shape.
4. X-ray analysis of samples to determine internal structure.

It is clear that in many excavation projects only the first 3 stages are likely. So that the necessary observation skills of the excavators are a key factor.

4.4 The problems involved in iron development and production

This section is couched in a terminology and understanding based on a modern industrialised viewpoint. The reason for this is that this aspect is discussed elsewhere in this thesis, and it is as well to lay out the basics and possibilities here, as we know them today.

From its very beginning, iron was a more difficult material to work, because it did not melt (i.e. did not transform into liquid phase) at the temperatures used to to melt other metals that were worked in LBA. Only when blast furnaces were introduced in more modern times was iron's temperature raised to a melting point in excess of 1,540 C. Iron could be cast in moulds from then on (although that alone was not sufficient to produce quality steel).

It seems clear that the interest in iron technology was increasing, but it was a difficult issue. In northern Anatolia there were iron ores which were easily available and gave a good result. Their availability enabled the pre-Hittite people there to make a start on iron technology quite early. However, it was Cyprus, which is much less fortunately endowed with such ores, and possibly didn't even start on iron seriously until after LCIII-A, that "got there first". It was also characteristic for the time and region that some people evidently made better quality iron than others, and it wasn't always clear why this was so. It may even have been a closely kept secret in some places.

What is clear is that accidental discovery of the ways to smelt iron, for example in a camp fire, are highly improbable. Iron only melts at temperatures significantly higher than the slag, as well as copper. The main potential of iron had to be revealed through controlled pyrotechnical research and development, and this requires expertise and experience with pyrotechnics as well as insight into metallurgy. One can say that the working of iron was an inevitable technical by-product of copper and lead smelting, in a "development environment" (Wertime and Muhly, 1980:1-16). It might be useful to point out here that this occurred only after the onset of IA (see discussion later).

Somewhat simplified, it can be said that when placed in a standard (but effective), very hot furnace of the period, which at best has a maximum possible temperature below about 1400C, iron ore would not become molten, but it would be "spongy". If taken out and hammered at that point, it would be possible to form the iron. If the iron was then placed in a suitable furnace, with plenty of charcoal, and kept there for a while, the iron would absorb carbon from the burning charcoal. Thus the iron became “carbonized”, (in other words it would be “alloyed”) and moved into a state of “steeliness”, becoming harder. In that state it was well on the way to becoming a harder material for weapons than bronze. This process had to repeated several times, the iron was hammered, and sometimes folded. The process, carried out repeatedly, introduced larger surfaces to the charcoal and uptake of carbon, and strengthened the product (van der Merwe & Avery, 1982). However, if kept in the furnace too long it might take up too much carbon and then become so-called “cast-iron”, which is brittle. It would simply break under hammering.

The hammering was necessary for iron (but not copper or bronze), so that the impurities contained might be removed. The iron does not melt, so the impurities from the ore and slag etc. remain in the metal. However, even though the iron doesn’t melt, the impurities do, so they are in liquid phase at the time the iron is hammered. An experienced artisan would have developed a procedure to hammer the iron in a certain pattern, somewhat like a laundry roller, to “squeeze” out impurities. This is not at a molecular level, but the pockets of impurities are very small and well distributed, so a thorough hammering is desirable and expedient. And this needs to be done each time the object comes out of the furnace.

After the carbonization step, which might well include many hours of heating and hammering, the iron object could be “quenched”. This involves an extremely rapid cooling, which tempers the steel so that the final object is hard and resilient. There are a number of pitfalls in the entire process, but in principle, a metallurgist would methodically examine the failures and learn how to avoid them, once the general principles as set out above had been learnt. This process is a further and necessary technical development of metallurgy, after development for the copper smelting process. Neither was it intuitive because carbonization and quenching does not harden bronze or copper, so a transfer of technology directly from copper to iron could not have happened. Therefore it would have required time and resources, as well as the interest and experience as a metallurgist working copper and iron ores to become fully aware of their qualities and to do the development work involved. It did also require a lot of heavy manual work, hammering the iron and maintaining the furnaces (van der Merwe & Avery, 1982).

Until recently, research into iron in Anatolia has mainly been oriented toward technological matters, rather than the symbiosis between society and technology, specifically iron. This lacks the aspect of focus on the integration of technology and society, and has not been entirely successful. The aim of combination of analysis of technological and social and cultural combined in new interpretations has not been accomplished (Sandars, 1978:177).

Research has not managed to prove that the expectation of the innovation of hardening iron was the threshold (or gateway) to the rising popularity of iron in LBA and early IA. Rather the opposite, for most artefacts of iron either are not hardened, or are not uniformly hardened, indicating other that factors may have caused hardening of the object (possibly inadvertently). In the same period, iron's popularity rose considerably, indicating that uniform hardening of iron was not a requirement. At least, not for the majority of iron objects that were made in this period (McConchie, 2004:14-15).

However, simply assessing the amount of iron that was used, in numbers and types of objects, raises difficulties. There does not seem to be enough from that period. The amounts of iron objects recovered should be regarded as indicators of the types of objects produced, not as quantitative measure of the number produced. In addition, where iron production is small scale, then the total production is also likely to be small and deposition small (McConchie, 2004: 12-21).

In conclusion, for iron being made to steel, it seems possible from the literature that it was possible for smiths of the time to make steel. However, there is some reason to believe that few, if any, metallurgists of that time were inclined to produce steeled iron. There is not an abundance of steel artefacts to be found, so that the process to produce steel must be seen as possible, with access to the right materials, conditions and resources, but either certainly not easy, or not desirable, or both.

4.5 The Hittites and iron working in Northern Syria

The Hittite kingdom and other areas in Northern Syria were active in iron production and development at an early stage. The Iron Age is generally thought to have started in the last quarter of the the third millennium BC ((Yalçın, 1999:177). Iron was used in that same region before the Hittite realm existed, although the method of production remains unclear (Yalçın, 1999; Akanuma, 2008:a, 2008:b). This is supported by some finds from this area and time, but they are few (Waldbaum, 1980). Some of the objects could have been made using meteoric iron, although tests on a gold-handled iron dagger show low Nickel values. Nickel values of about 6 % or more, are indicative of meteoric iron (Yalçın , 1999:180).

However, there is some doubt. For analysis results to be of maximum possible reliability, samples must be taken from parts of the object in question where there is no doubt of the metal's intrinsic stability over time and environment. This preferably from central, unused or unexposed locations. The samples in the case of this one artefact (a knife) were taken from the end part, where there was advanced corrosion. So the results are possibly flawed. Clearly, the desire to avoid damaging the artefacts unduly can be a costly aspect, as far as certainty and reliability of results are concerned.

In addition, Yalçın (1999:180) mentions that the nickel content for samples here was incorrectly reported in Waldbaum (1980), where they were given a higher value. This means that previous conclusions that they were meteoric iron are probably wrong. The point is, that previously there was little belief that terrestrial iron was used this early in this area. So the possibility of the artefacts being of terrestrial iron is an interesting development.

Other evidence for iron smelting in the 14th century BC does exist. This is based on finds of several iron axes, where at least one of these is carbonized. There were several pieces of slag from iron smelting and there were also iron nails, some pieces of iron and an iron arrow head. These were from contexts in Boğazköy , Anatolia, from the period 1450 – 1200 BC. These items are evidence that there was iron smelting in this area in the 14th century (Yalçın , 1999:182).

Textual evidence of the use and value of iron from the beginning of the 2nd millenium BC also exists. Iron was traded at Kültepe at a rate of 1 šekel of iron per 8+ šekel of gold (ie 1:8+), and 1:40 for silver. Iron was also a controlled material in trading, and was very valuable, symbolising monarchy and power. One document indicates that iron was beginning to be used in weapons from the 18th century. A text from that time also tells of many hundreds of iron weapons or weapon parts (Yalçın , 1999:182-185).

To sum up, it can be said that iron production started in Anatolia before the 2nd. millenium BC. There are at least a dozen finds, of which most were objects with a ceremonial or other prestigious role (Larsen, :55-56). Written texts mentioning iron appear in the 2nd. millennium and objects of iron are greater in number. The continuous production of iron starts at the end of the 2nd millenium. After this, iron starts to dominate in some regions, replacing copper and bronze (Yalçın, 1999:185).

4.6 Regional iron working

Iron was worked in various places in the region, and bronze artefacts often contain iron and some were ferromagnetic. In addition, metallurgical examination of ancient bronze objects frequently shows an iron content under 1 % but much higher contents of 10-20 % are also found (Strathmore and Aschenbrenner, 1975). It seems improbable that these latter could be merely "contaminated" with iron. In some processes sulphide ores are used and these contain more iron, which is precipitated into the copper in the furnace. This shows that metallurgists probably had to deal with iron itself, or its intrusion into their copper, at a time well before 1200 BC.

Waldbaum (1978) in her thesis on iron in BA talks of the distribution of iron then based on the finds of iron artefacts. These can be divided here into 3 groups for simplicity: low number of artefacts (Palestine, Syria and Cyprus) medium number (Greece) and higher number (Anatolia and Egypt). However, the total number artefacts was only 108 when Waldbaum summarised them. She also states that the artefacts' forms are indigenous to their regions of production, specifically, not to one central place (Waldbaum, 1978:23). However, their number seems to be few in relation to bronze, even though there are several authors who state that iron smelting began early. For example, Wertime (1973:875) states that the first use of iron in Anatolia (pre-Hittites and Hittites) as well as Mesopotamia occurred in the late third and early second millennium B.C. This is also stated by Yalçın (1999:180). However, he also raises a matter which clouds the issue on early iron finds. Use of meteoric iron yields a superior iron product than use of iron from other sources (Yalçın, 1999). Meteoric iron lies on the Earth's surface and seems to have been distributed unevenly geographically, being more plentiful in some regions. One should also bear in mind that we do not know if or what selection criteria might have been adhered to while collecting it.

The importance or influence of iron technology on the LBA collapse is a relevant issue. As seen above, iron technology did exist at that time, and the artefacts demonstrate this. However, the significance of iron objects originating after 1200 BC (but before 900 BC) must be demonstrated by comparison with iron objects from before 1200 BC Waldbaum (1978;17).

4.7 Numbers of iron artefacts in the eastern Mediterranean

The following depends very much on the work by Waldbaum (1978), where she presents a publication (based on her PhD thesis) about the transition from bronze to iron in this area.

She presents a lot of data which I have tried to present in a different way, in the light of more recent work, excavations and articles on the same theme. There were finds of more than 108 iron artefacts from the Eastern Mediterranean before 1200 BC, whereof 15 weapons, 31 tools, 33+ jewellery, and 29 were miscellaneous. These numbers constitute too small a selection to support a sound statistical analysis,, and they are probably not representative for the total number of iron objects in use at the time, or their categories. For example, every day implements of iron are more easily discarded or lost, and rapidly oxidise (rust). They would only in few cases have been included in grave goods in later periods. However, it is notable that iron has been worked into objects in combination with more precious metals, so that it is apparent that it was highly regarded, and has been found in some "rich" graves. Nevertheless it cannot be said that there has been any real attempt to replace bronze with iron in any significant way before 1200 BC (Waldbaum, 1978;23).

For the region of the eastern Mediterranean iron finds are shown in figure 6. This is intended to show the differences between the different parts of the region. Unfortunately, the most interesting area, Anatolia, has so little data that it has been dropped, as has Egypt. The figure 6 shows that there is a significant increase in finds of iron artefacts throughout the region, from the 12th century, for Palestine and Greece (with Crete and the Islands), a slight hitch in the 11th century for Syria, but a quite different development for Cyprus.

Assuming that finds of iron and other metals from the 12th, 11th and 10th centuries in the region indicate preferences in society, the following observation can be made:

- **Palestine:** For <u>weapons and armour</u> we see that bronze dominated the 12th century at 98% preference. By the 10th century iron was preferred at 56%. For <u>tools</u> iron went from 10% preference to be more popular (60% against 40% for bronze). For Jewellery the preference for bronze was much greater than other metals (70%) in the 10th.
- It is interesting to note that iron went from very low preference to 50-60 % in the period, and gold went from 42 % preference to 10 % in the period. This could imply a change in society, causing iron to replace bronze as the “working metal” at the same time as gold is replaced by bronze as the “luxury metal”. Palestine has yielded the most representative number of finds with respect to the numbers of objects of the various metals for the periods examined (Waldbaum, 1978;38-42).
- **Syria:** For <u>weapons and armour</u> the situation in the period is similar to that in Palestine. But for tools the situation is very, extremely, different. Here, iron tools were

25% of the total of iron finds for the 12th century, and 86-87% of the total for 11th and 10th centuries. This shows clearly that iron tools were manifest after the collapse (1200 BC).

- We see the flattening of the curve (figure 4) for the 11th century for both Syria and Cyprus, which implies changes. The data, however, is enough to base a hypothesis on. The curve reflects almost no growth in iron use, but the data shows a stunning rise to 87 % dominance of iron, so we must hypothesise that something abnormal had happened. One possible factor in that particular mix is the failure of both Ugarit and the Hittite Empire, which probably would have caused development to stumble a bit in the 11th century, before picking up again in the 12th. The sting in the tail is that while the curve for the 10th century (figure 6) shows increases in iron finds, the proportion of iron to bronze does <u>not</u> change much (iron 86 % - bronze 14 %).
- For jewellery iron was generally more popular than in Palestine. But gold simply vanished after the 12th century. Iron dominated at over 50 % thereafter, with bronze at 42% (11th c.) and 37 % (10th c.), and silver and lead barely represented in the statistics.
- **Cyprus:** For <u>weapons and armour</u>, and for <u>tools</u> the trends in the period are similar to Palestine. But for jewellery bronze dominated with 58 – 66 % for the 12th., 11th., and 10th centuries. The big surprise is that gold is fairly stable at just over 30 %. Vastly superior to Syria. In other words an affluent place to be in the transition period. The flat trend for iron (figure 6) could also be interpreted in part of the function Cyprus had as metallurgical workshop in the Mediterranean. They probably had reserves of bronze at all levels of society after the collapse, at the same time as they may well have produced iron objects for distribution in the near-regions of the Mediterranean. In other words they **might** have manufactured it, but exchanged most with “buyers” abroad.
- **Greece, Crete, Aegean islands:** For <u>weapons and armour</u>, and for <u>tools</u> the trends in the period here are also similar to Palestine. However, there are signs of some variation from the pattern. Iron is adopted more rapidly in the 11th and 10 centuries, ending at about 65 – 70 % for <u>weapons and armour</u>, and 100 % for <u>tools</u>. For <u>jewellery</u> the 12th century is at about 50 %, but drops dramatically to about 4 % and 3 % in the 11th and 10th centuries.

As said already, data for Anatolia and Egypt are lacking, but basic iron technology was in some regions simpler than the production technology for bronze, although the finished product was not so hard. The use of better technology yields steel. The necessary knowledge of this technique probably existed in parts of Anatolia. In the following, the development in iron technology is in many cases not entirely clear, neither chronologically, technologically nor quantitatively. These aspects will be dealt with in the main discussion part of the thesis.

4.8 Developments in iron production

The Anatolian ability to produce steel, requiring the carbonization of iron in the production process is confirmed by Muhly et al (1985). Finds of iron used for jewellery is the largest class, but the other classes (tools and miscellaneous) are pretty similar in size, depending more on how you care to classify them (Waldbaum, 1978:23)

Steel is known to have been produced by at least the 11th century BC (Smith et al, 1984), who states that a dagger fragment was in a dated context and is believed to be one of the earliest artefacts of steel in the region. This demonstrates the possibility of steel production at approximately the time of the LBA collapse. Unfortunately we cannot from this alone postulate its general relevance or popularity.

However, there is evidence to suggest that hardness was not the only, or even the principal characteristic for selecting iron in preference to bronze (McConchie, 2004:15-18). Also, in LBA at Hama, Syria, jewellery of iron was found more often in the graves of the ordinary people. It was apparently not the exclusive (and expensive) property of the elites (McConchie, 2004:18-21). This provokes the idea that iron was on the way to be accepted for what it actually was (an affordable, locally producible utilitarian metal), rather than what it wasn't in comparison with another utilitarian metal.

5 Types of mining operational organisation

In the case of early copper production in the Polis Region, western Cyprus, three main models of organisation have been suggested: 1. State organised, full-time and large scale; 2. local, village based and seasonal; 3. transitional, mobilized and local. It is beyond the scope of this project to follow up all the types, but it can probably be said that all 3 are points on a gradient from local industry, for a nearby village, to a much larger operation with many mines in a network and an overseas distribution network. This “model” hypothesis applies well to the probable development in the eastern Mediterranean from early BA to about LCI period (c. 1700-1400 BC), when localised operations were the main activity (type 2) and thereafter types 1 and 3 probably becoming more common as the industry expanded, before crashing in 1200 BC . Copper was is apparently produced until the Late Medieval period (Raber, 1987).

The same author goes on to discuss the environmental constraints on the industry, which were also important. The necessity of producing charcoal for the various processes is potentially a huge problem, both for the metallurgists, but also for environmental reasons. He estimates that in the period CA (Cypriot-Archaic) to Hellenistic, about 3,900 tons of copper was produced here. This is based on 36,100 tons of slag, and is roughly equivalent to 13 tons per annum in the period. Deforestation was rife within c. 60 km^2. The area was originally densely forested Raber (1987).

5.1 A typical small-scale mining operation

In the excavations at Politiko Phorades, Cyprus, through several seasons up to 2000, researchers found 3.5 tons of slag, many tuyères, fragments of furnace lining, and some gossan (gossan is an iron-containing secondary deposit, usually reddish, occurring above a deposit of a metallic ore [Oxford, 2005]). There was also a stone-lined pit which was believed to be a part of the process, but what function it might have had was unknown. The pit was not a furnace because in that period furnaces were vertical above ground level, and of clay. Further conclusions were that the metallurgic workshop was active at times when agricultural activity was down, probably annually. Secondly it was suggested that this was typical for the area of the Troodos mountains.

At Politiko Phorades the findings indicate that the workshop produced a matte, not a refined copper (it is very unusual to find matte on site, because normally it all goes to secondary processing). It was a partially reduced copper sulphide, obtained by roasting copper ore. Further processing of this product, either on the production site, or possibly elsewhere, would have resulted in production of an ingot of copper. The form of the slag found on site was consistent with a circular matte, with a weight about 44 lbs (Knapp et al, 2001:206-207). The resulting copper would have weighed less. It is from the secondary melting process that such product (matte) could be re-smelted, with product from other mines, into ox-hide ingots.

A further conclusion, supported by findings of snail shells in the annual accumulation layer on site, is that the metallurgic workshop was only operational part time (when agriculture was in its annual low activity period). This was the rule up to about 1600 BC, but at some time thereafter it probably became a full-time operated mine. It would have been initially dependant and coordinated with a nearby settlement for food and cultural activity, but after 1600 BC it would have been part of a regional network of continuously operational mines. This was a result of the growth in the industry and establishment of larger regional administrations under more powerful elites (Knapp et al, 2001).

The Late Cypriot pottery (ca 1700 – 1050 BC) recovered here was a style thought to be favoured by elite groups: Black slip, White Slip, Red Lustrous Wheel Made, Base Ring, among others. All were found mainly within the clearly stratified metalworking levels, and there was very little coarse ware. The site seems to have a specialized nature, since the pottery recovered was luxury ware with very little “common” ware. The mine itself was located near to mineral deposits, fuel, water, and refractory clay. Thus making available the ore and flux, and a nearby creek providing water and clay for construction of the furnaces, as well as fuel for the charcoal. A spring near the site could have been used for drinking water for the workers (important, and especially so in summer months). The probable source of ore was only 800 m away ((Knapp et al, 2001).

5.2 Impacts on the regional ecosystem

There is not much in the literature on deforestation or ecological consequences of the BA metallurgical activities, but there appears to be a general consensus that the impact was severe in the vicinity of the mines. This would probably have been the result of the operators both cutting trees for firing furnaces (using charcoal), and polluting the area with smoke and sulphurous gas (e.g. from roasting ores). In principle, sulphurous gas could lead to acid rain which kills vegetation if the discharge is prolonged and dense enough. In addition, the production of charcoal (burning wood without access to oxygen) also releases mixtures of

CO, H_2, CO_2 and N_2 gasses. These can also lead to acid rain. This can kill vegetation by falling on to it, but in turn also ends up in the streams and rivers, with impacts on the biota there. Whether this was a major impact regionally is not easy to say without perhaps more experimental archaeological projects, which are obviously beyond the scope here.

That there has been extensive erosion is shown by several projects, but usually for certain specified sites. Nevertheless, descriptions by van Andel et al (1990) make it clear that for some regions in Greece, erosion in the Holocene period is anthropogenic in origin. Assuming that similar influences will apply to other parts of the region, it is likely that the exacerbated erosion which they found had occurred in BA in their investigation, also applies more generally. Their findings were that the depositions of alluvium in the plains at the foot of hillsides came from the slopes above them. This was attributed to various human activities, but none to copper production. Depending on the density of mining operations in the area, it might well be that the erosion caused would be of both agricultural and mining activities.

There had been drastic ecological changes with anthropological causes in the Mediterranean region since early Neolithic, because of use and misuse of land. There was considerably more forest and other vegetation before BA. All of the lowland forest had gone, and was replaced by *maquis* (shrub lands) and later by thorny scrub, by the start of BA. Erosion had also affected the region where deforestation had occurred, removing soil, salts, nutrients and minerals. The population had already started various husbandry practices to control the negative effects. But the forest was gone in the lowlands Angel (1972:89). There were also similar conclusions, for eastern Anatolia (Willcox, 1974). There is support for a the desertification hypothesis, as well as for communal reactions on perpetrators in the ancient/ classical world, on people who damaged the ecosystem (Hughes, 1983). Thus was born the concept of environmental protection.

But if this helped is a moot point. Both use of timber for construction of various types of structure and for pyrotechnology (furnaces etc.) to make tiles, bricks and process metals, caused further major deforestation (Wertime, 1983). Elephants were found in northern Syria in the second millennia BC. Increased demand for pyrotechnics and fuel in the run up to, and the early stages of the IA caused deforestation in their habitat, and extinction of the species, who probably wandered into the area at some time before the second millennia (Miller, 1986).

6 Societies, collapse and metallurgy

The collapse of the Hittite kingdom has been accredited to natural forces, such as earthquakes (e.g. Nur and Cline, 2000) or climatic events, which Kuniholm (1990) regards as very uncertain. Theories of widespread and prolonged drought in the eastern Mediterranean are discussed by Drews (1992) who finds them not reliable. Other explanatory devices are the introduction of iron technology, enabling the production of superior weapons with which to overthrow several Bronze Age kingdoms, or the development of new types of weapons and tactics, with the same purpose. Bryce (1998:374-377) dismisses all the above theories as lacking substance. Although there could have been droughts in various areas, that could have been long, and earthquakes almost certainly occurred from time to time, some groups may have had iron weapons etc., but there is simply not enough evidence to support any of them as fully responsible for the extent of disturbance and chaos on a scale big enough to overthrow all states in the region and plunge it into chaos.

In the following the two main facets of the situation in the eastern Mediterranean region are in focus. On the one hand the actual meaning (and the causes) of collapse, and on the other the changes in perception of societies as regards their own situation and society, as well as their perception of technology, especially iron. Anatolia is the main focus from the point of view of the process of collapse, but other states are in a general way also affected. Anatolia was the main factor as regards iron, and also was the first major power to collapse

6.1 The mechanisms of collapse

Collapse is a matter of the socio-political sphere, and in this thesis is defined: "*A society has collapsed when it displays a rapid, significant loss of an established level of socio-political complexity*" (Tainter, 1988:4). Collapse is apparent when there are significant reductions of the following characteristics:

- stratification of society and social differentiation
- regulation of economic and occupational specialization; centralized control by elites
- behavioural control
- investment in the epiphenomena of complexity (architecture, art, literature etc.)
- information flow, in all respects
- sharing , trading or distribution of resources
- organization of individuals and groups

- territorial integrity, integration and size.

A society has not necessarily collapsed if only one of these characteristics is reduced, but probably has collapsed if all are reduced significantly. There might also be cases of collapse where this list will not apply. Only very few examples of such societies are known archaeologically, but it seems probable that collapse is a general process and has occurred a lot more than one would think (Tainter, 1988:4-5).

Tainter (1988) posits 11 main explanatory categories in collapse theory:

- Depletion of vital resources
- Establishment of a new resource base
- Insurmountable catastrophes
- Inappropriate response to challenges
- Other complex societies
- Invasions/intruders
- Class conflict and/or inappropriate elite behaviour
- Dysfunction in the society
- Religious or mystical factors
- Chance events occurring in an unfortunate combination and short period
- Economic matters

Several of these types of event could bring down a society on their own. However, just the onset of difficulties is not always enough to cause the society's collapse. A society might react to problems in different ways, where a critical situation can be turned into an initiative leading to growth, instead of a collapse. So it is not always given that a society in crisis will collapse. Success and survival also depends on how the society chooses to tackle the problems that beset it (Tainter1988:42, 51; Diamond, 2005; Fergusson, 2010; Jacobsen and Adams, 1958).

This possibility of tackling problems in a manner that allow some flexibility, thereby avoiding collapse to a significantly lower level of complexity, has been demonstrated by several cultures. The importance of this strategy has also been emphasised by the diametrically opposite “failure to adapt” argument which has been put forward to explain why some collapses happened. In this line of reasoning, the onset of problems to the society could have been responded to with some changes by the society, which would have reduced the impact and maybe avoided collapse. But society in crisis might also fail to respond appropriately, and so collapses. In this respect, some have suggested positive feedback loops, which simply generate more of the “wrong response” when stimulated. In this scenario it is impossible to change the normal response to certain types of event, and so the situation is made more volatile and collapse is ultimately inevitable (Tainter, 1988:59-61).

Complex societies are, by their nature and structure, problem solving organisations. When they collapse, then the problem often lies within the society itself, not externally. Tainter has studied collapse events in order to find a universal theoretical explanation. He has failed in this, but does comment positively on the economic model explanation, thinking it the best alternative (Tainter, 1988:87-90).

In summary, collapse is a recurring event in human history. Stratified society becomes flatter, with a loss of power and influence in the elite classes, who are perhaps replaced by headmen or chiefs in a smaller group, if they survive. For population also shrinks. The usual chain of events is the occurrence of increasing numbers of irksome problems, costs consequently increase manifold, perhaps also a positive feedback mechanism kicks in, and probably the decline in marginal returns for the society goes critical and causes the final collapse (Tainter, 1988:192-194; Fergusson, 2010; Tainter, 2006).

6.2 The collapse of the Hittites

The Hittites were central to the PRC. It is thought that they collapsed first, but possibly synchronously with Ugarit, and maybe even the Ahhiyawa. Liverani (1987) points out that the palace-based societies had all the formal functions of the state within the palace and its functions. So when the collapse of the palace occurred, so did the society lose all its formal state functions and bureaucracy. After that there was no chance of immediate recovery. The 11 criteria presented by Tainter for the collapse of complex societies can be used to assess the risk that the Hittites experienced:

Economic matters: Already at the time of the end of the Assyrian colonies there were varying conditions of unrest. So they terminated their activities just before the formation of the Hittite kingdom. The Hittites introduced a more ordered society, but the cost was an increase in complexity. There had to be an army to keep order, and to defend the interests of the parent state. This in turn had to grow, to support the increasing state overhead of which the elite classes had to be a part. There had to be international agreements, palaces, and all the paraphernalia of government. There would be wars, and the state structure is better suited to conduct such affairs. In short, there was change from lower cost, lower complexity commercialism for a higher complexity state structure. It is highly probable that the cost of the state organisation would have increased throughout the period. The Law of Diminishing Returns would almost certainly have applied. For every initiative, the return on investment would fall, and this could continue to fall year after year.

Wars in the last stages of the kingdom were frequent. There was considerable disagreement within the central dynasty. At times the kings were rendered more or less impotent, and perhaps feared for their very lives. Then there is a king who is a stronger personality, that can persuade or manipulate people to support his ideas. But this process is also subject to the Law of Diminishing Returns. An attitude that is flexible enough without being too malleable, so that it does not appear that king is weak, is difficult to manage in a dynastic tradition of ruling. So that it also becomes less effective as time goes on.

Depletion of vital resources: We do not have much data on this, but the onset of a scarcity of tin available to the Hittites was possible. The Hittites used iron weapons at the battle of Kadesh, and written sources indicate a lot more iron in Anatolia than we have found to date. Production of iron in the late 2nd millennium was perhaps not a good exchange object against bronze. But if trade was failing internationally, then Hittite goods would be difficult to exchange on the markets, and they may have found it expedient to be as self sufficient as possible, especially possible as regards iron.

Inappropriate response to challenges: The Hittites faced many challenges, and even on a basis of a 50 % success rate, there would be enough failures to generate deficits economically. As this got worse, so would the population find things more irksome.

Invasions/intruders: There were a number of enemies, e.g. the Kaska and the Ahhiyawa , but no direct invasions. This would probably be placed in the previous class.

Other complex societies: These could in the last event, in theory, take over any of the other polities that were failing, but they were all under great stress themselves. Tainter states that in a conglomerate of complex societies, collapse is not possible for various reasons. Especially that only in a condition of a complex society isolated in some respects can a collapse occur. Since so many of the complex societies collapsed in so short a time implies a chain of events that caused either that all states simultaneously succumbed or did so one after the other in a short space of time.

Dysfunction in the society: This was likely as a result of the infighting that occurred in the central dynastic family of the Hittites.

Chance events occurring in an unfortunate combination and short period: This probably happened in the region on a frequent basis as the collapse developed.

Establishment of a new resource base: The transition to a new metal (iron). This is discussed later, but the development and use of iron would ultimately work to reduced the Hittite elites' control over the economy and populace, and reduced economic returns would feed negatively into the law of diminishing returns, and they would experience even more problems.

6.3 After the collapse

Within a few generations after their collapse, the Hittite kingdom was little remembered. The interesting question is what happened to the people who populated their world, and who inherited whatever could be salvaged from the ruins? Bryce (1998:381) says that the centres totally destroyed were only Hattusa and Ugarit and the ones burnt were one west of the capital and some east of it. There is absolutely no evidence of damage in west Anatolia. In the other Hittite domains only a few were destroyed, for the rest were just left abandoned by the populace. There does not appear to have been any widespread destruction and killing, just a widespread desertion of their homes and lands. Many people “just up and went”. This migration happened in a short space of time, and just after the Hittite society was terminated (Hawkins, 1974).

However, some groups, especially the Lukka, either returned or perhaps in part, remained. They were in the main Luwian speaking, and this is evident from the continued use of the same names for their gods, and slightly adapted place and personal names, based on traditional Luwian ones, after the collapse. Similarly along the western coast, small centres of population as well as larger, like Millewanda/Milawata, seem to have continued to live in the same places at least until the Iron Age, for some as long as into the Roman period. At some point after the collapse they received numbers of Greek speaking migrants from across the Aegean which formed the basis for the region known later as Ionia.

On the eastern side of Hytta, the kingdom of Carchemish which was one of the two Hittite viceregal seats in Syria passed through the collapse with relatively little damage. In fact there was claim that a part of the Hittite royal dynasty that had moved to the kingdom (or coalesced there) after the collapse. However, although Carchemish prospered, the central

Hittite dynasty had not survived the upheavals and end of Hattusa. This area was a Hittite territory along the west bank of the Euphrates, and attracted more of the surviving elite of the Hittites, although none of the central dynasty. They became involved in the development of the so-called Neo- Hittite culture (Bryce, 2012:9-32). This persisted perhaps until biblical times and is alluded to several times in biblical literature (Bryce, 1998:380-385).

The successors to the Hittite king in central Anatolia included, by their own claims, kings of smaller kingdoms. They claimed to be related by blood to the lost central dynasty and titled themselves as “Great Kings”. One whose father was Hartapu, who in turn was the son of the Great King Mursili. It is not entirely clear how they were in fact connected to the central Hittite dynasty, if indeed they were. Nevertheless it does seem probable that there was a connection at least to a smaller kingdom Karatepe (Azatiwataya), of the Hittite realm, in eastern Cilicia.

The Hittite realm represents the worst case scenario, but Cyprus was the apposite opposite. All that could go wrong seems to have gone wrong with the Hittites, but for Cyprus, after or during the collapse (and continuing into the 11th century) there was an initial negative economic reaction to the changes, with following migration to the island, establishment of new coastal settlements and probably an improvement economically. The start of the IA seems to have gone well for Cyprus (Negbi, 2005:27-31).

I**n a regional perspective,** it might be said that the Palaces had controlled all high value materials, and exchange of much of these between states was by formal exchanges of royal gifting (Sherratt, 2000:83). Sherratt (2000:82) suggests also that there is a connection between the collapse of the centralised elite controlled economy and the development of utilitarian iron. Developments with regard to iron also prevented the re-emergence of centralised economies, and this aspect made iron-working activity important (Sherratt and Sherratt, 1993:362-4). This in effect meant that after the collapse, control of high value bulk materials was devolved from palaces to lower levels, e.g. temples, and mercantile enterprises, that became the main traders. The production of iron was not under palace control, so any group, company or society could engage in producing iron wares (if they had the knowledge and resources).

6.4 Summary

The Hittite realm was established in 1620 BC at the start of the strongest growth economically that the eastern Mediterranean had seen until then. The Hittite realm grew with trade through the caravan routes to Mesopotamia, as well as sea routes to Egypt and the Levant (and probably Cyprus) of textiles and minerals (and metals) for tin, which was needed for their own bronze production. The Hittites were continually under pressure, from external enemies and internal disagreement. The Kaska were always a potential problem, and may well have been the executive agent in their final demise. But the Kaska had always been a problem, who the Hittites had always bested, so their success in quelling their oldest adversary cannot have been of their own device.

As the crisis developed, the Hittites, who were the first to develop iron, were the first to collapse. Possibly they were the first to reach a critical state and then imploded. Their extreme circumstances, after wars and other problems, possibly caused an insurrection by the people in the capital of Hattusa. In any case, their demise fuelled the migration problems in the region, and helped bring down other complex societies.

The region had gone into a collapse, and the elite power structure had lost its grip on the complex societies. Iron development and the freer markets were on the ascension, and new commercially oriented agents and groups were on the rise.

7 Changes in perception, Discussion, Conclusions

This discussion will treat the various theoretical models for the adoption of iron in preference to bronze or during shortage of bronze, before, during or after the PRC event. Earlier it was pointed out that some popular explanatory models are as follows:

1. A shortage of tin, leading to an inability to make the alloy of copper and tin (bronze)
2. A quality of hardened, tempered iron, that was superior to bronze
3. Another reason, here called a change in perception, i.e. iron was preferred because it was perceived to be more attractive than bronze for some other reason.

The transition from the bronze age to the iron age may have been caused by any (combination) of these factors.

7.1 Relative scarcity of bronze, and possible collapse of trade networks

The first of the main theories above, concerning iron's entry onto the technological and cultural arenas in LBA and very early IA, has been that bronze was becoming difficult to acquire in the Mediterranean. According to this theory, the more accessible, but less desirable iron would gain ground at the cost of the less accessible but more desirable bronze. Snodgrass (1980:348-349) argues for a scarcity of bronze in the last part of the second millenium, and that this might have caused a greater demand for iron, as an alternative. A further element in this respect is the theory of a break-down of trade networks in the late 2nd millenium BC, e.g. the one through the Northern Euphrates (McConchie, 2004:16; Waldbaum, 1978:65, 71-73).

Nevertheless, the weakening of supply because of closure of the routes might have had the effect of reducing access to resources, but doesn't seem to have been catastrophic:

- There was extensive bronze-making debris at Hasanlu. Other Western Iranian sites also show that there was plenty of bronze from the period LBA to early IA. So it seems there is little basis in the claim that breakdown in trade networks led to scarcity of bronze, and thus caused a move toward iron (McConchie, 2004:16).
- When the trade routes to Urartu and Assyria were developed in the early first millennium BC, copper and tin were important exchange commodities. Bronze was at that time a viable and accessible alternative, but iron continued to be used and it retained its popularity, at a similar level to the period preceding the opening of the trade routes (McConchie, 2004:17).

So the argument that trade network collapsed and led to bronze shortage and thus to growth in the popularity of iron is not entirely valid for these cultures. The end of LBA was a time of crisis in most of the cultures of the eastern Mediterranean, but the explanation often put forward, that iron was widely available and tin was in short supply is not strong enough in itself (Budd and Taylor, 1995:138-9). There is also a theory that there was more than enough bronze to be found in the region at that time (Sherratt, 2000:83). There may have been a growth in the use iron because of a new preference for that metal (McConchie, 2004:16-17).

7.2 Hardened, tempered steel

A different point of view often held by modern authors is that tempered and/or hardened iron would always be preferable to bronze. But this springs from a modern viewpoint, that hardened steel is the best utilitarian metal of the two. This is not necessarily the view held by people in the ancient world. Superior hardness was probably not the criteria for iron objects in the LBA.

McConchie examined the archaeological record for iron in the period following the start of the IA. It appeared from this that there were ways to harden iron which the smiths would possibly have been familiar with, either by experience or knowledge of particular combinations of ores and techniques, but very few artefacts from the first half of the first millennium BC actually are hardened iron (steel) (McConchie, 2004:21). One possible advantage is that iron swords which were not hardened, would not shatter in battle but bend, thereby allowing the users to bend them straight again. Harder bronze weapons could break in battle and thus would have to be returned to a bronze smith for repair (McConchie, 2004:18; van der Merwe & Avery, 1982:146-149).

Examination of some artefacts of greater hardness have shown variation in carbon content. One hypothesis about such objects is that some blooms (ores) simply contain carbon in varying quantities, for natural reasons or because of unintentional variations in the various process and the furnace priming. Further processing these in a standard way to produce iron would have produced objects of varying hardness, with parts of the same object harder (with more carbon) than others. So that it would seem that smiths could have produced hardened iron, where they had in reality just intended to produce standard mild iron (Stech-Wheeler et al, 1981:245-247; McConchie, 2004:19-21).

Generally, one can say that even in the early iron age there does not appear to be much hardened iron (steel) in existence, but plenty of the softer (or less brittle) iron types.

There is a plethora of tools and weapons that were excavated in the Urartian territory (eastern Anatolia, formerly part of the Hittite realm). There simply does not appear to have been any consistent attempt to deliberately carburise or otherwise harden products of iron until well into the IA (McConchie, 2004:15,27; Meyer, 2008:65-68).

7.3 Iron production as a small local operation

Iron known from written sources is more plentiful than the actual numbers of artefacts found in museums today, since the rate of preservation for iron is more like an organic item (McConchie 2004:12). Also, iron has varied in value, considered a valuable metal in the early stages. Iron became more frequently used in a gradual way, and mining and metal production was often done in village or smaller populated area, at locally known mines. Deposits of iron are often found in the same places as copper, and the mines can be very limited in “footprint” above ground (Waldbaum, 1978; McConchie, 2004). These mines were used in agricultural “slack” seasons, and the metal produced probably at the same time. This means it was a “small local operation” in mining and smithing, similar to the copper mining at Politiko Phorades in Cyprus (Knapp et al, 2001).

Another thing is that iron products (from its ores) were probably not traded in the same manner as bronze and copper. Since iron production was in large part a local affair (as copper production had been in the early stages) iron could be produced more on a local demand basis. It was used to produce tools and other objects that were harder wearing than wood. It could also be taken to the local “blacksmith” for re-cycling (heating, forging and “welding” or joining) with other iron objects or scrap. This manner of iron production process is more suitable to a society at a lower level of complexity. It does not require so much infrastructure such as state control or inputs, long transportation routes to market, or complicated transactions to acquire the raw materials. Most of the resources required are available at short distance from the mining village, as in Politico Phorades.

There was also an advantage of economy, in using iron. The processing of iron is more cost-effective than for bronze Wertime(1983). This would also make it more attractive to small alchemy projects and sites. Once the iron was processed and the objects made, the process was finished. Unlike copper, which required tin transported over long distances in order to make the final bronze objects. Modern approaches to the evaluation of ancient iron production and variety of types produced tend to undervalue the importance of small-scale iron production to the smaller societies. These workshops would be smaller and local.

Objects like these would have been re-cycled or mislaid, and thereby lost to the archaeological record. Where bronze or copper is concerned, archaeologists can look for moulds and other pertinent objects. But for iron, it was done by smiths, manually, leaving no such very specific tools.

Quite possibly, some jewellery could have been produced also. This type of use would probably not change in a predominantly agricultural environment (the products were intended primarily for local usage), so once the design had been developed for a specific use it would not need to be changed radically over time (Waldbaum, 1978; McConchie, 2004).

Prestige items made from meteoric iron had a high price, because there wasn't much of it. As soon as it became possible to mine the ore, then charcoal heat and then hammer it to produce a product similar to wrought iron, then it would have become a product that many could use, at a cheaper price per item than bronze. Production methods for iron would also allow relatively ordinary people with a modest economic backing to become smiths. They would be able to function in small communities in most parts of the region, supplying local communities with metal products. As long as they had access to iron ore, and charcoal.

It is probable that most iron produced in LBA and 12th to 9th centuries BC was not as hard as steel. It is also likely that in the next 1-3 centuries after LBA there was not much "steeled" iron. At the same time, there was still bronze in the market which was de-regulated after the collapse of the elite controlled complex societies.

One of the indicative techniques in the period right after the PRC was the production of iron knives on Cyprus, which had bronze rivets in the handle. At the same time in the Aegean, knives were all-bronze (Snodgrass, 1980:346-8). Given that Cyprus was more advanced in iron production than was the Aegean, this bronze rivet technique indicates that they had problems making iron rivets, but bronze was available, and used. This could mean that economic constraints were working. Iron could be produced cheaper than bronze, but they had to used bronze for handle rivets.

It is clear from the archaeological record that there must have been destruction of centres of population and culture, armed confrontations and migrations or invasions. All indicate a time of crisis. It is during this difficult time that iron possibly "forges" ahead and starts to nudge bronze off its pedestal as the major metal in the region.

7.4 The elites' gifting and exchange systems in the region

The economic exchange system was based on gifting between elites. The main exchange commodity was metals, which are suitable for that role as well as having the characteristics of being functional as finished products. Bronze, silver, gold and lead are also particularly suitable in a role as stored reserves over time. They don't become degraded physically in this role. Gifts of metals were ideal, but heavy. The gifting system is based on giving and receiving gifts. This within a framework of mutual expectation. There is in action an obligation on both sides, so that it is not a truly stochastic process. But there is a mutual understanding that the gift that is given by one party and received by a second party, should be met with a gift that is just as valuable, to be sent in return to the first party. In other words an equal value exchange of materials (Mauss, 1974; Moran, 1992; Morris, 1986; Zaccagnini, 1987).

The gifting occurred between groups, represented by the group's elites. The elites controlled the domestic bulk metal business and international exchanges, and took control of the gifts received, and themselves secured all reserves in their palaces. But the elites had also an obligation within their group (i.e. to the people), and gifting to them was necessary. They had to distribute the resources coming in to their subjects, who were in general dependant on the resources. This in theory obligated the people, who had to give something back, and here that something was probably their time and labour (Mauss, 1974). The system was thorough in that all artisans and workers/specialists were fully employed by the palaces. The only slaves that were employed there were weavers (Zaccagnini, 1983). However, this can't have been the whole story. There are often enough time-limited projects which demand large numbers in manpower, such as road building, new palace structures, extensions to ports etc. At that time such people would be the first to be “laid off” if the economy developed even small problems, so that any reversal would immediately cause bigger problems. It should also be said that at the end of the LBA a free labour market appeared (Zaccagnini, 1983). This as a probable result of the collapse of the palaces.

Gift exchange was mostly a luxury or prestige item exchange. Gold was paramount, women (generally) were extremely difficult to get as a wife by exchange, but in the case of Egyptian princesses, the sky was the limit for their exchange value (Zaccagnini, 1987). This is obviously the pinnacle of the exchange system, but it's mentioned here in contrast to the probable requirements of the ordinary people in those societies. The question is: was the palace's exchange arrangements seen as reasonable by the majority of the people? What if the people came to the opinion that the system did not work in their interest, or that perhaps inflation and cut-backs caused them too much hardship?

It follows from Mauss (1974) that part of the relationship is a moral obligation on the part of the elites, who are the part in the relationship that had real power. It is probable that with the passage of time, the people came to consider the contract as not properly honoured by the elites. The people would expect something in return for their time and labour (e.g. food, materials, security), and if the elites provided too little of it, the people might consider their moral obligation to be in neglect, and then feel they were justified in taking some initiative to ease their own situation, as they experienced it.

There are many ways to do this, but there are 2 ways that seem more obvious. They could in theory enter a state of civil disobedience (very unlikely), or they could maybe “get a second job”. We have already considered iron production as a sort of “small local operation”, and this entails groups of people who engage privately in alchemy, the sort of activity that is not easily seen by the society as a whole. This strategy has several attractive returns. Firstly, to produce iron, the ore has to be mined, but people are not so dependant upon distribution of resources from the elites. This means the obligation of giving of their time and labour is lessened. This redresses the original situation. The second advantage is that they can exchange the iron objects they produce in the sub-markets that are not controlled effectively by the elites. In short; new job – better conditions.

The results for the elites of such a tendency among the people would over time be to gradually erode the power of the elites, and their ability to control the markets and the complex society.

7.5 Metals and the free trading sub-market

The importance of metals to society is fundamental in several ways. In LBA gold, silver, copper and tin (or bronze) can be seen as the life-blood of the region, functioning as the prime convertible value for exchange in the market. These metals can also be stored as assets, re-used or managed and are thus resources in a general economic manner, as well as the physical means to make objects of use in a utilitarian manner, such as tools, weapons, monuments etc. (Sherratt, 2000).

Metals can thus be seen as powerful, and this is the reason that elites chose to regulate access to them, and distribution of them. Exchange of metals was arranged at the highest level in society, between societies. In practice this was often from ruler to ruler (King or Emperor). The exchange could for example be arranged by letter (on baked clay tablets) between interested parties at elite level. This would be the basis of the following exchange, but some risks remained (e.g. the ship wreck at Ulu Burun). This is an example of the market at work. But this was an inflexible market, and vulnerable in at least the way it could function with respect to social changes. This would also have been in the elites' interests.

But there was also a “lower level” market, free of elite control, for exchange of pottery, etc. It is likely that this market would have been able to exchange pottery for finished and other goods that were not normally within the remit of the elites (Sherratt, 2000:83-87). In the case of this market, bronze could probably be exchanged in smaller quantities than that for bulk trading, and so could iron. Large amounts (bulk shipments) of copper were unlikely to have been available for exchange, because it was a regulated material. Iron on the other hand, was probably not a regulated material in the 13th century.

The cargo on board the wreck of the ship at Ulu Burun was a high value consignment of articles within the remit of trading for the elites e.g. bulk metals, and was probably a shipment from one elite to another (Sherratt, 2000: 83, 87; Sherratt & Sherrat, 2001:29). The wreck has been dated at about 1305 BC, and contained oxhide ingots of copper and other elite items, unlike the Cape Gelidonya wreck from about 1200 BC, which contained a main cargo of scrap metal. This type of cargo probably increased in size and frequency, with respect to elite cargo shipments. We might assume that the sub-market was functioning well. Perhaps so well that it was threatening the prestigious elite gifting system, since it was beyond centralised control. Iron also fits into this picture, of maritime routes and increasing circulation of precious metals, in a market system below the elite market (Sherratt, 2000).

The maritime network in the final stages of LBA and the early IA extended from ports in the the coastal areas around Italy, with bronze goods such as swords from Europe to the north, or more similar locally produced items. These would have been acquired by mercantile agents and moved on boats to ports, or smaller harbours along the coasts of the Adriatic and the Tyrrhenian Seas, to Crete and the Aegean, and to Anatolia and Cyprus, as well as the Levantine coast and possibly the Black Sea. This network was probably dominated by agents established in the coastal towns of Cyprus, where it was probable that they would be outside the controlling influence of the elites in the region (Sherratt, 2000).

7.6 Metallurgical development, society, religion and power

Blacksmiths, or the function of working iron in a professional capacity on a regular basis, can have existed from the times of the working of meteoric iron, but it was probably usual for the palace-based smiths to work both bronze and iron. The elites controlled access to raw copper, and probably also tin, and thereby the access to bronze for the population in general. The elites gained this control by using the role of the sacred to regulate society, sanctify individuals and implement the exploitation of base resources. In other words to encourage and use religious beliefs among the population to regulate behaviour, instigate and promote the implementation of a fiefdom, with thus the most effective exploitation of base resources (Knapp, 1996; 1988; 1986:115-118).

On Cyprus, metallurgy was linked with a well organized and extensive range of religious imagery and practices. This ideology was used to justify higher status in society and from the 17th century a socio-political elite arose that thereafter controlled metallurgical activity (Knapp, 1986:115-118). In Cyprus, in the 17th to 15th century BC, society became stratified, the development of the economy was regulated, and there was increasing social complexity. There was also considerable resistance to social changes. The archaeological record shows that this resistance was resolved, and a centralised regime was established, ruling over much of the island (if not the whole). This system validated the politico-economic basis of the authority implemented by some groups in the society. By LBA on Cyprus, the religious ideology implemented by these elites had been a part of the manoeuvring that enabled them to gain complete control over the copper industry (Knapp, 1986:117-118). As Knapp says, this established a mutually enforcing system whereby power created religion, and then religion stabilised power.

There is no reason to think that this coupling to religion was unique to Cyprus. It may well have been common to most states in the region. The belief by society in divine figures who protected, encouraged and perhaps demanded sacrifice of some sort, probably established the basic perception that divinity, priests and magic-making were part-and-parcel of the whole world of metallurgy.

Enkomi (Cyprus) has yielded 2 “god-figures”, the Ingot God and the Horned God. The latter is quite large, at 55 cm, and was probably worshipped in Enkomi in a Mycenaean type megaron, before the populace moved the town to Salamis, on the coastline of Famagusta Bay. The Ingot God was probably worshipped in a type of Syro-Palestinian temple in Enkomi

(Mountjoy and Gowland, 2005; Negbi, 2005:26).

Perhaps the political developments may not seem to be significantly affected by iron technology, but as previously said, technology is a social phenomenon wholly embedded within society. It must therefore be understood that there will be feedback between society's needs and technological development and the possibilities offered to society's cultural development by advances in technological development (Doonan, 1994).

The transition from the BA to the IA was a period of new and fundamental social transformation. The elite controlled economies gave way to less centralised forms of economic reality and arrangement which were essential for the next phases of increased growth in the region. The collapse of the palaces (and their stranglehold on economic growth) led to a devolution of economic executive power to lower levels. The developments were both technological and social, inseparably bound in the new arrangements with their own logic and ambitions (Sherratt and Sherratt, 2001: 361-363).

Summary:

The changes that took place in the LBA were fundamental, and unleashed new social forces in the eastern Mediterranean. These changes had already began in the centuries before the collapse, but were only noticeable in the final stage of LBA, with the collapse. Their result was the end of control of high value bulk materials by the elite. Previously controlled at the elite level, and only released to lower levels of administration or craftsmen/women controlled by the elites, they were thereafter released by the elites' fall.

7.7 Modern technology versus ancient alchemy – magic and myth

It is assumed that modern technology is so well known as to obviate any formal definition here. To differentiate between modern technology and the working of metallurgy in ancient times, the term alchemy is used here for ancient metal working. Alchemy is a name that originated in Byzantium and was given by its practitioners for “the Art”, and which probably included aspects of magic (Keyser, 1990). Alchemy has after a promising start, experienced a “difficult childhood” in the Middle Ages, but now people see it as a science that has rendered good service to mankind in the past (Principe, 2011).

Alchemy probably provoked a major reaction from pre-neolithic people who investigated the effects of fire on all sorts of materials, including metals. Texture, phase changes from solid to liquid state and vice versa, as well as colour changes. It is from this not difficult to imagine how impressive and magical processes using pyrotechnics can be, and how useful to people in pre-history (Keyser, 1990).

The term “magic” is defined in an original work by Mauss (1872-1950), in France. In this thesis the translation by Robert Brain (Mauss, 1972) is used. In general magic is a cult modelled on religious cults, that occurs in private, secret or mysterious circumstances, yet occupies a place in social customs. Magical rites are often carried out in “out of the way” places, such as woods, caves, remote houses, in darkness or at night, and always in secret. They differ in this from religious rites which are carried out in open, public places (Mauss, 1972:23).

In early alchemy there was probably not a systematic approach to the methods required to exploit the new resource. Humans had to learn for themselves how to work it, and how best to put it to use. They probably had to invent and learn (memorise) many different protocols. This probably involved some religious or cult aspects, as well as local cultural elements. But in its beginnings it was a matter of religion and/or magic (and perhaps some superstition). The practice was to mix various elements, minerals and energy to achieve the desired result. This was mostly about metals, and the most precious metals were of greatest interest (Dubs, 1947). It has been said that iron at an early date was the most precious in Anatolia, and of great interest to the palace-based smiths and priests of the elite controlled complex societies. It is possible that since most early iron was meteoric and came from the heavens, it might have acquired some religious or magical characteristic.

Man's first successful experiences with the forming of metals was to achieve the smelting of them, whereby they were reduced to liquid state by the application of fire (energy), and then e.g. formed by crude moulding, perhaps on bare earth. The multitude of colours and various degrees of hardness must have been most impressive. Metals were discovered in the 6th millenium and methods of transforming them well advanced by 2000 BC, in the region from central Anatolia to the edges of the Iranian desert (Wertime, 1964).

Briggs (1980) argues that mining for metals has, since its inception, always been of great interest to humanity. The business of extraction of metals has also been of great advantage to the human race, and there is also the aspect of “the hunt for treasure embedded in the bosom of mother earth”. He also points out that alchemy only gave way to technology and science in the 18th and 19th centuries (AD). He also states that in his opinion the engineers involved in the Industrial Revolution in England had a higher status than they have in modern times (1980). If this is representative also for ancient times, then people involved in alchemy would probably also have had high status at that time.

Modern perception of metallurgy in ancient times has probably been affected by Childe (1944), who was a protagonist of a certain idealistic view. He set up a framework that has come to guide modern archaeologists in their basic perception of ancient metallurgy. In his article Childe stressed his idea of "industrialisation", although this did not exist in the early ancient times of metallurgy, when the τέχνη (art) went through its first 4-5000 years of development (at least in Anatolia).

Application of the modern "industrial model", whereby rational science is considered the driving force behind technological development, still characterises understandings of the alchemy of the ancients. Modern concepts of industrialisation and mass levels of standardised production are probably inappropriate as a basis for understanding production in the ancient world. Where standardisation may appear to have occurred in cases of a series of similar products, it could easily be explained by re-use of old moulds, types of tools commonly used, making new moulds from older castings, or cultural reasons (Budd and Taylor, 1995).

Insomuch as the gender issue is concerned, both explicit and implicit in Childe's work, the model doesn't ring true, that it was a man's work only, since children of both sexes were employed in the mines in England in the early Industrial Revolution. If children can do it so can grown women. In the case of the ancient world, family groups were active in gathering ore and various other tasks. This sort of tasking would have built on cooperation from all individuals. Even the responsibility for child care, often seen in modern times as a female responsibility, can't have been impossible to organise in a metal using society (Budd and Taylor, 1995:136-8).

To gain a greater insight it is necessary to subsume or remove those principles, and in greater degree focus on the ritual and magical perspectives of the ancients. These ancient perceptions should have a much greater place in modern interpretation and generation of hypotheses (Budd and Taylor, 1995:133). It seems clear that if these aspects are ignored we risk discounting the quality of their work in alchemy, religious (priestly) smithies and women as alchemists, as well as the power of the leaders of the alchemy movement to sway the ancient peoples' thoughts and opinions.

In short, metal-making was a non-scientific business, which was both variable and carried out synchronous to, or alongside other social activities of all kinds. In such conditions, the complex activities would be ritualised. They were non-literary societies and would necessarily have had to remember everything, so there would have been need for memory aids, and therefore formulated “spells” that all would remember, and use to carry out various tasks. From this, it is a short step from metal-making to magic-making. This would have been enhanced with the magnificent colourful shows that might be put on with pyrotechnics! That should impress anybody. So it should be no surprise to find that the smith, political leader and magician all live in the body of one person, female or male, who commands respect from all others in the society. Once power and charisma were installed as a part of awe-inspiring alchemy there is no reason why it should have been discontinued (Budd and Taylor, 1995:138-9).

7.8 Magicians and metallurgy

The ability to work magic has been linked to social aspects such as class and occupation. A person cannot become a magician on their own, but must be seen as a magician by other people. That person will then be able to take on the qualities of a magician, in most cases also seem to become another person. This is not confined to men, and in fact women are more likely to be recognised as magicians by society. Children are also seen as particularly good in the role of magician's assistant, as long as they have not passed through initiatory rites. Other types of social positions which are often regarded as magicians are **blacksmiths**, shepherds and doctors (i.e. qualified medical practitioners). Their use of so very complex techniques (for human benefit) makes their activities seem marvellous and supernatural (Mauss, 1972:26-31).

The use of rites, spells and magicians possibly had a similar effect in alchemy. In the period of interest the intention was exploitation of iron, but it could easily have been the case with copper production, earlier. Then, as in iron production, the groups were probably smaller, and there was no elite group ruling over the entire society in the name of a god.

The development of alchemy and the production of iron, possibly with the expansion of a new class of artisans and cult leaders (or priests) and “headmen” who were able to sway a growing segment of the community. Their new deities and the practice of magical procedures could possibly have gained more influence in the population and led to a lesser support of the established elites. A part of this could have been growth in the number of sites for mining and production.

The requirements for pyrotechnics and iron production lent themselves to many small, non-centralised sites, especially in that the location of mines could not be controlled. That was decided by geology, i.e. the location and access to the deposits. The small settlements on such sites would have supported those that worked there. This type of site would have been difficult for the elites to control, and those who lived or worked there.

The introduction or increase of iron goods in the low-level markets, which already facilitated the exchange of pottery and metal objects would have perhaps caused a rapid expansion. Possibly also helped by an uneven demand for bronze. All this would have "fed back" into the economic system and strengthened the need and desire to fall back on a lower level of complexity, as defined by Tainter earlier.

In short too many of the people didn't want the elite societies to continue, or preferred to develop the lower level markets. This could have weakened the elite controlled economy, and the elites' ability to control their domains. As for the metal, iron could have proved to be preferential to a considerably larger number of people. Despite its being lesser hard than bronze, and its appearance, less shiny than bronze, but absolutely good enough for their uses. The end result would have been more people practising freer commercial activities, in competition with the bigger, elite controlled economies.

7.9 Conclusions

Iron was a prestigious material in the BA to early LBA, when the raw material was meteoric iron, probably collected from the landscape, possibly at high cost, and solely owned by elites. Once it began to be made from its ores, its popularity probably declined, because ordinary people could have had it too. It's not a luxury, prestigious object if non-elites possess it.

Self-styled, independent alchemists among the people had probably begun to produce utilitarian iron from its ores on a small scale (in "out of the way" settlements) well before the collapse in 1200 BC, possibly as early as the start of the LBA, or before. Parallel with the economic growth of the LBA, the iron was produced and used as tools, jewellery, exchange items and maybe some weapons, among ordinary people. Considering its humble beginnings, and its tendency to rust and disintegrate, it was probably of little interest to the elites, but filled some of the requirements of ordinary people in their lives and work. When objects were lost, they rusted away, so they are not in the archaeological record. When the the collapse occurred, there was probably an increased incentive on alchemists to produce more utilitarian iron.

There was a connection between the collapse of the centralised elite controlled economy and the new resource base, utilitarian iron. This “function”, concerning activities in iron production and distribution, prevented the re-emergence of centralised economies. Which in effect meant that after the collapse, control of high value bulk materials was devolved from palaces to lower levels, e.g. temples, and mercantile enterprises, who then became the main traders. The production of utilitarian iron was not under palace control, so any group, company or society could engage in producing iron wares (if they had the necessary knowledge and resources). The alchemists producing iron probably moved to a more “centre stage” position in society.

There may have been some shortage of tin in the region at some point near the end of LBA. But it seems likely that this could only have given increased incentive to alchemists who were already producing iron wares. It seems eminently clear that bronze was a better material for most uses than iron was at that time, so it must have become more popular than bronze **despite** its apparent failure to be harder than bronze. Perhaps the production and use of iron wares put more control of their circumstances into the peoples' own hands.

At that time, there was increasing dysfunction in society. For the Hittites this was perhaps a result of the infighting that occurred in the central dynastic family. Some of the Hittite kings were unable to deal adequately with this, so the problems could have accumulated and spread down into the general population. The ordinary people were probably disenchanted with the complex societies they lived in, in much of the region.

As the crisis in the economy grew in the 13th century BC, the exchange system between the elites faltered. This system was being gradually weakened by the popular use of traditional sub-markets, where small item exchanges were already common. There was also the increasing movement of goods on ships owned and operated by a small but new class of entrepreneurs, commercially freighting and selling wares, such as the Gelidonya wreck.

As the crisis developed, the Hittites, who were the first to develop iron, were also the first to collapse. The people dispersed, possibly adding to the general confusion and difficulties of discerning between migrating people, “Sea People” and other groups.

This perception of iron was gradually developed, but was a strong influence. It was based on a mixture of social conditions, changes in metallurgy, and changes in belief systems. This mixture fed back into society over a long period of time, possibly from the early 13th century BC, or maybe earlier. It affected the lives of people, because it offered an alternative to them, when they needed it. Then, as the crisis' first tremors were noticed by them, it could help offset the inevitable social and economic changes. Following that, iron would probably have been the only relatively easily obtainable metal, and rapidly popular. The events in society in the eastern Mediterranean in the latter part of LBA also accelerated the metallurgical developments within iron technology.

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Appendix

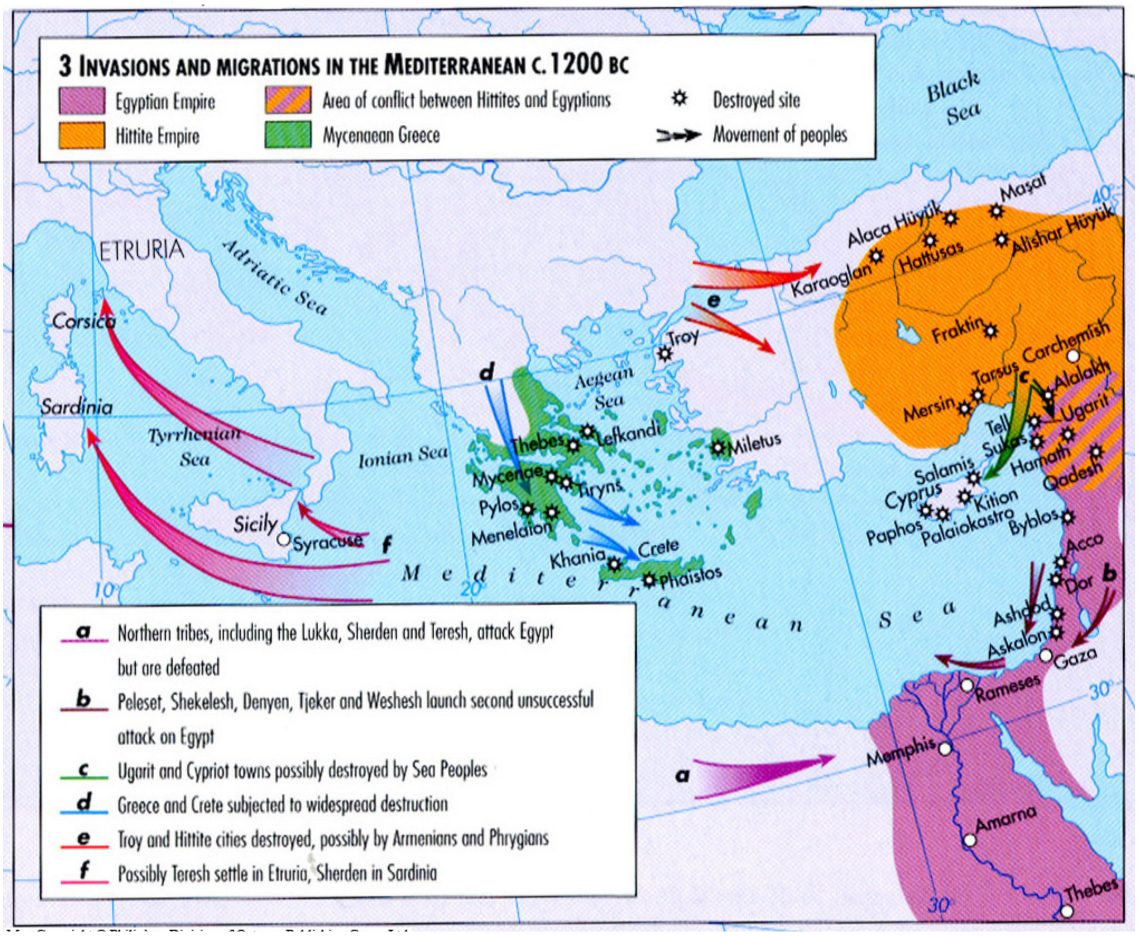

Figure 1. Migration map showing migrations, destructions, and general disturbances in the eastern Mediterranean in the 13th century. The Sea Peoples have been proposed as the "culprits" for some of these events, but the matter is controversial.

Source: *http://qed.princeton.edu/main/Image:Invasions_and_Migrations_in_the_Mediterranean_c._1200_BC.jpg*

Figure 2: Open furnace of clay, partly buried in soil, with bellows, crucible, iron grips, rocks to crush the ore, ore and burning charcoal in furnace.

Figure 3: A shaft type furnace for metal smelting

Figure 4: Part of a crucible (lower part) broken to show slag (black upper layer), copper prills forming in the lower slag, as well as holes evacuated by copper prills (lost in breakage of crucible). The crucible shows some damage from the furnace.

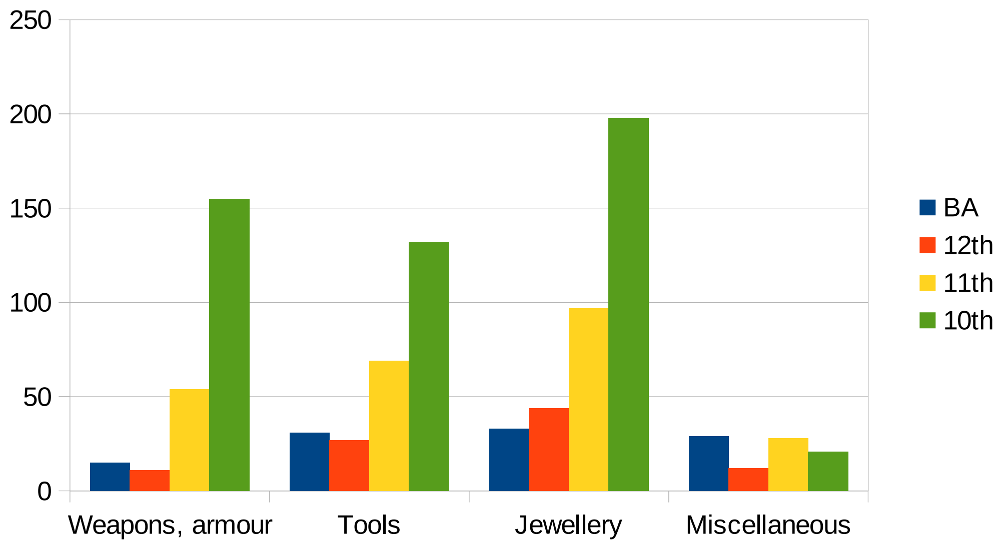

Figure 5: Finds of iron objects from the Bronze Age and the 3 centuries 1200 to 900 BC (source Waldbaum, 1978).

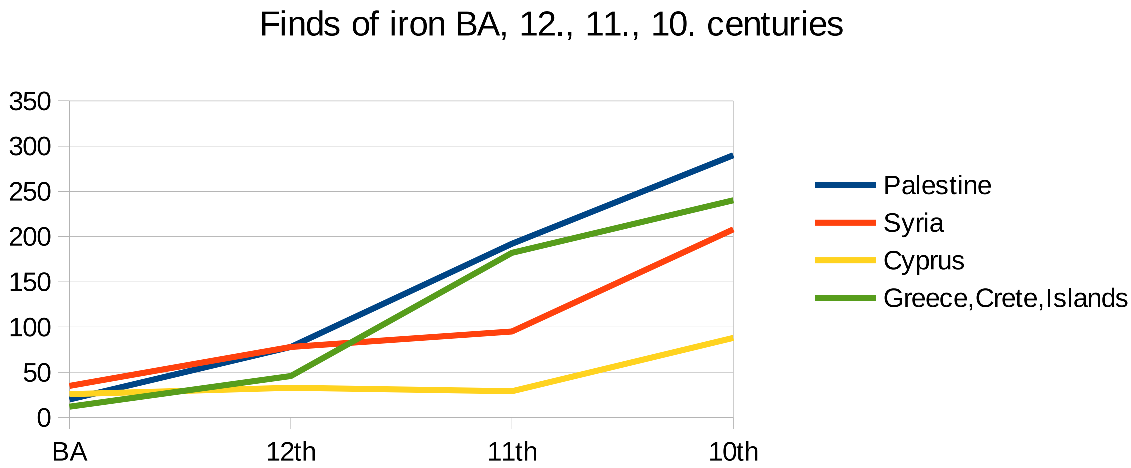

Figure 6: Finds of iron in the eastern Mediterranean distributed geographically, for Palestine,Syria, Cyprus and Greece (including Crete and Islands). Source Waldbaum (1978:36)