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Assyrian Iron Working Technology and Civilization

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Introduction

The goal of this document is to provide a resource for all audiences to comprehend the advancements in metal working technology concurrently with the changes that occurred in Assyrian civilization. The main question answered by this document is how and where did iron working technology develop in Assyria between 1200 and 700 B.C.E. and in what way did it reflect and impact the civilization. This time period is significant because Assyria was the first empire to have both iron tools and weapons while expanding its borders.

Motivation

The militaristic society of Assyria is often misrepresented as a brutal and ruthless nation of barbarians, due to the nature of their imperialism. This is a narrow-minded simplification; the Assyrians can also be viewed as a civilization that promoted an economy of agriculture, trade, and craftsmanship. One example lies with the metallurgists in Assyria who developed the ability to smelt and forge iron into new and useful products, which shows their intellectual awareness and technological vision.

Chapter 1: Overview of Assyrian History

The ancient Assyrian culture existed from about the 19th to the 7th Century B.C.E. (Kramer, 54). During the first half of this period Assyria was a relatively weak Mesopotamian kingdom. However, in the second half of this period, between 1350 and 612 B.C.E., it proceeded down an imperialistic path of attaining power over foreign lands. In the mid-14th Century B.C.E., Assyria gained its independence after serving as a Mitanni vassal state for nearly 100 years (Kramer, 55). At this time, the newly independent kingdom was surrounded by powerful rivals: the Hittite Empire to the far west, the Mitanni Kingdom to the immediate west and the Babylonian Kingdom to the east. Then, in 1200 B.C.E. the status quo of this region was disrupted. The Ancient Middle East and Mediterranean were infiltrated by travelers called the Land and Sea People. With this vast influx of people in numerous locations, most empires and large kingdoms were unable to maintain their extensive borders. In effect, both the Hittite Empire and the Mitanni Kingdom collapsed.

Unlike their neighbors to the west, Assyrians were able to maintain their kingdom because it had grown strong since its independence in 1350 B.C.E. and had a relatively small amount of land to defend. Despite Assyria's good fortune to stay united during the migration of the Land and Sea People, its economy was in danger from the loss of trade routes previously provided by its powerful western neighbors. Based largely on the desire to restore trade networks that accessed distant resources and the opportunity for glory on an unprecedented scale, Assyrian king Ashur-resh-ishi I (1133-1116 B.C.E.) began the expansion of Assyria's boundaries to the northwest. His son King Tiglath-Pileser I (1115-1077 B.C.E.) perused conquests to previous Hittite territories, by leading multiple military campaigns (Saggs, 43). In part, these conquered areas were benefited by the Assyrians because they were provided stability for their regional language and culture, while several parts of the Mediterranean plunged into a Dark Age. From the expansion under Tiglath-Pileser I, Assyrian forces succeeded in securing trade routes previously guarded by the Hittites, which re-introduced the consistent transportation of goods. He also reached the Phoenician coastline of the Mediterranean Sea, which granted him trading access to far-away lands (Saggs, 44). This re-established trade network significantly improved Assyria's economy because resources that Mesopotamia was naturally deficient in, such as timber, zinc, iron, gems, and general building materials, were easily imported (Forbes, 104).

Initially, Assyria used military force to gain dominance over foreign lands. This was accomplished with armies of Assyrian peasants, who were forced to serve as soldiers for a few months nearly every summer in the kings' military campaign (Kramer, 60). Yet, battles were not the only military tactics that were exercised. After the Assyrian Empire had been established and its army tactics had been refined for many years, likely by the 9th Century B.C.E., Assyria employed propaganda. Before arrival to the battleground Assyrian forces would send men ahead to spread rumors of the army's brutality (Saggs, 122). The goal of this performance was to reduce guerilla warfare with villages in revolt and scare opposing organized armies (Saggs, 123). These acts of premeditated psychological warfare may have attributed to the spread and caused an exaggeration of the Assyrians' infamous reputation of being uncivilized brutes.

Within a few centuries of initiating its military campaigns to rule prior Hittite and Mitanni territories, the Assyrians had amassed land from the Aramaean nomads of Mesopotamia, the

Armenian tribes in southeastern Turkey above Lake Van, the Zagros mountaineers of Iran and the Phoenicians of the northern Levant (Kramer 56). With the addition of these regions to the Assyrian Empire, usually as vassal states, a regular flow of taxes came in to Assyria. The wealth gained from these areas was used by the king to spur economic productivity. For example, King Adad-nirari II (911-891 B.C.E.) improved the Assyrian economy through agricultural expansion by installing more ploughs in the fields, increasing grain storage, and raising the number of work horses (Saggs, 44). In sum, he made conscious effort to expand the economy by making land cultivation more efficient.

The majority of people in Assyrian society were peasant farmers, and therefore would have seen many of the agricultural improvements implemented by the Assyrians' increased wealth from conquests and regular taxes. However, society's elite members lived in cities, so they would not have experienced the same benefits of Assyrian imperialism that the rural areas did. Thus, the political, governmental, and cultural transition from kingdom to empire was experienced differently in urban areas than rural ones. In important cities, mostly capitals, some of the Assyrians' surplus wealth was spent to create major works of public art by the 9th Century B.C.E., such as those in Figure 1 and Figure 2 (Feldman, 297). While in these cities, societal elite were exposed to Assyrian public art, which depicted successful military conquests and glorified imperialism with a new art form called architectural sculpture (Feldman, 297). These sculptures were important because they reminded the most influential people in Assyria of the glory, riches, resources and power that resulted from their continued support of imperialism.

Figure 1: Lamassu, The Winged Bull from Khorsabad, 8th Century B.C.E. (See Image References)

Figure 2: Portrayal of Susa's Destruction by Assurbanipal in 647 B.C.E. (See Image References)

Assyrian imperialism brought material wealth, often in large amounts, from newly conquered regions and vassal states. The Assyrian king then re-distributed it to: prominent Assyrian elite, public works, army campaigns, agriculture reforms, etc. One example of tribute to an Assyrian king was 3 talents of gold, 100 talents of silver, 300 talents of iron, 300 talents of copper and 1,000 copper vessels from Sam'al of the Hattina people near Carchemish to King Shalmaneser III's (858-823 B.C.E.) in 856 B.C.E. (Maxwell-Hyslop, 149). However, the success of the

Assyrian Empire slowed by 712 B.C.E. when King Sargon II dealt with many large revolts, particularly those in the southern Levant region incited by Egypt (Kramer, 60). Despite this, Assyria continued to expand its borders and gain tribute until about 640 B.C.E. (Saggs, 49). This was largely because King Essarhaddon (680-669 B.C.E.) placed a strain on Assyria by over-stretching the military's resources in an attempt to conquer Egypt (Saggs, 50). In 612 B.C.E. Assyria's capital city Nineveh was taken by the Iranian Medes and the Babylonian Chaldaeans, marking the end of the Assyrians' dynamic empire (Saggs, 52).

Chapter 2: Metal Working in the Middle East

By 4000 B.C.E. the Sumerians had simple furnaces in Mesopotamia that could melt copper (Saggs, 130). This was a significant achievement, because it allowed copper to be smelted [*definition: the extraction of a metal from its ore*]. Smelting gave metal workers the ability to separate copper from the minerals in ore [*definition: a rock made up of mineral aggregate and metal elements, it is naturally formed in Earth's crust and generally attained by mining*]. Early copper was smelted in an earthen pit.

The initial technique to smelt copper is shown in Figure 3 and begins by placing the copper ore in a simple pit furnace in which the temperature rose above 1084°C (1983°F), the melting temperature of copper. Then, the copper ingrained in the gangue [*definition: the unwanted minerals in the ore*] of the ore changed from a solid state to a liquid state. When the metal liquefied, copper sank to the bottom of the pit and slag [*definition: the byproduct of excess minerals (gangue) in the ore from smelting*] rose to the top. After this separation occurred, the melt was left to cool into a solid piece of copper and slag. Then, the slag was removed by hammering until it was broken off of the piece of copper. This piece of copper, referred to as an ingot [*definition: a mass of metal in a standard shape*], was relatively soft so a stone hammer could shape it into the desired object. If the copper was shaped at room temperature, the material underwent strain hardening and became stronger due to forced movement of the metal lattice structure [*definition: the organization of atoms in a crystal shape*]. However, if the metal ingot shaped with heat then it was forged [*definition: a repetitive process of heating to soften and hammering to shape an ingot*]. Forging is a good method of shaping a metal because when a metal is heated to soften the ingot it also anneals the material, causing a re-crystallization of the metal lattice and provides increased strength and hardness when the metal cools.

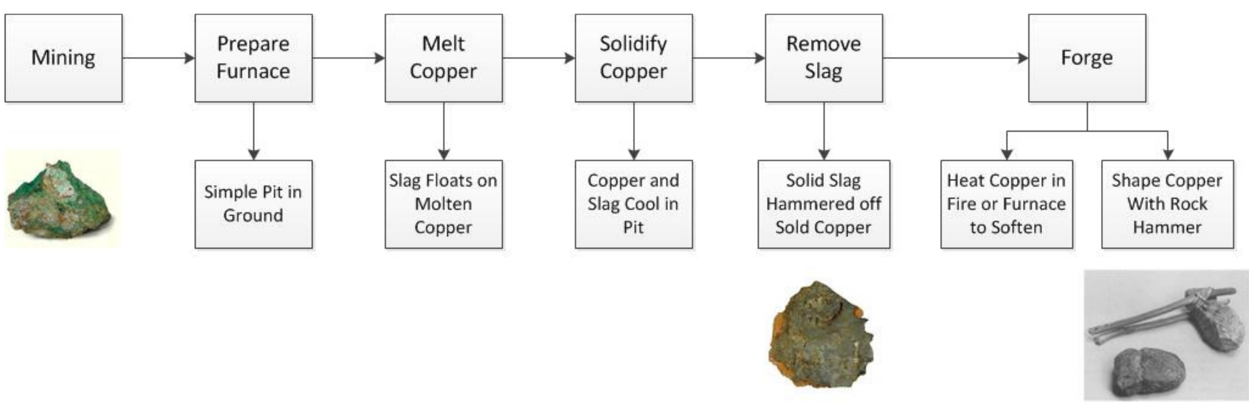


Figure 3: Copper Flow Chart: Mining → Furnace Smelting → Shaping Techniques from 4000 B.C.E. (See Image References)

Mesopotamian copper workers had advanced copper techniques by 3500 B.C.E., these additions are shown in Figure 4 (Joseph, 2). On major change was liquefying the copper in a clay crucible within the furnace, which effectively contained the metal as opposed to having metal disperse through the pits' ground (Joseph, 2). Among the advancements in smelting was the addition of copper flux [*definition: a chemical that attaches to oxygen from the ores' oxides*] to the liquid copper inside the crucible, which assist the separation of slag from the melt. Slag is an impurity within metal – when the amount of slag decreases the mechanical properties of the metal improve. Therefore, better ingots of copper were made by using flux to increase the amount of slag that floated to the top of the copper melt where it could then be removed by scooping it out of the crucible with a spoon made of rock. The main benefit of using a crucible was that it allowed copper to be cast, the act of pouring liquid metal into a mold so that it solidified into the shape of the mold as it cooled. To perform casting, liquid metal in a crucible was lifted with tongs from the furnace and carried to a mold, followed by pouring the liquid metal into the mold [*definition: a clay or sand structure that has been hollowed, the metal melt fills the empty cavity and takes its shape upon cooling*]. This mold holds the copper in a shaped cavity until it cools it into a solid desired object.

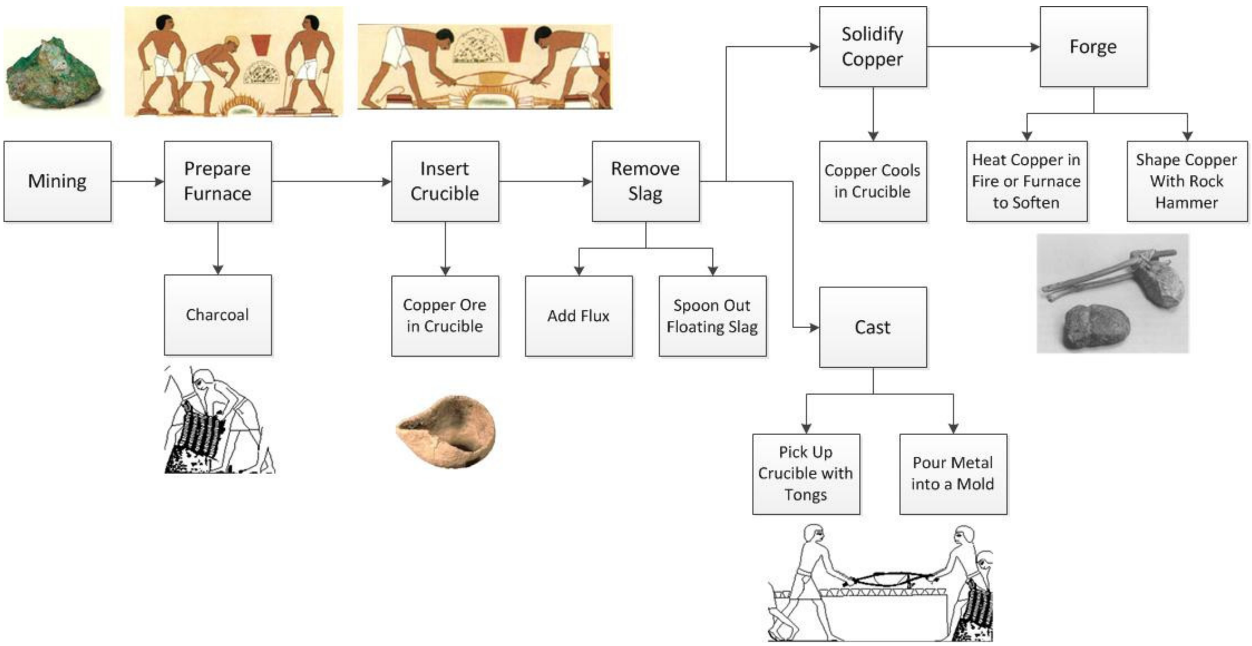


Figure 4: Copper Flow Chart: Mining → Furnace Smelting → Casting or Forging Techniques from 3500 B.C.E. (See Image References)

Metallurgists dealt with copper for thousands of years until bronze, an alloy of tin and copper, was discovered. The Bronze Age in Mesopotamia started around 3300 B.C.E. and it denoted that bronze tools, decorations and weapons were commonly used and owned items. The transition from the Copper to the Bronze Age was simplified because the melting temperature of bronze is less than copper, between 1084°C and 232°C (449.4°F) depending on the percent of tin, so new techniques to cast and forge bronze were not required.

The Iron Age, which started about 1000 B.C.E. in the Middle East, followed the Bronze Age. Prior to the Iron Age iron had been known, but only used in limited quantities. The earliest iron objects discovered are dated at about 2000 B.C.E. (Hodges, 144). One of which was excavated in 2009 C.E. by Japan's Middle Eastern Culture Center archeologists, who found a 5 cm (2 inch) long steel knife blade 100 km (62 miles) southeast of Ankara, Turkey from the Hittite Empire (Hindu). It has been determined that most of these early iron objects were supplied by meteorites because of their high nickel content (Parr, 33). However, meteorite iron was rare, so it was minimally used. When it was worked, forging techniques from thousands of years copper working was employed, as indicated by Figure 5. Despite infrequent use of meteorite iron, this was the only source of iron objects, because there was not a process to retrieve the iron from the ore deposits in Earth's crust.

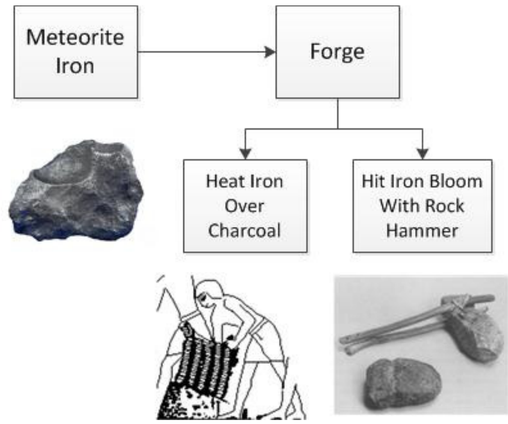


Figure 5: Meteorite Flow Chart: Gather → Forging Techniques from 2000 B.C.E. (See Image References)

By 1400 B.C.E. a new metal working process for smelting iron ore, which allowed iron ore from Earth's crust to be usable for the first time, was performed within the Hittite Empire. Written correspondence between the Hittites and Egyptians around 1300 B.C.E. reveals that Ramses II expected to receive a supply of iron dagger blades from the Hittite king (Parr, 36). This record also verifies that the iron dagger blade in Pharaoh Tutankhamun tomb, made about 1350 B.C.E., was provided by the Hittite king (Parr, 36). One of the likely origins of Hittite iron working is from the Kaska people. Although there is minimal evidence, the Kaskans were known for burning charcoal, a necessary fuel for high-temperature furnaces, and were located in a mountainous region south of the Black Sea, where iron ore is readily available on the ground (Maxwell-Hyslop, 145).

This new smelting process, called blooming, was not easily inferred from hundreds of years of smelting copper, gold, and silver because iron could not be melted or cast. This is because iron requires a temperature of 1536°C (2797°F) to melt, a much higher value than the 1200°C (2192°F) capacity of ancient Mesopotamia furnaces (Saggs, 130).

Similarly to other smelting techniques, the iron working process began by placing the ore in a furnace, as shown in Figure 6. In this case, the furnace was called a bloomery; Figure 7 shows that a bloomery was a deep pit with a short chimney or a shallow pit with a tall chimney. A bloomery was important because it is shaped to reduced heat dissipation from the furnace, so that the iron ore remained hotter for longer compared to earlier pit furnaces. The chimney of a bloomery could have been made of clay or stone. It also included a hole for bellows, available by 2000 B.C.E., to provide a constant draft that kept the charcoal hot (Hodges, 142). While inside the bloomery the iron ore was heated with charcoal, and when the charcoal burned it released carbon monoxide and combined with the iron oxide. This caused a release of carbon dioxide from the chimney hole and left iron behind in the furnace; this removal of oxygen from a metal oxide without adding extra chemicals is referred to as self-fluxing. Also, at these high temperatures some slag in the iron mass, now called an iron bloom due to its porous condition, melted off. Yet, not all of the gangue would melt off the iron bloom as slag. To remove this excess material the bloom was repeatedly hammered, which caused the slag to squeeze out of it. In order to draw out the majority of the rest of the impurities from an iron bloom a repetitious cycle of heating the bloom in the bloomery to soften the iron and hammering the bloom into a compact shape so excess slag would be pushed out was undertaken. Finally, when the blacksmith was satisfied with the reduction of slag in the bloom the material was qualified as wrought iron.

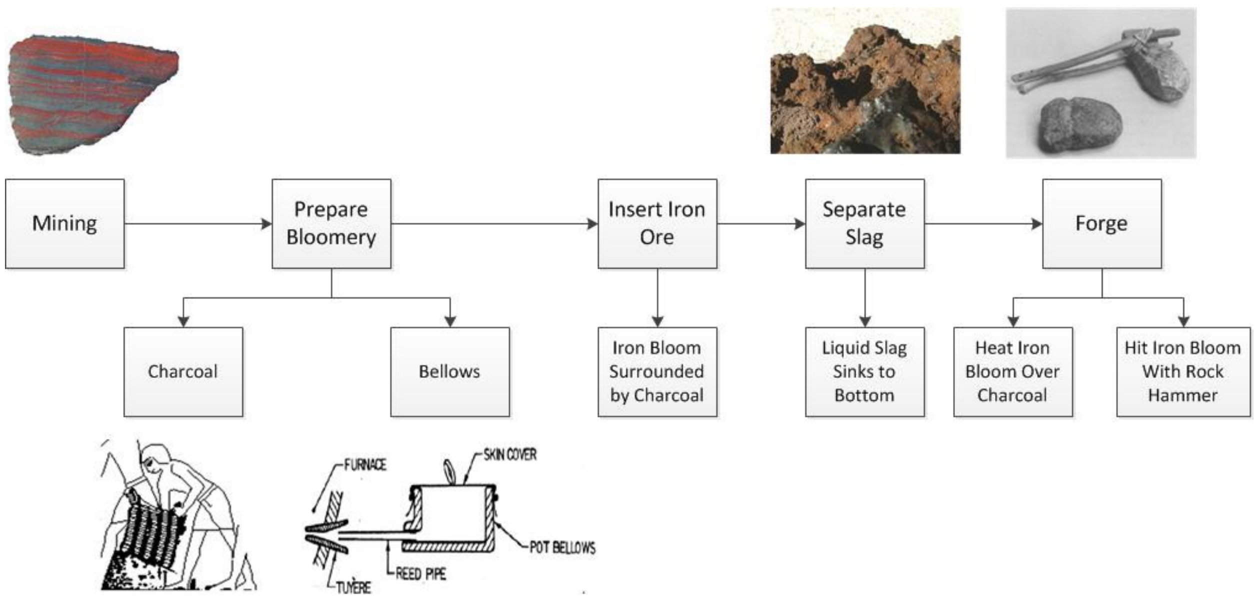


Figure 6: Iron Flow Chart: Mining → Bloomery Smelting → Forging Techniques
(See Image References)

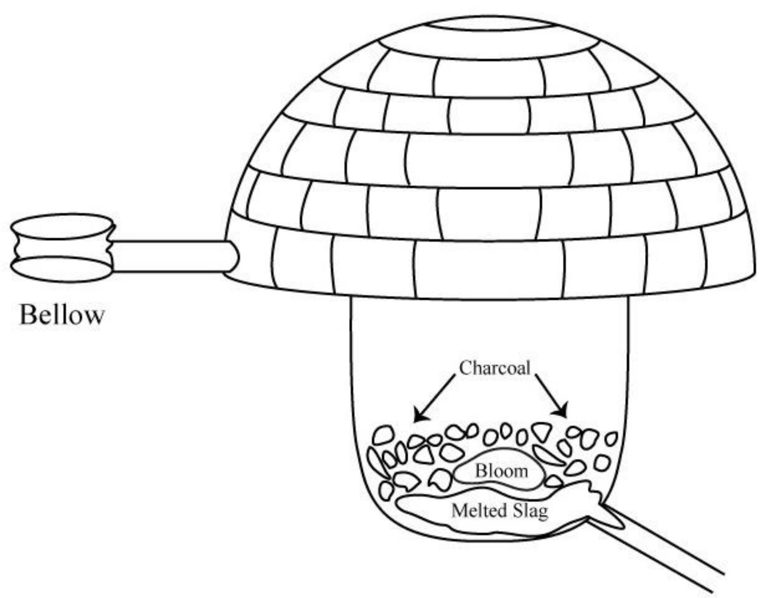


Figure 7: Bloomery (Haidar, Diana. Illustrated by Tania Richter)

After 1200 B.C.E. the Assyrians, not the Hittites, were the major iron producers in the Middle East. Although they did not need to improve the iron bloom process, they did use trade to separate the creation of wrought iron from forging iron into the desired object. There were many cases in which the blacksmith that completed the smelting process did not forge it into the final shape. Instead, he would make iron ingots that were transported from the bloomery area to blacksmith shops elsewhere, such as the ingots discovered in Nimrud from Figure 8 and Figure 9. It was with these secondary blacksmiths that forged wrought iron into the desired items. During the final shaping process the iron was forged with a charcoal furnace. Unlike in the bloomery, excess carbon released in these forging furnaces did not have an oxide to combine with. Instead, the carbon from the charcoal interacted with the iron to make the alloy called steel. These objects were not true pieces of steel because they did not have carbon distributed uniformly throughout the material, alternatively the outside surface was carburized as steel and the inside was still wrought iron. In effect, the carburization of the iron only provided a hardened surface. Despite the fact that iron working was an arduous task, it became very common because iron is much stronger metal than copper and bronze.

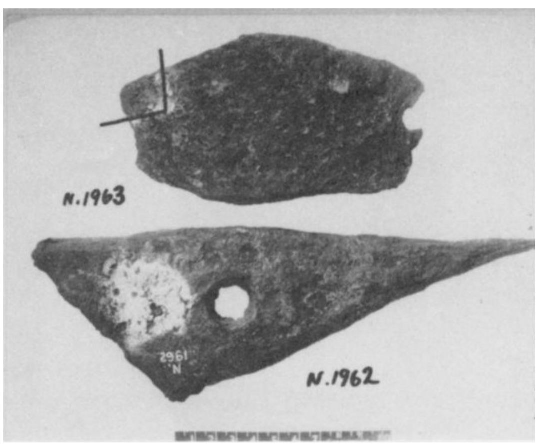


Figure 8: Nimrud iron ingots, scale cm,
N. 1962 and N. 1963
(Courtesy of Dr. J.E. Curtis)

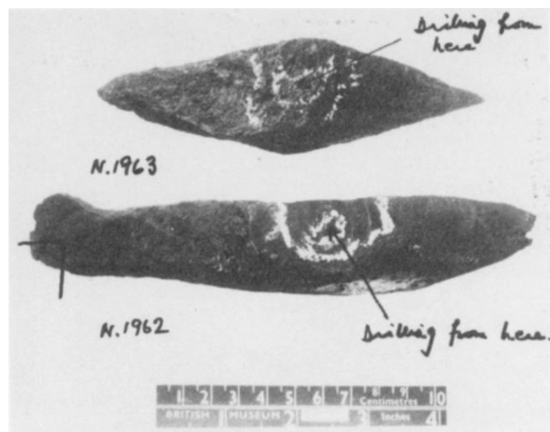


Figure 9: Nimrud iron ingots, scale cm,
N. 1962 and N. 1963
(Courtesy of Dr. J.E. Curtis)

Chapter 3: Assyria's Technology and Culture

Between the 3rd and 1st millennium B.C.E. Mesopotamia was the center for multiple civilizations: the Sumerians, the Akkadians, the Babylonians, the Assyrians and the Babylonians again. At first glance these peoples seem divided by language, preferred gods, and political ambition, but these societies share many principal characteristics. By residing in the same region of the Fertile Crescent these civilizations were more easily able to pass down their traditions to the next generations, and therefore maintain their culture. For example, long after the Sumerian society had passed, its language and writing were still commonly used by Akkadians. In addition, new civilizations desired to be recognized and accepted by the populace, so they incorporated the traditions and practices of their predecessors to more easily gain legitimacy to rule. Thus, a level of cultural consistency was maintained between the successive civilizations of Mesopotamia. This is shown in part by the Assyrians, who continued the Sumerian believe that the gods were instrumental in providing their people with new ideas and inventions. Like the Sumerians, Assyrians believed that the God of Wisdom Enki created civilization by bringing all of the skills of man together into a cohesive world order. Assyrians also held the belief that Enki was to thank for giving his people metal working skills. Clearly, Assyrians had great respect for and personal connection with the development of technology. Despite this fascinating explanation by the Assyrians themselves, one must look further to justify how Assyria became the first empire to have both iron tools and weapons while expanding its borders.

By 1400 B.C.E. the Hittite Empire was the first sovereignty to have the entire iron working skill set required to produce iron objects from Earth's ore deposits, as depicted by Figure 6 (Parr, 36). This was a significant achievement. For thousands of years, open pit furnaces were used to smelt copper, gold, and silver by melting them. However, to extract iron from its ore required an act of original thought – not only the invention of a new chimney furnace called a bloomery that would maintain high temperatures for longer periods of time – but an entire iron working process of repeatedly melting gangue into slag and hammering the iron bloom to push out un-melted impurities to make wrought iron.

One of the main reasons that the first iron working process for iron ore was created within the Hittite Empire was location. This empire encompassed central to eastern Turkey and the northern Levant region, which included several mountains where approximately four dozen iron ore deposits are currently known (Maxwell-Hyslop, 141). Conversely, Mesopotamia is nearly barren of metal ores (Forbes, 104). The only way for Assyrians to attain minerals, metals, and gems was via trade routes. Due to this deficiency, trading networks existed for thousands of years, but were particularly strong between the Assyrian Kingdom and Hittite Empire during the Bronze Age. Specifically, in 2000 B.C.E., Mesopotamians had a high demand for tin, the material added to copper to make bronze, because it was not commonly found in Mesopotamia. Based on the need for tin during the Bronze Age, Assyrians founded trading colonies in central Turkey to capitalize on the market (Curtis & Reade, 18).

Near the end of the Bronze Age, roughly 1270 B.C.E., Assyrians were trading with the Hittites for iron objects (Maxwell-Hyslop, 142). This is known from the Kizzuwadna Letter, a recorded of the diplomatic exchange between Hittite king Hattusilis III (1289-1265 B.C.E.) and Assyrian king Adad-nirari I (1307-1275 B.C.E.) for iron dagger blades made in Kizzuwadna (Maxwell-

Hyslop, 142). Kizzuwadna was a region in southeastern Turkey that bordered the Mediterranean Sea and Syria, and then stretched to the north to enclose a section in the center of the Taurus Mountains (Maxwell-Hyslop, 142). The Hittites possessed the Kizzuwadna region and used it as a controlled location for distributing iron ore, iron bloom, and fully-formed iron objects from the king's storehouse and iron working center (Maxwell-Hyslop, 142-143). This control succeeded in protecting the Hittite's intellectual property until about 1200 B.C.E., when the Middle East was permeated by travelers known as the Land and Sea People. This huge influx of people in numerous locations caused both the Hittite Empire and the Mitanni Kingdom to collapse.

Without the Hittite Empire in existence to trade with for objects of iron, a material superior in strength to copper and bronze, the Assyrians began working iron themselves in the 12th Century B.C.E. (Curtis & Wheeler, 369). This was possible by three main factors: the Assyrian trading colonies in central Turkey, the close proximity of Assyria to Turkey, and the capture of iron mines in southeastern Turkey by Assyrian king Tiglath-Pileser I (1115-1077 B.C.E.). After the fall of the Hittite Empire, around 1200 B.C.E., it was only two hundred years later that iron objects were commonly used and owned, marking the beginning of the Iron Age. This implies that the fall of the Hittite Empire caused a dispersal of iron working knowledge. Yet, the Assyrian Empire was the first to make use of this liberated knowledge. This advantage was likely gained by the members of Assyrian trading colonies in central Turkey, who had the means to transport the iron process home to Assyria. Assyria was also much closer to the Hittite realm than other important nations that were well known for metal working, such as Egypt. Lastly, in the 12th Century B.C.E. King Tiglath-Pileser I had attained control of some iron mines in Turkey, including those in the Kizzuwadna region. Dominion over such areas gave Assyria the advantage of easy access to mines and safe transport of iron materials via their re-captured trade routes.

When iron was transported to Assyria, the first iron blacksmiths in Assyria were linked to the royal court and initially forged iron objects into dagger blades and arrowheads, seen in Figure 10 and Figure 11 (Curtis & Wheeler, 369). The presumption that iron was initially availability to only the societal elite is supported by tablets and grave sites. From an excavation in Nimrud of early iron working period in Assyria, 405 graves were identified and 203 contained metal objects, but only 33 of those had items of iron (Curtis & Wheeler, 370). Furthermore, 35 tombs from this early iron working time, including burial spots of kings, were studied; it was found that 27 contained metal objects and 5 possessed items of iron (Curtis & Wheeler, 370). Therefore, the assumption that elite Assyrians had iron objects first is confirmed by comparing the two sets of tombs, where only 8.15% of general tombs and 14.29% of higher class tombs contained metal objects.

Figure 10: Nimrud sickle blade, scale cm, ND. 1720 (Courtesy of Dr. J.E. Curtis)

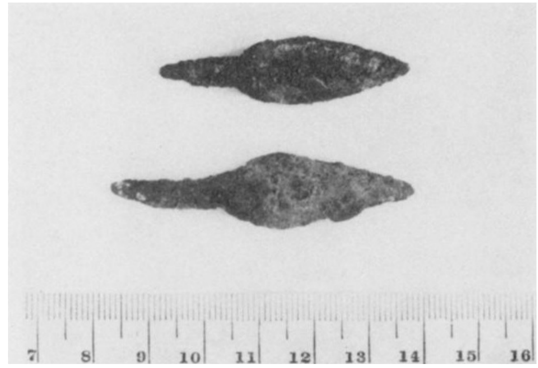


Figure 11: Nimrud arrowheads, scale cm, ND. 7534 (Courtesy of Dr. J.E. Curtis)

Despite the fact that iron ore is largely available in areas surrounding Mesopotamia, such as Turkey, the Levant and Asia Minor, few excavated Assyrian cities have been found to contain iron artifacts. The Assyrian cities that do contain a recognizable number of iron artifacts have been capital cities – Ashur, Nineveh, Nimrud and Khorsabad. Thus, the Assyrians copied the Hittites by keeping knowledge of iron working as their own intellectual property by geographically restricting it to the heart of the Assyrian Empire.

In order to control the iron working process, as much as possible considering the knowledge had already begun to spread since 1200 B.C.E., the Assyrians dominated three main locations: mines, trade routes and blacksmith shops in important cities. The location of Hittite iron mines was not a secret to Mesopotamian monarchs whom traded with them for iron goods. For example, Adad-nirari I asked Hattusilis III for permission to visit iron ore deposits in the Amanus Mountain range now known as Nur Dağlari in Turkey, which is southeast of the Kizzuwadna region and runs north to south on the Mediterranean coast (Maxwell-Hyslop, 145). Hattusilis III refused the request, indicating that it was not the location but the activities at the iron mines that were concealed within the Hittite Empire borders.

Before roughly 1200 B.C.E. the Hittite Empire guarded the trade routes in northern Levant and central to eastern Turkey, which provided the territory necessary to connect their iron mines at that time. After the fall of the Hittite Empire these trade routes were unguarded and therefore unreliable. Assyrian king Tiglath-Pileser I changed this by conducting distant campaigns to secure trade routes, that when combined formed a large trading network and re-introduced a consistent means to transport goods. A few of the iron ore deposit Assyrians likely controlled were the Amanus Mountain, Kizzuwadna region, and Diyabakir region approximately 200 km (124 miles) west of Lake Van (Maxwell-Hyslop, 144). After about 1000 B.C.E. the process required of iron working was well known throughout the Middle East. Therefore, it was more important for Assyria compared to their Hittite predecessors to protect the trade routes, because stolen iron ore or iron bloom could be shaped into usable iron objects instead of simply re-trading it in a market to Assyrian blacksmiths.

As the knowledge of iron working spread, the variety of iron objects increased. In the 9th Century B.C.E., Assyrian blacksmiths were forging iron into rings that have been found at burial sites in Khorsabad and axes that were documented to have cleared walking paths along side the Euphrates River (Curtis & Wheeler, 369). Other objects made with iron were armor scales and agricultural hoes, images of these are shown in Figure 13 and Figure 14. Having agricultural tools as one of the first new objects made of iron in the 9th Century B.C.E. signifies the importance Assyrians placed on agriculture in their economy. One of the reasons Assyrians transitioned to making a wider variety of iron items, that were traditionally made with bronze, was that iron objects had a longer lifetime and a reduction in sharpening or reshaping, because iron is a stronger and harder than bronze so it was better at maintaining its shape. Another benefit to replacing bronze with iron was a reduction in weight of the same sized object; the density of iron is $7.87*10^3$ kg/m^3 (490 lb/ft^3) and bronze with 10% tin is $8.64*10^3$ kg/m^3 (540 lb/ft^3).

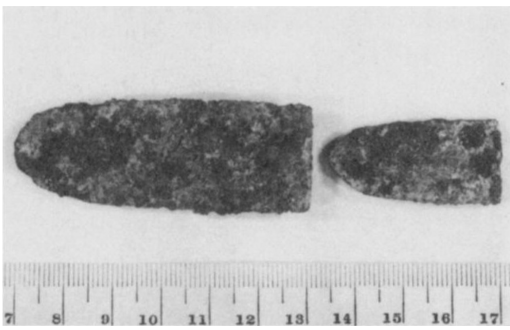


Figure 13: Nimrud armor scales, scale cm, ND. 9267 (Courtesy of Dr. J.E. Curtis)

Figure 14: Nimrud hoe, scale cm, ND. 6164 (See Image References)

Iron weapons and tools became common items in Assyria's military campaigns in the 9th Century. This made the Assyrian Empire unique, because it was the first empire to have iron weapons while expanding its territory. When the Assyrian army went on campaign they brought with them many skilled groups: chariotry, cavalry, bowmen, lancers, and engineers (Kramer, 57 & 60). It was the engineers that applied iron in new ways. King Assurnasirpal II (883-859 B.C.E.) had engineers that created an iron-headed battering ram as a siege weapons, this concept is shown in Figure 12 (Kramer, 57). Cities that came under attack usually had wooden, copper or bronze doors, which were broken down more easily and sooner with an iron-tipped siege weapon. This is one example of the large advantage Assyrians had over their military adversaries.

Figure 12: Assyrian Battering Ram with metal-covered tip and six wheels, 9th Century B.C.E. (See Image References)

In sum, the bloomery and gangue removal process used to smelt iron ore were original and revolutionary inventions. The Hittites were first to have this knowledge, because of the plentiful iron ore deposits available in Turkey. They maintained the secrecy of the iron smelting method until the empire fell and residents of the empire spread out with the knowledge, such as members of Assyrian trading colonies in central Turkey who transported the intelligence to Assyria. This singular piece of information utterly changed Assyria. Without the Hittite Empire and Mitanni Kingdom present after 1200 B.C.E., the kings of Assyria were unchallenged as they proactively pursued the resources unavailable in Mesopotamia, particularly iron deposits in the northern Levant and Taurus Mountains. Then, they attained the means to transport iron to the heart of Assyria by gathering land under their control to make trading networks, which led to the kingdom expanding into an empire. The transition from kingdom to empire provided wealth from conquests and regular taxes, which was beneficial to the Assyrian people because it was used to improve the economy by boosting agricultural production in rural areas and promoting the continuation of imperialism by building architectural sculptures in urban capital cities. Also in the capital cities Ashur, Nineveh, Nimrud, and Khorsabad were some of the first blacksmiths that experimented with iron blooms in order to make a variety of new iron objects – hoes, armor scales, rings, axes and more. From experience, Assyrians learned that it was advantageous to replace bronze objects with iron ones because of the increase in strength that lengthened object lifetime, the enhanced hardness that kept the object in its original form so re-shaping was conducted less often, and the decrease in weight per volume. In effect, the Assyrians' desire to use iron provided not only a purpose for conquering new territories with such resources, but a critical military advantage over them.

Image References

(in order of appearance)

Lamassu from Nimrud

© The Metropolitan Museum of Art. www.metmuseum.org

Destruction of the city Susa by Assyrians

GNU Free Public License. Wikipedia. "Susa." Retrieved March 2011, http://en.wikipedia.org/wiki/File:Susa-destruction.jpg

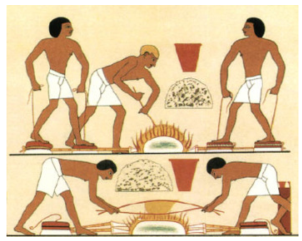
Copper ore with malachite green oxide

Courtesy of Sterling Hill Mining Museum. Zobel Exhibit Hall, http://sterlinghillminingmuseum.org/whatshere/zobel.php

Slag solidified with some copper

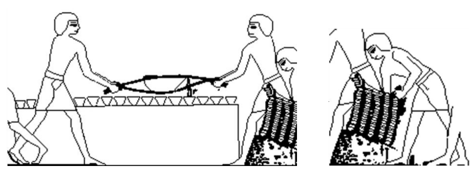
Courtesy of Copyright Owner Petrie Museum of Egyptian Archaeology, University College London, UC20079. http://www.digitalegypt.ucl.ac.uk/buhen/kiln.html

Stone Hammer



Egyptian Smelting - prepare furnace, use bellows to provide air flow, insert crucible with solid metal, melt metal, scoop out slag floating at the top, use tongs to lift crucible with melted metal out of furnace

Graphic by Achille-Constant-Theodore Emile Prisse d'Avennes and based on an Egyptian Wall Painting in Rekhmire's Tomb.



Casting metal around 1540 B.C.E.

Crucible from South Asia

Courtesy of Copyright Owner University of Pennsylvania Museum of Archeology and Anthropology. http://www.digitalegypt.ucl.ac.uk/buhen/kiln.html

Meteorite iron – can be forged into desired object

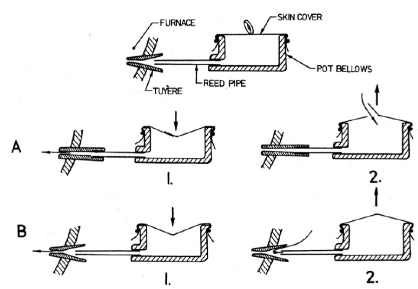
Courtesy of Copyright Owner Aerolite Meteorites. http://www.aerolite.org/iron-meteorites-2.htm

Iron ore with bands of hematite red oxide – must undergo smelting in a bloomery before forging into desired object

Courtesy of Copyright Owner Mining Artifacts and History Museum. http://www.miningartifacts.org/IronOres.html

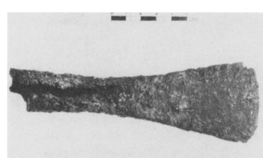
Mass of iron bloom, slag, and charcoal

Courtesy of Copyright Owner The Dhamurian Research Society - The Gympie Pyramid. Queensland, Australia. http://www.gympiepyramid.org/slag.html



Mesopotamian bellows for blowing air across charcoal, style A and B

Courtesy of Copyright Owner Davey, C.J. “Some Ancient Near Eastern Pot Bellows.” *Levant* 11, no. 1. (1979).



Farming hoe from Nimrud, ND. 6164

Courtesy of Ashmoiean Museum of Art and Archaeology. http://www.ashmolean.org/

Bronze gates of Balawat show a metal-tipped Assyrian siege weapon

Glossary

Anneal
definition: a re-crystallization of the metal lattice, which provides increased strength and hardness after the metal cools

Bloomery
definition: a deep pit with a short chimney or a shallow pit with a tall chimney for smelting iron, usually made of clay or stone

Cast
definition: the act of pouring liquid metal into a mold so that it solidified into the shape of the mold as it cooled.

Flux
definition: a chemical that attaches to oxygen from the ores' oxides

Forge
definition: a repetitive process of heating to soften and hammering to shape an ingot

Gangue
definition: the unwanted minerals in the ore

Ingot
definition: a mass of metal in a standard shape

Metal lattice
definition: the organization of atoms in a crystal shape

Mineral
definition: a naturally occurring solid chemical substance that is formed through geological processes and is a homogeneous substance with a highly ordered atomic structure

Mold
definition: a clay or sand structure that has been hollowed, the metal melt fills the empty cavity and takes its shape upon cooling

Ore
definition: a rock made up of mineral aggregate and metal elements, it is naturally formed in Earth's crust and generally attained by mining

Slag
definition: the byproduct of excess minerals (gangue) in the ore from smelting

Smelt
definition: the extraction of a metal from its ore

Strain harden
definition: shaping a metal at room temperature, which forces movement of the metal's lattice structure and produces increased strength

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