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The relative value and role of copper within an Egyptian New Kingdom economic context: Using production, trade and use of copper as indicators of copper's value

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THE RELATIVE VALUE AND ROLE OF COPPER WITHIN AN EGYPTIAN NEW KINGDOM ECONOMIC CONTEXT

Using production, trade, and use of copper as indicators of copper's value

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ABSTRACT

This thesis, The Relative Value and Role of Copper within an Egyptian New Kingdom Economic Context, was submitted to the American University in Cairo by Daniel Shay Matthew Johnsen, under the supervision of Dr. Salima Ikram.

Ancient Egypt's use of copper was extensive and represented a sizable portion of Egypt's metallurgical focus. There has been limited discussion about the metallurgical technologies of the New Kingdom or the role of copper in an economic context. This thesis examines the modes, methods and technologies involved in copper acquisition, processing and use to ascertain and demonstrate the relative value of copper within the economy of New Kingdom Egypt. It is argued that copper represented one of the greatest and most widely used commodities available to the Egyptians. Various economic theories are also highlighted to compare possible effects of copper on both local and foreign trade. This work is designed to elicit further study into the interplay between metallurgy and economic development and provide a possible methodology for such a study.

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Chapter 1 - Introduction

Metals play a key role in the material culture of both ancient and modern civilizations. One of the most important metals to be used in ancient Egypt was copper, which was a key material in the production of Egyptian goods and the development of Egyptian economy and technologies from the Predynastic period onward. Although used intermittently during the earliest periods of Egyptian history, copper was particularly vital to the manufacture of weapons, tools, and other objects during the New Kingdom (c.1550 to 1070 BC). This thesis will examine the modes, methods and technologies involved in copper acquisition, processing and use in an attempt to ascertain and demonstrate the relative value and role of copper within the economy of New Kingdom Egypt.

Materials determine and guide the advancement of the societies in which they are used, and copper use shaped Egyptian civilization and technologies more than any other readily available industrial material. Copper is among the first metals mined and used anciently, and while the technologies utilizing it have shifted, it remains a valuable and useful commodity. Although many scholars have discussed different aspects of copper and copper related industries, limited scholarly work has been done on the role these materials and technologies played within the Egyptian economy, which is the focus of this study. Most previous economic discussions have relied heavily, and in some cases exclusively, on textual sources for their analysis. This study will utilize archaeological, textual and ethnographic information together to examine the impact that copper, along with its coordinating fields of influence, had on Egypt's economy. The inclusion of additional source types greatly enhances potential analysis performed by historians and archaeologists, and facilitates in a deeper understanding of how individual commodities functioned within an overarching economic context.

Earlier Studies

Metallurgy is a multi-disciplinary topic, requiring at least a basic understanding of geology, engineering, chemistry and historical contextualization on both a local and regional level. If one is to fit metal use into a wider context, some knowledge of various economic theories is also useful. It is the goal of this work to use information from each of these fields to create a more holistic perspective than previous works, and to emphasize the interconnectivity between disciplines that study copper and its related metallurgical activities. Prior studies all add unique perspectives and inform the overall interpretations of the role of copper within New Kingdom Egypt presented in the current work.

In reviewing materials and technologies of ancient Egypt, two seminal works standout as the primary contributors – A. Lucas's *Ancient Egyptian Materials and Industries* (1926) and P. Nicholson and I. Shaw's *Ancient Egyptian Materials and Technology* (2000). For many decades Lucas represented the foremost voice in the field of technologies and materials, which lead to many of editions of the work, including the 1962 revision by J. Harris. However, more recent editions of the Lucas and Harris volume are merely reprints of the 1962 edition, and thus fail to incorporate new analysis gathered from archaeological findings on resource management, tool production and metalworking in the past five decades. After some 70 years, it has been superseded by the Nicholson and Shaw volume. Nicholson and Shaw sought to update Lucas and Harris by drawing in experts to provide information on their specific fields within the overarching context of materials and technologies. Their work is substantial and relevant for those researching metallurgy. J. Ogden, who writes the chapter on metals within the Nicholson and Shaw volume, presents the specific metals used by the ancient Egyptians as well as pertinent archaeological findings and how they contribute to our understanding of metalworking. Each metal, including copper, silver, gold, iron and various alloys like bronze, receives individual attention.[1] Copper, gold and copper alloys receive the greatest consideration as they are heavily associated with and important to Egypt's status in the ancient world. Some of the specifics Ogden discusses about these metals include their primary mining and processing sites, a general chronology of their use, a basic overview of refining methods, the manufacturing processes involved in the creations of ancient metallic objects and the potential social significances of the use of metals within certain contexts. He also addresses the advancements and experiments involved in ancient alloying technology and the various mixtures used by the ancient Egyptians. Because the chapter discusses metals in general, focusing on the importance of one particular metal is beyond the scope of Ogden's work, but he lays the groundwork for such a discussion to take place.

B. Scheel (1989) provides a brief, easily accessible synopsis on the processes involved in mining and metallurgy, explaining both the metal purification, or smelting, processes and the preparation of metallic goods. This work is valuable as a primer for those new to the study of

[1] Ogden, 2000: 148-176.

ancient metallurgy. His earlier work (1987) on the depictions of metallurgy in Egyptian tomb scenes focuses on some of the guidelines that the Egyptians used when displaying metalworking activities during the New Kingdom.[2] This analysis is useful when examining scenes in the tomb of the 18th Dynasty vizier Rekhmire (TT 100), which includes several of the key depictions of Egyptian metalworking during the New Kingdom.[3] These scenes are perhaps the most frequently cited examples of illustrations of Egyptian metalworking, and many individual elements of those scenes are used by Scheel to demonstrate particular metallurgical practices.

The *Proceedings of the First International Conference on Ancient Egyptian Mining and Metallurgy and Conservation of Metallic Artifacts,* edited by F. Esmael (1995), provides a wealth of information for those desiring greater insight into the use of all types of metals in Egypt. Several contributing authors, including C.T. Shaw's discussions on New Kingdom mining technologies, J. Merkel's report on experimental archaeological projects, A. Herold's comments on high temperature industries and G. Castel and others, who review the early metallurgical activities at Wadi Dara, provide valuable information on the context for ancient Egyptian metallurgical activities. While these authors' contributions include important additions to the topics of the mining and industries reliant on copper work in the New Kingdom, little is directly stated about its economic value and significance.

Other works that discuss mining also include at least brief considerations of processing practices as well as other metallurgical activities, such as fire-setting, annealing and casting. P. Craddock (1995) prepared a lengthy and detailed treatise on mining and metallurgy, which provides valuable insight into the general technologies employed in the removal of material and the development of certain techniques and technologies across the world. While Egypt and the Near East are addressed in the work, they are not the main focus and some of the more recent archaeological discoveries, which occurred at the time of the work's publication, like those of E. Pusch at Qantir, are not included. D. Arnold covered quarrying practices in Egypt specifically, providing valuable examples, photos and illustrations in *Building in Egypt* (1991), which discusses the various uses of stone in Egypt. B. Rothenberg's (1966) excavations, which covered mining operations in the area of Timna, give insight into the copper processing occurring at or near ancient

[2] Scheel 1987: 248.
[3] Davies 1973. Davies, originally produced in 1943, provides comprehensive reproductions of the scenes available in TT 100.

mining sites. Timna also contains multiple mining sites from different time periods, which have provided valuable information for New Kingdom technologies of ore extraction and processing as well as comparison to techniques used during other periods. Pusch's (1990 and 1995) publications on Qantir shed light into the practices of metal refinement, alloying and general metallurgy in Egypt proper specifically during the New Kingdom. Pusch's identification of an industrial center at the capital city of Per-Ramses provides a very important case study for how copper was further processed and prepared. This processing site is, however, atypical in that its location is far from any mining sites, which were the traditional settings for smelting and other refining procedures.

N. de Garis Davies's facsimiles and evaluations of tomb depictions from Thebes (1947, 1963 and 1973) provide artwork of metallurgy and trading. These documents and scenes give contemporary examples and sources of information from which one can postulate the value of copper within the New Kingdom. The facsimiles of the tomb of Rekhmire (TT 100), published in 1973, and the tombs of Kenamun (TT 162) and Hepu (TT66), both included in the 1963 publication, are of particular importance to this study as they provide clear examples of metalworking and trading activities during the New Kingdom. Rekhmire's tomb contains a number of different types of craft production, but the clear depiction of smelting, metal shaping and large-scale casting gives indication of the processes followed by the Egyptians.

While these works provide insight into the technologies surrounding copper and copperworking, there is little work that provides direct information on the role of copper in ancient Egypt in economic terms. However, J. Janssen's (1975b) *Commodity Prices From the Ramessid Period* offers an invaluable contribution to the discussion of the role of copper within the New Kingdom economy, taking the form of a collection of commodity prices from the workmen's village of Deir el-Medina. Janssen's work is consistently referenced and relied upon in any discussions of commodities, objects and economic factors within the New Kingdom. The difference between his work and the present discussion is his focus on textual sources. This thesis focuses on archaeological and pictorial evidence, as well as addressing issues such as social organization and politics together and discusses the relation these sources had with copper and copper use. W. Helck (1975) has also enriched the discussion on the economic values of commodities, but his work focuses primarily on the value of foodstuffs and, regrettably, does not address metals.

General discussion on the organization and theoretical analysis of the Egyptian economy relies heavily on the work of K. Polanyi (1957). Polanyi postulated that the economies of early civilizations did not engage in what could be considered pseudo-capitalism, nor did ideals focus on wealth acquisition and the principles of supply and demand in the way modern economies do. His theories have shaped many "Substantivist" models proposed for the Egyptian economy and are routinely referenced in most of the literature on the topic. Helck (1975), Janssen (1975a) and E. Bleiberg (1984, 1988 and 1989) all follow the Substantivist economic model, claiming that systems of redistribution constituted the primary method of exchange in ancient Egypt.

Opposing this theoretical economic model are those scholars labeled "Formalists" who argue that free-market exchanges played a significant role within the Egyptian economy. The foremost proponent of this model is D. Warburton (1997, 2009 and 2012). Warburton follows a modified Keynesian economic model claiming that the redistribution systems were used as a method of economic stimulus and control, similar to the involvement of governments in present-day economics. B. Kemp (2005) also claims that the "economic man," or rather the cultural values that drive personal economic advancement and the roles played by supply and demand, began developing much earlier than Polanyi suggested. A. Zingarelli (2010) further points out the role individual exchanges, usually involving privately-owned commodities, played within Deir el-Medina. Zingarelli, in particular, adds substantially to the role market and private exchanges held within New Kingdom village economics, even within a village that was largely controlled by state and religious institutions. Ultimately, the two prevailing theories, the Substantivists and the Formalists, debate primarily on whether or not Egypt had a self-regulating market economy, and to what degree the temples and state organizations influenced or directly controlled trade.

Recently, B. Muhs (2016) proposed another model that shifts focus away from the degree of power that markets held over the Egyptian economy to discuss instead the costs and benefits associated with exchanges made in both redistributive systems and market systems. This New Institutional Economic (NIE) model argues that citizens had the ability to choose between available systems of exchange and would make their decisions based on the best perceived outcome for their individual needs and wants. It is through analyses like that presented by Muhs that discussions on individual commodities will begin to have greater import, since holistic approaches provide a broader context in which to make the costs and benefits associated with certain commodities clearer.

Methodology

Unfortunately, none of the existing literature attempts to analyze a single type of material or commodity within an economic context. As a result, there does not appear to be a standardized methodology for executing such a study. The vast majority of previous economic analysis focuses on recorded exchange rates and prices, which of necessity must come from textual sources. The failure to include or acknowledge other indicators or influences, usually only identified from other types of sources, on the value held by certain commodities creates an often limited picture of the economy of ancient Egypt and the interplay between the various social forces and organizations governing daily life. In an effort to create a methodology that addresses these factors and provide a broad contextual understanding of the role of copper as a commodity within Egypt, this thesis will use general information on the commodity, ancient images, copper artifacts, excavation and processing sites, proposed techniques for the production of goods and other related technologies along with the more traditional textual sources to discuss the role and value that copper held within an Egyptian New Kingdom economic setting. This work is designed to help create a methodological template for future studies analyzing single materials to shed light on their processing, significance and economic value.

To adequately cover the subject matter and place an analysis of the commodity within academic and economic contexts, the proposed methodological model must first focus on the attributes of the commodity that contribute to its value. Next, the procurement methods of the commodity need be discussed along with the difficulties associated with those methods. The commodity's refinement should also be reviewed if applicable. The use of the commodity within material goods and other aspects of daily life have to then be outlined and analyzed. A discussion of which modes of economic transactions the commodity was involved with and any relevant economic theories should round out the discussion and provide direct information on the exchange rates between commodities used by the society or civilization in question. Finally, all this information must be used to synthesis a conclusion on the relative importance and value the analyzed commodity held within a specific cultural and economic context. This thesis will use this proposed methodological framework to identify copper's role and value within Egypt.

Following the Introduction (Chapter One), Chapter Two will discuss copper as a material, outlining its attributes, the accepted chronology of its use in Egypt, and sources for it within Egypt and the Near East. This general information will facilitate in the further discussion of copper as a commodity and outline some possible reasons for its intrinsic value, which is discussed in detail in Chapter Six.

Chapter Three will address the processes and technologies involved in extracting copper minerals and ores from mining locations. The discussion will include the types of mining operations and tools used in Egypt, as well as the process of removing material from the mines and sorting it for attempted alloying. Due to the lack of standardization in alloying technologies, the discussion will of necessity include some speculation.

Chapter Four will deal with smelting, its supporting technologies and the number of individuals required for the completion of such tasks. These refining activities were a necessary step in the use of copper, as well as other metals, and represent significant factors to its economic role. This chapter depends primarily on general knowledge related to copper working framed within an Egyptian context. Chapter Five will provide a detailed examination of the types of artifacts produced with copper and the modes of their production. A discussion of the artifacts, along with their relative reliance on copper and their designated functions, will be included with examples drawn from museum collections.

Chapter Six will relate some of the economic theories prevalent in the discussions of ancient Egypt. These theories frame the majority of previous economic analysis and without discussing them the methodology proposed in this work will be difficult to place within the overarching discussion of ancient economies, and ancient Egypt's economy in particular. A brief analysis on possible methods of long distance trade with Egypt's regional partners and vassal states during the New Kingdom will also be presented. While an in-depth analysis of such trading operations would greatly add to the discussion of copper's regional significance, such a discussion goes beyond the scope of the present work. Documented exchanges, contemporary with New Kingdom Egypt, will provide preliminary examples of, and guidelines for, establishing the relative value of copper within the prescribed context.

Before proceeding, some terms used in this work will need to be defined. The term *value* will herein mean the degree or quality of usefulness or desirability and how it relates to the principle of fair exchange.[4] As such, it is important to establish that this work is not primarily concerned with the quantitative evaluation of copper, as the primary evidence for such an analysis is limited principally to exchanges within Deir el-Medina that Janssen admirably covers.

[4] Ikram 2011: xviii – xix; Muhs 2016: 9.

Quantitative analyses focus on the role commodities played as a form of currency or barter exchange, which is broadly defined as a standardized unit of exchange and storage for wealth. This quantitative value is difficult to identify for the New Kingdom since standardized coinage was not introduced into Egypt until the Late Period.[5] Although the use of coinage is just an extension of the processes of standardizing exchanges and the monetization of an economy, its development represents a type of formal cultural acceptance of these ideals and the establishment of fixed quantitative values for commodities. The accepted exchange rates of the New Kingdom fluctuated greatly as economic situations during the period in question changed at various times, sometimes quite drastically.

The focus of this work will instead be the qualitative value of copper within Egypt and its economy. This qualitative value is relative, and can more easily be discussed within non-monetary systems of exchange. Multiple types of sources, beyond traditional textual sources, have been included along with research from various fields in order to better identify the qualitative value for copper. Special attention will be given to the impact copper related industries had on production and technology as well as the significance that copper tools held for craftsmen. A discussion on the types of employment and the necessary workforce required for the acquisition, processing and production of copper and copper alloyed goods will be included to account for the unique systems of labor used by the ancient Egyptians, which directly impacted the way their economy functioned. To establish contextual theoretical understanding from which to evaluate and assign value, multiple economic theories about ancient economic development will receive attention and explanation. This thesis will attempt to address the discrepancies between the prevailing economic theories by drawing attention away from establishing a *monetary* value for copper and instead discussing a *relative* value of copper with regards to its utility and desirability in technological, social, administrative and religious functions within Egypt, and its tradability in exchange scenarios between the civilizations of the ancient Near East.

The conclusion, Chapter Seven, will attempt to provide a clear indication of copper's relative value to New Kingdom Egyptians through comparison and analysis of the information presented in previous chapters. Such an analysis should provide a useful addition to the discussion of copper in ancient Egypt, not just in terms of a raw material and the technologies associated in its extraction and working, but also the role that it played in Egypt's economy.

[5] Curtis 1957: 71; Bolshakov 1992: 9; von Reden 2006: 165.

One problem that overshadows the process outlined for this thesis is the subjective nature of value. Value can only be established through the mutual consent of those involved in transactions and exchanges. These transactions and exchanges are vulnerable to the context in which they occur. That context can include things not easily shown in the archaeological record including the needs and desires of those involved in the exchange, the ideological or social forces driving the use of the materials, and the fairness – an attribute largely determined by cultural norms and attitudes – of the individuals participating in the transaction. To better understand the subjectivity that value has within exchanges, one should consider the different values two hypothetical craftsmen might give a particular weight of copper/copper tool. One craftsman is a stoneworker with an ample supply of state provided copper chisels, while the other is a carpenter in need of a new copper-bladed saw. They both have access to the metal through an open market system and the price is fixed. The craftsman in greater need of the metal for a new saw will perceive the value of the metal to be greater than the craftsman who does not need new tools. In either case the price remains fixed, but the value changes as a result of the conditions of those involved in the exchange. Economists will sometimes refer to this subjective increase in value as a commodity's *utility*. Since this utility and value are only determined through the exchange, and more broadly through group consensus, this work seeks to merely provide additional perspective and a possible methodology through which commodities may be analyzed rather than seeking to definitively state a quantitative or monetary value for copper.

Another problem with addressing copper's role within the New Kingdom from an economic standpoint is the integrated nature of economies. Economies rely on nearly every other sector of the societies in which they develop. They are indirect indicators of the norms and values that civilizations espouse. They both shape, and are in turned shaped by, the political motivations of leaders and institutions as wells as the circumstances of foreign affairs. While ancient economies do not clearly follow the market driven systems of supply and demand, they nevertheless rely on the availability and preference of certain resources over others. The wide breadth of topics that impact economy mean that it is likely one cannot cover effectively all of the possible factors on copper's value.

Chapter 2 - Copper as a Material

Copper, known to the ancient Egyptians as *ḥmt* or *bi3,* is a naturally occurring metallic element that forms thin, crumpled, sheet-like or small nugget formations in its native form.[6] It is identified as the 29th element listed on the periodic table (Cu), having an atomic mass of 63.546 u, a melting point of 1085^0 C, and falls into the category of transitionary metals, which do not react with water. It is lustrous, meaning it reflects light, and it is salmon-pink or metallic orange in color. At a microscopic level copper is poly-crystalline in form, meaning that it is made up of tiny irregularly aligned crystals.[7] These crystals provide structure while the amorphous conglomerate allows the metal to be shaped either through cold-hammering or molten processing.[8] Although copper's hardness is low in comparison to other metals, 2.5 to 3.5 Mohs, copper's durability, once it is processed, contributes to its utility and use within ancient tools.[9] Copper is primarily recognized in the modern era for its electrical and heat conductive properties, which is why it is widely used today in electrical wires and in plumbing.[10]

Although copper is unreactive with water, it is subject to atmospheric oxidation, which causes exposed copper surfaces to develop a thin coating, called a patina, which protects the copper from further degradation.[11] This patina is normally green in color, although through different processing methods various colors can be achieved.[12] This patina also contributes to the coloration of minerals that contain copper, most commonly malachite. Malachite [$Cu_2CO_3(OH)_2$] is a copper carbonate that develops within sedimentary geologic strata and is easily identified by its bright green color.[13]

Copper can be found in small quantities in its native state, but it is most commonly found within minerals, such as malachite and azurite. It is estimated that nearly two thirds of the Earth's copper supply can be found within igneous geologic layers and that the most common orebody containing copper is porphyry, usually as chalcopyrite ($CuFeS_2$).[14] While Egypt contains deposits

6 Muhly 1999: 522-523.
7 *The New Encyclopaedia Britannica – micropaedia*, 15th ed., s.v. "Copper."
8 Poole, et al. (1996): 559.
9 Junk 2003: 22; Poole, et. al. 1996: 563.
10 Doebrich 2013.
11 *The New Encyclopaedia Britannica – micropaedia*, 15th ed., s.v. "Copper."
12 Mohamed and Darweesh 2012: 176; Doebrich 2013.
13 *The New Encyclopaedia Britannica – micropaedia* 15th ed., s.v. "Malachite."
14 Johnson, et al. 2014.

of porphyry, copper deposits are also found within Egypt's sedimentary geologic layers, which are a product of the prehistoric Tethys Sea which covered Egypt during the Mesozoic era. The sea plants, especially kelp, and blue-blooded mollusks naturally contain high amounts of copper that, along with ore bearing discharges from magma vents in the ocean floor, create copper rich brines.[15] This brine then seeps into the developing sedimentary geologic layers and into pockets within the sedimentary layers where the copper crystals can form and bond with the surrounding rock. As these deposits become oxidized, the color shifts and makes them more easily identified.

Ancient Egyptians sought four primary ores for their high copper content: azurite, a blue colored copper carbonate; chrysocolla, a green-blue copper silicate; malachite, a distinctively green copper carbonate; and pyrites, commonly called fool's gold, distinguishable by their metallic yellow coloring and their tetragonal crystalline structure.[16] Copper within Egypt was found most abundantly in the Eastern Desert and the Sinai Peninsula. While copper ores occur along the length of the Eastern Desert, some locations of note for copper mining include Gebel Atawi, Hammash, Wadi Dara and Um Semiuki.[17] The prime mining location within the Sinai is Serabit el-Khadim and its surrounding area, along with the Wadi Maghara and Wadi Nasb.[18] (Fig 2.1)

[15] *The New Encyclopaedia Britannica – micropaedia*, 15th ed., s.v. "Copper;" MacIntyre 1991: 56.
[16] Scheel 1989: 14, 61.
[17] Ogden 2000: 150-151; Castel et al. 1995: 15.
[18] Lacovara 2001: 295.

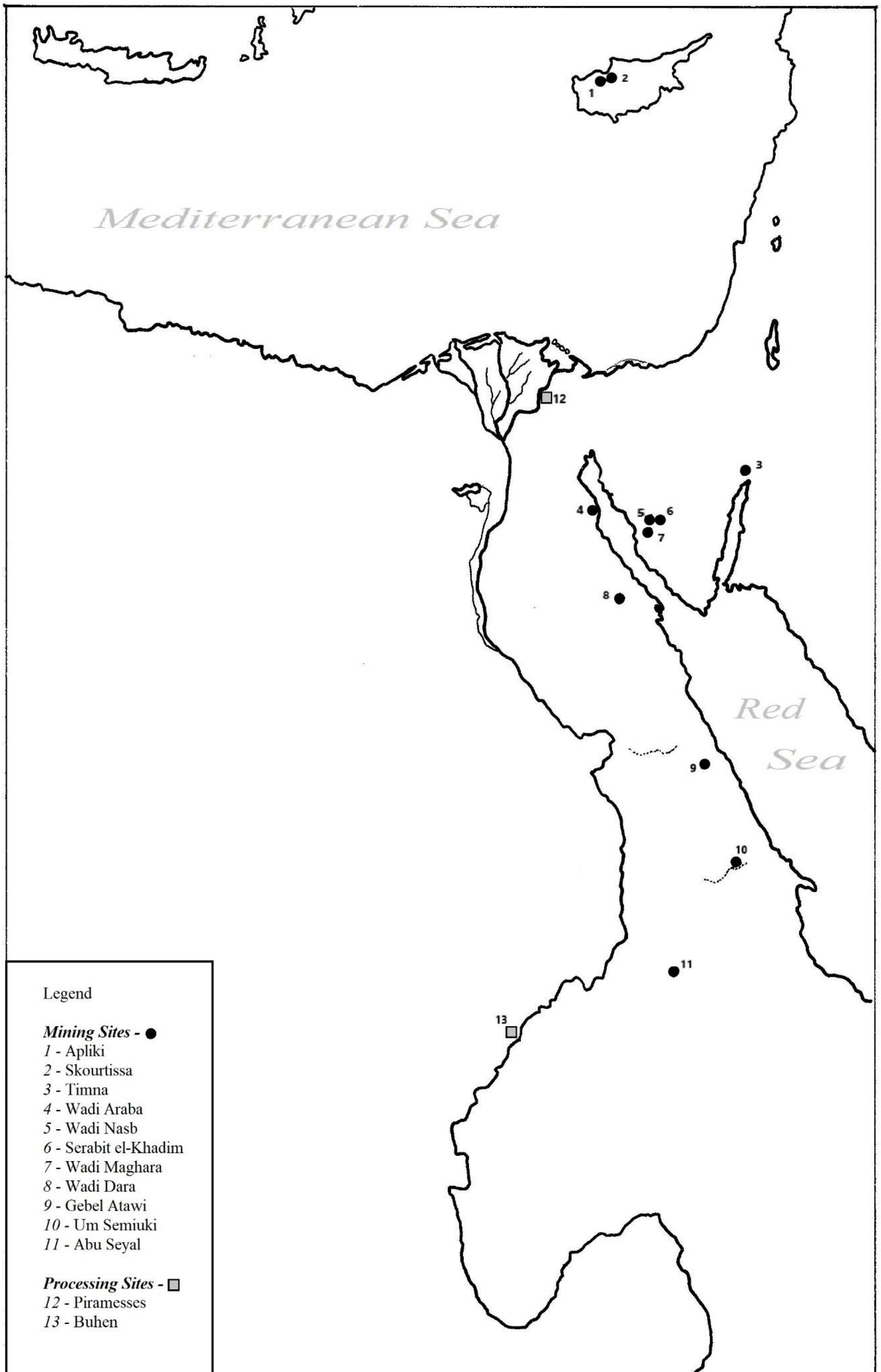

Figure 2.1 Map of Copper Deposits and Processing Sites

Chronology of Copper Use in Egypt

While this work is focused on copper use during the New Kingdom, it is important to address earlier use of the material in Egypt. Most people recognize that the early history of mankind is divided into periods identified by the use of certain materials, i.e. the Stone Age, the Bronze Age and the Iron Age. The use of copper also establishes a stage of development for early cultures and is given the name of the Chalcolithic Period. Each culture has different absolute chronologies for their development, but evidence for copper use in Egypt dates to the Badarian phase of the Predynastic Period (c. 4000 BC), although in other Near Eastern regions it goes back even further, to c. 8000 BC.[19] The early uses for the metal were largely ornamental, taking the form of pins, beads and bracelets and other decorative jewelry. In Egypt, these artifacts have been primarily found in graves dating to that period. These graves also contain scattered examples of copper tools in the forms of knives, chisels and borers. The copper used in the creation of these artifacts was likely native copper, which is evidenced by their relatively infrequent presence, in comparison with stone tools, and the inclusion of small amounts of gold and silver that occur naturally in native copper nodules.[20]

During the Old Kingdom, Egyptians actively engaged in copper exploitation and processing from copper rich minerals as evidenced by mining at some of the locations mentioned above.[21] Facilities dedicated to smelting, the act of obtaining and processing metals from minerals, are found south of Egypt in Nubia at the site of Buhen, and mining structures are found in the Sinai Peninsula at Serabit el-Khadim and Wadi Dara, both of which show evidence of Old Kingdom use.[22] There are records, especially later in the New Kingdom, that discuss the deployment of royally appointed expeditions to locate desired stone or minerals, but it is unclear exactly how early mining locations were discovered or identified. It seems likely that the rich coloration of the minerals would have been a primary factor in locating new deposits. In areas around the Wadi Feinan, in present day Jordan, green malachite deposits stand out in stark contrast to the surrounding reddish stone of the valley.[23]

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[19] Lacovara 2001: 295; Doebrich 2013: 1; *The New Encyclopaedia Britannica – micropaedia*, 15th ed., s.v. "Copper."
[20] Lacovara 2001: 295; Lucas and Harris 1989: 201.
[21] Castel et al. 1995: 15.
[22] Garenne-Marot 1984: 98, Fig. 1 & 100 Fig. 2; Castel, et al. 1995: 23; Lucas and Harris, 1989: 202-206.
[23] Craddock 1995: 30.

Sites like these probably provided the material used in major copper projects like the copper statues of Pepi I and Merenre, although some scholars have suggested the statue of the latter is Pepi I when he was younger.[24] It is commonly believed that these statues were possibly constructed from large copper sheets shaped by hammering over wooden cores and affixed with rivets.[25] However, Eckmann points out that if this technique had been used there would be at least wooden fragments or impressions remaining within the internal surface of the statute, which there are not.[26] Copper tools, such as adze blades, also become increasingly common in the archaeological record during the Old Kingdom. This might be an accident of archaeology, but it seems more likely that it reflects an increase in the use of copper as a material for tool production. The expanded supply of copper also meant that it could be used more commonly in weapons. Depictions of battle, such as the one displayed in the tomb of Inti at Deshasheh, demonstrate the increase in copper weaponry as more knives and axes with metal blades become progressively common.[27] Copper rich minerals were also greatly desired for their use as colorants, medicines and makeups. Malachite was ground into a powder and could be applied around the eye to provide color as decoration, to serve an apotropaic function, or to stave off infection.[28] Copper's natural antimicrobial properties ensured that its use in medicines was extremely effective.[29]

The Middle Kingdom witnessed significant expansion and exploitation of previously known copper deposits. Serabit el-Khadim, in particular, continued to be a main source for copper. A temple was actually constructed at the site, dedicated to Hathor, the "Mistress of Turquoise." Turquoise is also a copper-rich mineral/gemstone and was likely designated as *mfkꜣt* by the ancient Egyptians.[30] At the site of Serabit el-Khadim it is unclear which material was primarily exploited since evidence for copper, malachite and turquoise mining each exists in the area. The newly expanded mines supplied copper for mirrors and several different types of axes that became more common place in the archaeological record of the Middle Kingdom and that use metal as their primary material component.[31]

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[24] Hill and Schorsch 2007: 8.
[25] Lacovara 2001: 295; Hill and Schorsch 2007: 8.
[26] Eckmann and Shafik 2002: 11-12.
[27] Shaw 1991: 34, 36, 37 & Fig. 28.
[28] Lucas and Harris 1989: 99, 103; Ogden 2000: 149.
[29] Dollwet and Sorenson 1985: 80-87.
[30] Levene 1995: 366-367; Mumford 2013: 6163.
[31] Scheel 1989: 14, see also Chapter 5 in the same for descriptions of various metal-based tools.

By the New Kingdom, copper, alloyed with other materials to increase its effectiveness, was being used commonly for tools, including chisels, saws, and adze; toiletries including razors and mirrors; jewelry of all types; weapons and other militaristically oriented items generated by the creation of a standing army, including elements of chariots; and large scale decorative work, such as cast temple doors, as depicted in the tomb of the vizier Rekhmire.[32] Bronze and arsenical copper, two of the early alloys used in ancient Egypt, rely on copper as a primary ingredient in their composition.[33] For more information on alloying see Chapter Four.

Egypt was also being introduced to new metallurgical technologies as a result of its expanding territory and influence in the areas of Syria Palestine and Nubia. At the site of Timna, Egyptian smelting furnaces appear to have been worked alongside those of other Near Eastern cultures.[34] Several of Egypt's Near Eastern neighboring civilizations began their Iron Ages at the close of the New Kingdom (c.1100-1000 BC). Despite the contact with the Near East, Egypt did not transition into the Iron Age. This might largely be due to the low numbers of significant and easily exploitable iron deposits within Egypt, but also it could be attributed to the long-term success of copper as a material resource.[35] Although iron processing requires similar temperatures (1150^0 C) to copper production, iron was nearly impossible to cast anciently and would have been quite dangerous to shape as it responds best to forge work, or shaping while the material is red hot.[36] If iron had been used in the production of large numbers of objects anciently than it stands to reason that such objects would have been preserved in a similar manner to other artifacts and that archaeologists would be able to identify them in the archaeological record. Unfortunately, few such items exist. The primary evidence of iron use is found in the slag that remains from copper and bronze smelting operations. Small amounts of iron oxide were used as fluxing agents to process copper and separate it from its impurities in the smelting process.[37] One other, often cited example of an iron artifact from New Kingdom Egypt is Tutankhamun's iron dagger (JE 61585A-B). However, the dagger is not necessarily an Egyptian product. It appears to have been a gift given by a foreign, likely Hittite, dignitary or king.[38] Furthermore the dagger is purportedly made

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[32] Ogden 2000: 156.
[33] Ogden 2000: 151,152.
[34] Shaw 1995: 2, Hauptmann 1989: 7, 10.
[35] Ogden 2000: 167.
[36] Partridge 2002: 26.
[37] Ogden 2000: 151, 152.
[38] Reeves 1990: 177.

of meteoric iron.[39] In either case, the general use of iron as a material resource seems not to have taken root with in the technology of Egypt. Whatever the reason, the failure to develop and use iron as a resource put Egypt at a distinct technological disadvantage when compared to its neighboring Near Eastern kingdoms and is one of the possible causes for the downfall of Egyptian civilization during the Late Period and the success of foreign invaders like the Persians.[40]

Regional Availability of Copper

During the New Kingdom, Egypt held its greatest degree of influence in the surrounding areas of the Near East. This influence is demonstrated in the expansion of mining operations into the areas of Syria Palestine and specifically the Wadi Arabah, near present day Timna. Excavations during the 1960s through the 1980s showed clear evidence of Egyptian involvement at the site, although questions remain to what degree the region was directly controlled by Egypt.[41] Egypt was by no means alone in its exploitation of copper. During the New Kingdom, despite the vast quantities of copper available at Timna and other sites under Egypt's control, Egypt needed to import copper from nearby kingdoms to meet its economic and production demands.[42]

The island state of Cyprus also contained substantial copper deposits, which the Cypriotes exploited for trade with other nations in the region.[43] The copper trade with Cyprus extended into the Roman Period as well, when copper was identified as the "metal of Cyprus."[44] The Amarna letters, which are a collection of correspondence between Egyptian royal family members and rulers in the area of the Levant written on clay tablets during the early 18th Dynasty, show that nearly 950 talents of copper, weighing roughly 30 kilograms each, were requested from Cyprus during the reign of Amenhotep IV (Akhenaten).[45] An ancient shipwreck off the coast of present day Turkey at the site of Uluburun, dated to c. 1300 BC, was discovered to be transporting ten tons of copper ingots along with one ton of tin ingots.[46] The ratio of ingot types follows the recipe for making bronze during that time. The ship was identified as Cypriot in origin, and effectively demonstrates the scale of trade in which Cyprus was engaged. The cargo is considered on par with

[39] Comelli et al. 2016: 1307.
[40] Ogden 2000: 168.
[41] Ogden 2000: 150; Rothenberg and Lupu 1966: 134; Bimson and Tebes 2009: 104; Shaw 1995: 5.
[42] Hikade 1998: 48-49.
[43] Knapp 2006, 49.
[44] *The New Encyclopaedia Britannica – micropaedia*, 15th ed., s.v. "Copper."
[45] Hikade 1998: 49; Moran 1992: 104-110, translations of EA 33-36.
[46] Gestoso Singer 2007: 21, 24.

royal accounts of gift exchanges between the kingdoms of the Near East.[47] While it is unlikely this ship was travelling to Egypt, given is sinking off the coast of Turkey, it is probable that shipments with similar cargo would have been sent to Egypt as part of the Mediterranean trade network.

Two of Egypt's most well documented trading expeditions are Hatshepsut's expedition to Punt and the Report of Wenamun. Hatshepsut's expedition to Punt was likely one of the greatest accomplishments of her reign as it is recorded on the walls of her mortuary temple at Deir el-Bahari. The Report of Wenamun comes from either the end of the 20th or the beginning of the 21st Dynasty and relates the story of a priest sent on a trading mission to Byblos.[48] In either example, no copper is reportedly traded. Since neither Punt nor Byblos were regarded for copper deposits, it is probable that the absence of copper recorded in these transactions was simply a result of local scarcity. Both reports demonstrate the power and extent of trade networks available to the Egyptians even if they do not record the commodity of the present discussion.

Chapter Six will more expressly discuss the effect copper had on the economy of Egypt, but for now it is important to understand that Egypt had access to extensive trade networks and that acquiring copper in such quantities as those recorded in the Amarna letters displays the demand for the material in Egypt was greater than its available local supply. It is possible that this increase in the demand of copper during the New Kingdom was largely because of its military activity. The military needed copper for weapons and armor as well as parts for their newly acquired chariot technology.[49] For example, the copper lost in the shipwreck at Uluburun is suggested to have been enough metal to supply 300 helmets, 300 swords, 300 corselets and 3000 spearheads.[50] However, the loss of this metal represents just one shipment in what likely was an active trade network across the Mediterranean.

Bronze as a material

Alloys, such as bronze and electrum, require the purposeful mixture of molten metallic elements. Therefore, the development and use of bronze represents a significant advancement in the technology of the Egyptian civilization. The recipe for bronze can change depending on the final purpose of the alloy being produced, but the required materials always include copper and

[47] Karageorghis 1995: 76.
[48] Lichtheim 2006: 227-228.
[49] Spalinger 2005: 141, 145.
[50] Hikade, 1998: 50; Gestoso Singer 2007: 24.

tin. Copper acts as the core component of bronze, usually accounting for between 80 – 90% of the total weight.[51] The amount of tin within a batch of bronze is the factor that can most greatly modify the alloy. In the 20th Century bronze with a tin content of 3-4% is useful for springs and coinage, 10% is good for casting, while 15-18% is used in bells.[52] As more tin is added, the melting temperature for the bronze alloy drops, which facilitates its fluidity as a molten metal, and the rigidity of the metal is enhanced.[53] These qualities together create the ideal material for producing long-lasting items through casting methods. In any of these mixtures however, bronze remains a stronger and more durable material than pure copper, which is why bronze became the primary metal used in the production of tools and weapons during the New Kingdom. Some instances of bronze artifacts from early periods of Egyptian history are known, but their rarity demonstrates that the bronze produced during this period was likely more exotic or the result of experimentation. Indeed, there is little indication of standardized mixtures of bronze during the Old and Middle Kingdoms, as tin accounts for anywhere between one and sixteen percent of the make-up of these artifacts.[54] It is unknown why the Egyptians did not transition to bronze as a primary material until the New Kingdom, but it possible that the availability of tin played a significant role.

Although tin minerals are exploited by present day Egypt, in the Eastern Desert as cassiterite and in the Sinai as chalcocite, tin ore was not widely available as a natural resource to the ancient Egyptians and it remains unclear where they procured the material used in the alloying of bronze in the New Kingdom.[55] Some have suggested some unrecorded exploitation of deposits within the Eastern Desert of Egypt, but it is more likely that Egypt traded for tin.[56] Cyprus appears to have been one supplier, or at least trader, of tin as shipwrecks at both Ulburun and Haifa contain significant quantities of tin ingots, some of which are marked with Cypriote symbols.[57] Other sources for tin could include tribute gathered from the tribes of the Retenu (the tribes and peoples of Syria Palestine), such as those recorded and collected by Thutmosis III, and ores which naturally contained both copper and tin. The areas of Iran, Turkey and beyond could also have been accessed

[51] Rehren and Pusch 2012: 215, 217.
[52] Birchon 1965: 85.
[53] Partridge 2002: 25.
[54] Ogden, 2000: 153; Lucas and Harris, 1989: 217.
[55] Ogden 2000: 171.
[56] Garenne-Marot 1984: 107; Ogden 2000: 171.
[57] Garenne-Marot 1984: 108; Gestoso Singer 2007: 24.

through trade caravans coming by way of Susa in Mesopotamia.[58] The issues surrounding the ancient sources for tin are currently unresolved and must primarily rely on speculation until more scientific studies can produce comparative databases of elemental characteristics of regional tin samples. Such databases would allow for greater compositional analysis of artifacts and increase the understanding of ancient trade routes and alloying processes.

Bronze can also be augmented by including other metals in the alloying process. In particular, lead (Pb) was added to modify ancient bronze. The inclusion of lead reduces the melting point of bronze thus making the metal easier to liquify and allowing it to flow more effectively within complex molds.[59] Lead was gathered from deposits of galena widely available in Egypt and particularly at the site of Gebel Rosas found south of Luxor along the coast of the Red Sea. Because of lead's low boiling point, it was perhaps used earlier than copper, but its poor durability makes it unsuitable for most anything other than decorative pieces.[60] Along with the rise in copper use during the New Kingdom lead use also increases, both because of its inclusion within bronze and in its own right as a ornamental material.

By the end of the New Kingdom, bronze almost completely replaced the use of unalloyed copper within Egypt. While this new metal certainly proved more durable and easier to cast, copper's role in the economy of the New Kingdom in no way disappeared. It is possible that because bronze relied on copper so heavily as an ingredient, copper could have become more valuable to the ancient Egyptians: an example of the sum being greater than the individual elements.

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[58] Van de Meiroop 2010: 169; Garenne-Marot 1984: 108 – The translation of the *dḥty* as tin is contested and Garenne-Marot acknowledges the unconventional interpretation.
[59] Ogden 2000: 154.
[60] Ogden 2000: 168.

Chapter 3 - Extraction Methods

The acquisition of copper represented a sizable endeavor in the ancient world. Some important mining sites have been mentioned previously, as have the minerals that the ancient Egyptians were looking for, but the technology and methodology of mining now becomes important to the discussion of copper's relative value. In Egypt, large royal expeditionary teams numbering into the thousands were sent to acquire and process commodities, whether they were simply stone, like granite from Aswan; limestone from Tura; natron from Wadi Natron and greywacke from Wadi Hammamat; or metal-rich minerals, like gold infused quartz from the Nubian Desert, and malachite and turquoise collected in the Sinai.[61] In modern media, mining technology is depicted one of two ways: either the mine is a giant hole dug into the earth spiraling ever deeper and wider like a hole left from a screw in a piece of wood, or it is a series of tunnels like a human sized ant colony within the mountainside. These models tend to be over-simplifications of the technology and planning that go into modern mining efforts, but can provide readers a mental image of the scenes described below.

It is also of great importance to recognize the difference between a mine and a quarry. Both are concerned with the removal of desired material from the surrounding earth and rock; both used similar tools and techniques; but to lump them together over-simplifies the processes involved and makes it more difficult for archaeologists and researchers to distinguish between them in the field. Mines, which this study focuses on, are concerned with the removal of metals along with their respective minerals and ores that primarily exist underground. Quarries on the other hand are focused on the surface removal of stone, such as granite or limestone, for the purpose of construction and building materials. There are examples of areas in Egypt that operated as both; the Wadi Hammamat was a source of both gold and greywacke.[62] One of the primary differences between quarries and mines is found in how the deposits are worked. Quarries are traditionally worked in a top-down manner leading to structured and regular patterns in excavation, as can be seen at the basalt quarries of the Fayum and the sandstone quarries of Gebel Silsilah. Mines are excavated following a vein of metal or mineral in a more irregular path.[63] While taking time to

[61] Labib 1995: 404; Mumford 2013: 6163.
[62] Ikram 2011: 19; Heldal and Storemyr 2015: 292.
[63] Craddock 1995: 68, 70.

distinguish between a mine and a quarry may seem unnecessary, some excavation techniques, as will be discussed below, lent themselves to one type of material over the other. Focus will be given to mines, as they relate most to the discussion of copper, but quarries will be addressed where they follow similar tool use and excavation practices. The attention given to mines and quarries is also important since the minerals exploited by the Egyptian miners are typically classified as stone with low-grade metal deposits, and the removal of the surrounding rock sometimes necessitated techniques usually used in quarries. The dating of mining sites is primarily accomplished through a combination of pottery analysis, translation of graffiti and other inscriptions, and occasionally by the use of certain chronologically restricted technologies. Unfortunately, most marks left by mining tools are fairly similar, taking the shape of either a divot or a gouge in the surface being excavated. Patterns in the tool marks can also facilitate in dating. For example Old and Middle Kingdom mining marks tend to be in one general direction with irregular lines while the New Kingdom mining displays more uniform and densely packed gouge marks sometimes with a herringbone (bi-directional) pattern.[64]

Types of Mines

Nearly all mines throughout the world initially take the form of a pit dug into the earth from which the desired materials are extracted.[65] If a mineral deposit was already exposed on the side of a wadi or cliff face, miners had the ability to strip the face of the rock back vertically as they extracted the material, keeping the face vertically aligned, similar to modern strip-mining. In pit-like quarries or mines, the pit would be extended and deepened to pursue the vein or deposit of the mineral. Quarries especially were worked from the top of the deposit down rather than from the side as demonstrated by the site in Aswan known as the unfinished obelisk and the quarrying marks in the limestone around the pyramid of Khafre at Giza.[66] Because most early mining sites were expanded in later generations, and because mining is destructive by nature, most mining sites that saw continual use can only provide archaeologists information on the most recently used technologies at that site.[67]

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[64] Arnold 1991: 33, 34 – Visual comparison of mark patterns are provided in Fig 2.7-2.9 in Arnold's volume.
[65] Craddock 1995: 31; Shaw 1995: 4-5.
[66] Shaw 2001: 99.
[67] Shaw 1995: 9-10; Craddock 1995: 40, Fig. 2.9

The initial design of the pit mine is only effective at the earliest stages when deposits are relatively easy to access. Once the surface deposits were exhausted, ancient miners had one of two primary methods that they could use to access further mineralized sediment. First, if the minerals were accessible from the side (vertical face), usually along the rock face of a cliff or valley wall, miners could carve out the mineral leaving cave-like depressions in the rock. This was the method most commonly used by miners at the site of Wadi Dara.[68] Second, pits could be extended deeper, creating shafts to explore for and access additional deposits. Once deposits were located, the shaft would be expanded laterally at the level of the mineralization into an underground gallery to gather the resource. At Timna, some of these shafts reached depths of 40 meters, but most were less than 10 meters in depth with a roughly 80 centimeter diameter.[69] Multiple shafts would be cut to facilitate with mineral discovery and extraction. The shafts at Timna contain footholds cut into the side of the shaft to facilitate travel up and down their depth.

Often the underground galleries would connect as different groups expanded to follow their mineral deposit creating a network of man-made chambers below the surface. From the 17th to the 20th Century modern mining used squared timbers to re-enforce the tunnels and excavation centers in underground chambers. However, due to the absence of sufficient and easily available high-quality timber, the ancient Egyptians supported their underground chambers with pillars of natural stone left in place as the gallery was expanded. This effort to support the chamber was only required in the largest of mining galleries as the surrounding stone was often quite structurally sound. Underground Egyptian mining operations that used the tunnels, shafts and galleries discussed above did not leave much space to work in. The tunnels at Timna average about one meter across, with many being too small for a modern man to enter or work.[70]

Ancient Mining Tools

The excavation of the tunnels, galleries and shafts used by ancient miners used remarkably simple tools: the pounding stone, the wedge, the chisel and the gad, also known as a pick or spike.[71] Pounding stones, or hammering stones, are hard dense stones or rocks wielded in the hand or attached to a length of wood to increase the power of the worker. These tools are used to apply

[68] Castel et al. 1995: 16; See also Fig. 2.1 for location.
[69] Shaw 1995: 11.
[70] Craddock 1995: 67; Shaw 1995: 8.
[71] Shaw 2001: 102-103; Arnold 1991: 260.

percussive force to the surface or material being shaped. In order for pounding stones to be effective they need to be harder than the rock it is hammered against. Thus granite and diorite were highly favored materials since they were among the hardest rocks available to the Egyptians, but any stone that was harder than the material being quarried would be sufficient as a pounding stone.

Archaeologists know that pounding stones were used regularly by the ancient Egyptians because they are not only depicted as tools used by Egyptian sculptors and miners but are commonly found at mining and quarry sites. Their presence is one of the defining characteristics of identifying ancient mines and quarries.[72] Hammering stones were most often hafted to allow for greater striking power, but their general shapes varied. Experiments attempting to reconstruct the mining process have demonstrated that hafts not only increased the effectiveness of stone hammers but also protected the user from excessive percussive shock.[73] The traditional hammering stone (Fig. 3.1) is rectangular or ovoid with pitting along its surface, especially on the smaller ends, from both its manufacture and use. To attach the stone to the haft, where it would be held by the user, stones could be notched along their midriff to provide more surface area and contact with the hafts that would be tied around them with animal sinew.[74] (Fig 3.2 & 3.3) However this technique was not necessary and many stones demonstrate their use as pounding

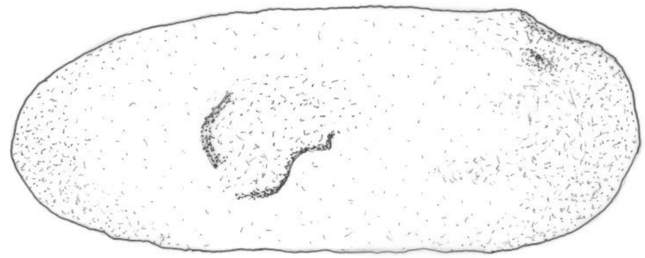

Figure 3.1 Handheld Stone Hammer after Craddock

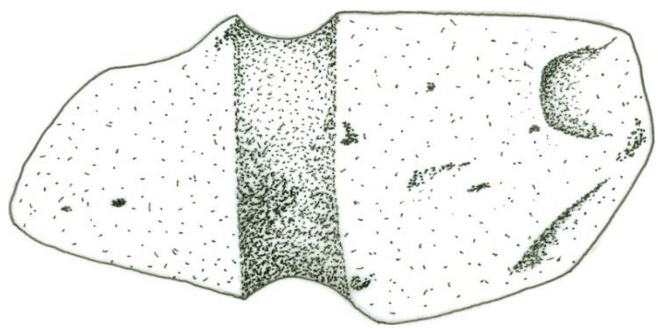

Figure 3.2 Grooved Stone Hammer after Craddock

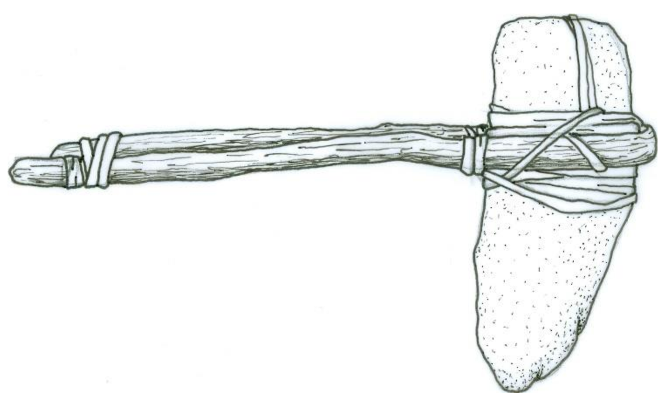

Figure 3.3 Hafted Stone Hammer after Craddock

[72] Craddock 1995: 37, 39.
[73] Shaw 1995: 6.
[74] Craddock 1995: 42 (fig 2.12) & 43.

stones simply by their severely weathered ends. The same process that removed rock from the mine or quarry surfaces also slowly destroyed the pounding stones being used as tools.[75] Even though the pounding stones were made of harder rock than the material being mined or quarried, the tools still broke down, eventually becoming unusable. This is one of the primary reasons that they are in such large quantities in ancient quarries and mines.[76] Once the tool had broken or outlived its usefulness, it would be abandoned for a new pounding stone that could be inserted into the existing haft. In many ways the modern utility, or Exact-O, knife works on the same concept: use the tool until it no longer functions properly and then replace the blade. Larger fragments that broke off stone tools could be reused, but thin fragments would have proved ineffectual as demonstrated by experiments conducted by the Early Mines Research Group.[77] Similar experiments suggest that pounding stones could have been used for a fair amount of time before becoming ineffective as tools.[78] Whether the stones were hafted or used by hand, they left the surface of the mine pitted with rounded dimples.[79]

Wedges, chisels and gads, also called spikes, are all variations on the same tool design and were primarily made of metal, although wedges made of wood and antler could also be effective. (Fig 3.4) Copper was the first metal employed in the production these tools, but by the New Kingdom most were made of a bronze alloy.[80] These tools left deep gouges in the mine walls and can easily be distinguished from marks left by pounding stones. The tapered shape of gads and picks was used to focus the percussive force of a hammer or pounding stone into a smaller area to increase the hammer's efficacy.[81] This increase in force and accuracy in the placement of that force was most successful when used along fault-lines within the material being quarried or mined. The tapered end of the

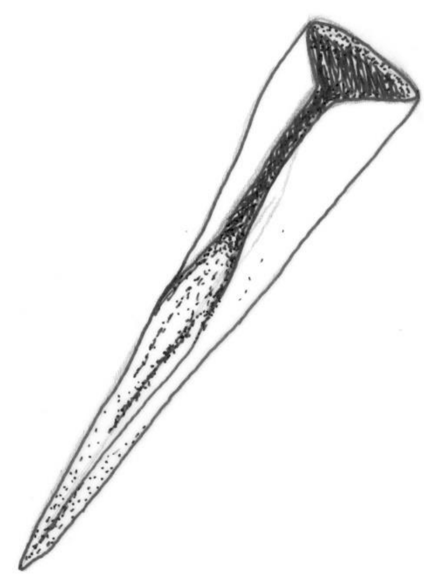

Figure 3.4 Copper Pick or Gad after Craddock

[75] Craddock 1995: 43.
[76] Craddock 1995: 43.
[77] Craddock 1995: 46.
[78] Pickin and Timberlake 1988: 166.
[79] Craddock 1995: 40, fig. 2.9 shows the different marks left by stone hammers as well as gads.
[80] Shaw 2001: 101.
[81] Shaw 1995: 6.

tools can be placed within existing cracks and faults that are then expanded as they are pounded, causing shearing and cleaving to occur in the quarried material. Each tool provides different edge types with wedges having a primarily triangular shape, chisels having a defined cutting edge at the end of a shaft, and gads, or picks, being conical in shape and providing a single point on which the force would be focused.

Earlier versions of these tools were made out of stone, but all tools designed for stonework, gads and chisels especially, were most effective when made of metal. Over time tools inevitably brake down with extended use, but metal tools required less maintenance of their cutting edges or points. While certain stones can make extremely sharp blades – the best example being obsidian, which can produce blades sharper than surgical steel – tools required for mining have a greater need for durability, which stone does not provide. There is some evidence that large stone chisels may have been used in early periods, but stone, as has been shown in the above discussion on pounding devices, breaks down with continuous percussive force and therefore stone chisels would have proved to be inferior to metal ones.[82] Site 30 at Timna contains evidence of the use of metal chisels or gads in the scoring of the rock where mining took place. These pointed tools leave deep gouge marks in the rock surface and are distinctly different than the softer pitting marks left by direct stone hammering.[83] The marks seen in various shafts and galleries also follows the different patterns outlined by Arnold and demonstrate that the site was used throughout multiple periods.

While gads, picks and chisels focused on increasing the external force applied to the rock face, wedges increased the internal pressure to cause shearing to take place. Wedges require placement within fractures within surfaces being mined or quarried. The triangular shape forced apart the rock at structurally weak points to ensure maximum cleavage. While metal wedges could be highly effective, the use of wooden wedges by ancient miners is also attested.[84] Wooden wedges would be inserted into faults and then soaked with water. Because wood expands as it becomes wet, this process would apply pressure internally, rather than using externally applied force, potentially shearing away part of the rock face without the use of additional percussive force. While Egypt is not well regarded for its wood or ample water supply, the amount and quality of

[82] Redford 2001: 101.
[83] Craddock 1995: 40 (fig 2.9).
[84] Shaw 1995: 7.

these materials needed to accomplish the task would have been insignificant to, and easily obtained by, the expeditionary force deployed at the quarry or mine.

Fire-setting

Ancient miners would also use natural elements to aid in the excavation of desired material. Fire, water and wood could all be used to speed up breakage of the rock face. In much of the ancient world, fire was used to create artificial fractures and faults in the rock, through a process called "fire-setting."[85] A large fire would be lit along the face of the rock being mined, and as the temperature increased the various elements within the rock would expand. Because this elemental expansion was not universally consistent throughout the rock face, fissures and cracks would result that could be exploited by the miners. Fire-setting causes rock to have distinctive fracturing patterns and rounded shapes both along the sides and the top of the tunnels.[86] It should be apparent that such practices were potentially very dangerous and required proper ventilation to avoid smoke inhalation and the possible death of the miners. The heating could also affect the rock in unforeseen ways that might cause collapses of the mining galleries where the fire-setting was taking place. This method was used until roughly the 19th Century by miners throughout the old and new worlds. Modern tools have made such preparation of the surface unnecessary.[87]

Fire-setting was primarily useful in quarries and mines with hard surrounding rock, as in the case of the granite quarries in Aswan around the "Unfinished Obelisk." There are also indications of fire-setting with softer stone, as in the case of the quarries of Khafre, even though the procedure would have not been considered necessary at such sites.[88] Granite is especially subject to temperature variations because of the quartz in its structure; its nonporous makeup also allows the heat to penetrate better into the stone.[89] While this technique would have proved useful in the hard bedrock of Aswan, it was not required in the relatively soft rock of the Sinai Peninsula and the area of the Wadi Arabah. The sandstone and limestone that served as the surrounding rock for malachite and copper deposits in these areas was much softer and could be more easily removed

[85] Craddock 1995: 33.
[86] Craddock 1995: 35-37.
[87] Craddock 1995: 33-35.
[88] Heldal and Storemyr 2015: 291.
[89] Heldal and Storemyr 2015: 293.

through traditional pounding stone methods.[90] In fact, the mines in the area around Timna, a site known to have been exploited by Egyptian miners during the New Kingdom, contained no evidence of fire-setting despite the procedure being used during the same period at other sites.[91]

Removal of Detritus

Once the desired material was broken off the surrounding rock, it was necessary to remove it from the mine. Due to the time required for the removal of the detritus, it is likely that additional workers, who were dedicated to this activity, carried out this task. No tools resembling shovels or spades have been recovered from New Kingdom mining sites. This leads to belief that removal of the material within the mine tunnel was done by hand, and/or by using baskets, although scrappers and other shoveling tools could have been used. The small size of most tunnels, measuring roughly 1 meter in diameter at the site of Timna, likely meant miners worked lying down. Such a position would have required the debris from the early mining phases to pass under the body of the miner working the tunnels.[92] In tunnels with large deposits, the passages could be expanded into larger galleries, but the extracted materials would still have to pass through areas with narrow access points. The vertical shafts sunk by the workers to access the mineral deposits also functioned as secondary avenues for removal of debris as well as increasing ventilation and light. Due to the small size of rock fragments being removed from the tunnels, baskets, possibly made from plant or leather materials, were the most probable container used to gather and transport the detritus. Although no evidence has been found to suggest production of such vessels at many of the New Kingdom mining sites, such use of baskets is attested at the Valley of the Kings and so it is likely that they would have been used elsewhere in a similar fashion.[93] It is unlikely that ceramic vessels would have been used for such operations given their weight and potential for breakage. Roman era baskets have been found intact at the site of Amram near Timna, however, no baskets have been located at New Kingdom mining sites to corroborate the theory of their use in Egyptian mines.[94]

[90] Craddock 1995: 67.
[91] Shaw 1995: 7; Craddock 1995: 67.
[92] Shaw 1995: 8-9; Hikade 1998: 47.
[93] *Černý* 1973: 20.
[94] Shaw 1995: 9.

Debris could have been carried out of horizontally accessible tunnels and galleries, but vertical access points would have necessitated the use of lifting apparatus to assist in clearing the mines and the removal of the desired minerals. Wear marks and grooves, reminiscent of rope burns, at the edge of shafts connected to mining tunnels are in evidence at the site of Timna and elsewhere. Ancient rope was actually quite effective at lifting heavy stones and statues.[95] However, the substantial breakdown of rope as it rubs against rock makes it probable that workers would have sought alternative technologies of hoisting beyond simple rope. Small holes, likely serving as anchoring post-holes for crossbeams, carved into the collar of the shafts at Timna, suggest the use of hoisting devices: for example a windlass or winch.[96] The posts to support such hoisting devices need not have been buried deeply and likely rested upon the surface soil at the site. Unfortunately, nothing remains of the mechanisms except for three examples of anchor holes sunk into the rock, and each example has little in common with the others.[97] This suggests that there was no standardization of the technology used in hoisting debris out of the subterranean galleries. It is possible that such removal activities were the primary responsibilities of the lowest of unskilled workers, prisoners, or slaves and were therefore of little concern to the administrative foremen of mining expeditions.

Beneficiation

Once the material was removed from the mine, workers began the process of sorting it. The waste rock was removed to a dumping area, sometimes filling up previously exhausted mines and shafts, while the ore was put through more rigorous sorting and grinding called beneficiation.[98] This process ensured that smelting operations produced the desired results. Because ore removed from the mine contained varying amounts of copper, it was necessary to maximize the percentage of metal within the charge placed in the furnace. Without the proper mixture of materials the product of the smelt could be ruined.

Grinding was an important part of this refining procedure as it freed the copper minerals from as much of the surrounding rock as possible and maximized the use of all available metal-rich minerals. Flat grinding stones, often made of granite or similarly hard rock, are most

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95 Arnold 1991: 269.
96 Craddock 1995: 68; Hikade 1998: 48.
97 Shaw 1995: 11.
98 Craddock 1995: 156.

frequently located outside the mine tunnels in workshop areas near the smelting furnaces of expeditionary camps.[99] Their surfaces demonstrate multiple, small yet substantial indentations, usually no more than ten centimeters in depth from continual use and powders from left-over ore embedded by the grinding process.[100] Usually these indentations are mirrored by the convex curve of another stone used in conjunction with the flat stone similar to a mortar and pestle or the large millstones that are used for grinding grain. Crushing and grinding stones rarely show evidence of hafting, which demonstrates they were most likely used by hand. This technique makes sense since constant pressure is what makes grinding effective, and the pressure applied by the workers would not have been as traumatic for bones and muscles as pounding activities. However, grinding would have only been useful to a certain point since powered ore packs more densely in a smelting charge and would therefore have limited the amount of air flow in the furnace and possibly smothered the smelting fire. Pea sized fragments, or prills, of metal-rich ores proved the most useful in smelting charges.

Beneficiation was also an important process in alloying metals for certain properties. Different qualities of material can sometimes be identified through variances in coloration. For instance, Turquoise is also subject to changes in coloration, with its chemically purest form, comprised mainly of aluminum and copper, exhibiting a medium blue tint, while addition of other minerals can create a more greenish hue.[101] Likewise copper deposits in Egypt that tend to have high concentrations of arsenic give the copper a slight silver coloring.[102] Early examples of copper-arsenic blended alloys were likely a natural result of the separation of these ores from the rest of the ore body set aside for smelting. As will be discussed below in Chapter Four, alloying allowed for the development of stronger and more durable goods and for technological progress. It is also important to note that these ores were not only used to create finished metal goods but were also used as pigments in paint, medicinal prescriptions and makeup.

While the subsequent chapter will address the processes related to copper refinement and processing, it is clear that copper's attributes as a material contributed to its use within Egypt. The effort spent to procure the metal from available minerals indicate that it was quite valuable to the Egyptians. Beneficiation suggests the Egyptians understood the differentiation of mineral qualities

[99] Rothenberg and Lupu 1966: 129.
[100] Craddock 1995: 159.
[101] Fritsch 1999: 7.
[102] Ogden 2000: 153.

and sought to control the outcome of refining practices. It is unlikely that working in such a difficult and potentially dangerous operation would have been well regarded, but it nevertheless increased Egypt's power by providing the society with a valuable and useful commodity.

Chapter 4 - Copper Processing

Supporting Technologies

Once the copper minerals were extracted from the rock, they needed to be purified and processed through a practice called smelting. Before discussing the main copper processing technique of smelting, three primary supporting technologies must be addressed: charcoal, ceramics and ventilation tools. Each of these technologies assisted in generating the heat necessary to produce a proper smelt for copper. Melting temperatures for copper cannot be reached with common wood-burning fires. The earliest effective fuel for high temperature fires was charcoal. Charcoal is produced by drying out wood in low oxygen, high temperature environments. While charcoal is generated naturally in nearly any wood-burning fire, ancient societies created charcoal in large quantities by completely covering a stack of wood with damp mud before lighting a fire within the stack, or by roasting the wood within an earthen kiln.[103] The high temperature thoroughly dries the wood, while the lack of oxygen keeps the wood from completely combusting. At the site of Timna, Area B is believed to have contained one such installation where large quantities of charcoal were produced to allow for smelting at the site of the mines.[104] In Egypt, the primary wood being used to create charcoal was acacia, although sycamore fig was also used in areas.[105]

Experiments conducted by Merkel and others suggest substantial quantities of charcoal were required for a proper smelt. Merkel reported that producing one kilogram of copper required 50 kilograms of charcoal fuel.[106] This is largely due to not only the high temperatures needed, but the time required to properly heat the crucible and furnace to avoid fractures caused by rapid temperature changes and for the charge of metal to fully liquify. Unfortunately, large amounts of wood are needed to produce relatively small amounts of charcoal. Present day practices ensure efficiency by reducing the wood consumed in the process and compressing charcoal powder into briquets, but the Egyptians did not have the ability to do so. It is possible that entire groves of trees were exploited for the production of the necessary charcoal to ensure a proper smelt at a highly productive mine. It is unclear how extensive the deforestation was and where the wood or charcoal

[103] Gerisch 2012: 47; Craddock 1995: 191-192.
[104] Rothenberg and Lupu 1966: 127.
[105] Rademakers 2015: 134.
[106] Merkel 1990: 86-87.

originated, but because charcoal production does not require high qualities of wood, it is possible that Egyptians used wood deemed unsuitable for other projects. A large-scale exploitation of trees might have contributed to changes in the environment, but this is the subject of a separate discussion, beyond the focus of the present work.

Charcoal not only served as a fuel for the smelting fires but also as a reducing agent, known as a flux, which assisted in the separation of the copper from within its various oxidized mineral compounds.[107] Copper rich minerals would be mixed with charcoal and placed within the furnaces where the smelt was to take place either with or without the use of a crucible, a technology discussed below. As the charcoal burns with intense heat, it releases its carbon atoms that bond with the oxygen in the minerals, which contain oxidized copper molecules. The reaction of transferring electrons via oxygen is known as reduction and is essentially the chemically opposite process of oxidation. As the oxygen is chemically removed from the mineral, the unbounded copper atoms separate in the solution, which allows the metal to be further refined.

Ceramics were likewise important to ancient metallurgic processes. Ceramic vessels and vessel fragments are among the most numerous artifacts found by Egyptologists involved in archaeological digs. While ceramic vessels can shatter, the durability of their construction material is demonstrated by the frequency of their presence within the archaeological record. Ceramics are produced through heat treating a mixture of clay, silt and organic material. Prior to heat treating ceramic mixtures are moldable and can take on whatever form they are worked into. Once treated the material hardens and is capable of withstanding high temperatures without significant damage. This attribute is what makes ceramics such an important supporting technology to metallurgy. Ceramic containers used to hold metal and metal rich minerals in the fire as part of the smelting process are known as crucibles.[108]

Crucibles can take many forms but nearly all are bowl shaped. High capacity crucibles tend to be deeper rather than simply being larger, as the smaller diameter opening at the top helps to contain internal temperatures. In some Old Kingdom metalworking scenes, crucibles have a general sock or stocking shape and rest against each other in the furnaces while being heated. The "toe" area of the crucible was then cracked open or un-stoppered to allow precise pouring of the

[107] Craddock 2000: 151-165.
[108] Rademakers 2015. 50.

molten metal.[109] This same design is used in New Kingdom hieroglyphs – N34 in Gardiner's list – as the ideogram for crucible, although crucible design and depiction had changed by that point.[110] Some Egyptian crucibles in the Petrie collection contain holes or spouts in their side walls to facilitate pouring of the molten material.[111] Crucibles were important because they allowed metal to be transported in a liquid state to molds where the metal would be poured into the desired shape. This process is shown clearly in the scenes depicting the casting of copper doors for the temple in the tomb of Rekhmire.[112]

Ceramics were also used in the creation of tuyères, heat resistant nozzles attached to the ends of blowpipes or bellows, which assisted in the circulation of air within the furnace where the smelt was taking place. Most tuyères were straight in design. However, in Cyprus there are examples of angled or elbow tuyères.[113] The construction and use of tuyères made it possible for the fires to be heated to the temperatures needed to smelt copper. They can be identified in ancient scenes as a bulge on the end of a blowpipe, but their presence, and those of other fragmented tuyères, are also one of the key archaeological identifiers of ancient smelting sites.[114]

Oxygen serves a mandatory function in the combustion of materials within the normal atmospheric conditions. With greater oxygen availability, fire can burn hotter. High temperatures were necessary for proper smelting to occur. In examples of early smelting, this need for more air and oxygen was accomplished by placing the furnaces and fires in areas where naturally prevailing winds could be harnessed.[115] However, this technique does not provide regularity or control and can have dangerous results should the wind carry the fire beyond its designated area. The use of blowpipes and bellows, protected by the presence of tuyères, manages this danger and produces a high degree of control in the smelt. Both of these tools are depicted with regularity in ancient metallurgy scenes.[116] Pot bellows in particular seem to be used abundantly in the New Kingdom. Bellows are usually made of an inflatable bladder that allows air in through a series of one-way vents and out through a nozzle or hose. This bladders is affixed between two hard surfaces that when pulled apart inflate the bladder and when squeezed expel the gathered air through the nozzle

[109] Duell 1938: Plate 30, from the tomb of Mereruka.
[110] Davey 1985: 147; Davies 1973: Plate LII.
[111] Davey 1985: 145.
[112] Davies 1973 : Plate LII
[113] Ioannides 2014: 128.
[114] Rothenberg and Lupu 1966: 129.
[115] Castel et al. 1995: 17.
[116] Davies 1922: Plate XXVIII; Davies 1973: Plate LII; Scheel 1989: Images throughout.

of the contraption. Pot bellows modify the design so that a ceramic cylindrical vessel is covered by flexible leather with one way flaps. As the leather is moved up and down it alternatively sucks in air through the flaps and expels air through the nozzle. In ancient Egyptian depictions of metallurgy these bellows are shown operated by the user's feet with a rope attached to assist in the re-inflation of the device.[117]

Archaeological experiments have been conducted that demonstrate at least three individual blowpipes were needed to achieve appropriate smelting temperatures.[118] On the walls of the tomb of Rekhmire, four bellows operated by the feet of the workers stoke each of the smelting fires.[119] Other scenes like those found in the tomb of Puyemra (TT 39) show a combination of both bellows and blowpipes being used, with the pipes being pointed down into the fire from above while the bellows send air along tubes into the heart of the fire.[120] Each of these technologies would have required sizable amounts of time and effort to prepare before the smelt could take place and more even effort was required to maintain them as the expedition continued their operations.[121]

Smelting

The word smelt refers to the initial refining of metal using heat to transform mineral and ores into usable metal, while subsequent use of heat for refining is referred to as melting or re-heating and focuses on the liquefication of the metal.[122] Because the process for both activities is similar, it is often unclear in tomb scenes whether a metallurgical activity is clearly smelting or melting. The procedure is as follows: after sorting the material, a furnace would be filled with charcoal and lit. The fire would burn for several hours to achieve the appropriate temperature of nearly 1000^0 C. A mixture of charcoal and minerals to be smelted, called a charge, would then be introduced to the furnace. Bellows and sometimes blowpipes would be used to introduce more air into the furnace in order to maintain temperatures in excess of copper's melting point (1085^0 C). This high temperatures would ensure that the charge remained molten for as long as possible and to help burn off some of the unwanted residue. A flux, a material designed to assist in the chemical separation of the various components within the mineral, could also be introduced into the charge.

[117] Betancourt and Muhly 2006: 125-132.
[118] Craddock 1995: 127.
[119] Davies 1973: Plate LII.
[120] Scheel 1989: 24.
[121] Shaw 2002: 246-247.
[122] Rothenberg 1999: 162.

Fluxes are intended to chemically bond with the unwanted material and usually float on the liquified metal. When malachite was used as the mineral for the smelt, charcoal not only acted as the fuel but the flux as well. However, other minerals required the use of iron oxides, sulfides or manganese as flux or fluxing agents, depending on the chemical makeup of the mineral being smelted.[123] These fluxing agents would aid in the chemical release of the metal from within the mineral and bind the impurities, or slag, together. Once the charge had been burned for an appropriate amount of time, the furnace was allowed to cool and the residue was removed. Small beads of copper, or prills, could be found within the slag left at the bottom of the furnace. The copper trapped within the slag would be released by crushing and grinding, and further refined by additional melting to form ingots.

Smelting originally took place in pit style furnaces (Fig. 4.1), but by the New Kingdom most furnaces were built using the more advanced shaft furnace design.[124] The changes in the design allowed the furnace to burn hotter for longer periods of time primarily by introducing controlled airflow technologies. Pit furnaces commonly harnessed natural breezes, or metalworkers used blowpipes aimed down into the charge, to increase the oxygen available in the furnace. The longer and hotter a mineral could be smelted, the greater the degree of separation between the slag and the purified metal.[125] Shaft furnaces (Fig. 4.2), like those used in the New Kingdom, relied on tapping, a process in which a hole was unplugged from the side of the furnace wall just above the level of the purified metal.[126] The impurities, or slag, would float on liquefied metal at the bottom of the furnace due to the differences in viscosity and would flow out of the tap hole in the side of the furnace and into a pit where it would gather and cool. The metal could then be allowed to cool at the bottom of the furnace without

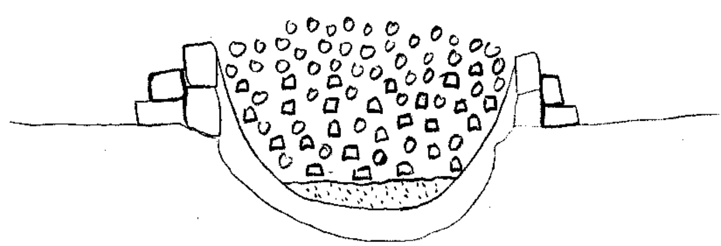

Figure 4.1 Example of Pit Furnace after Scheel

[123] Ogden 2000: 152.
[124] Castel et al. 1995: 17; Rothenberg and Lupu 1966: 135.
[125] Craddock 1995: 147-148.
[126] Scheel 1989: 16, fig. 9.

needing further crushing to remove it from the slag. The bottom of the furnace could be set with a mold that would establish the shape and size of the ingot.[127]

Site 2 at Timna, provides ample evidence of this smelting process and its supporting technologies. Excavations, as well as experimental smelting operations, carried out in 1964 by Rothenberg and Lupu found evidence for several shaft furnaces in Areas C, E and G, including the remains of one complete smelting furnace, designated furnace IV, with its associated slag pit. Rothenberg reported that the furnace was roughly 40 centimeters in diameter and 40 centimeters deep with a clay lining averaging about 6 centimeters in thickness. A clay tuyère was found embedded within and through the clay lining and would have supplied the furnace with air from a bellows during the smelt. The furnace's side wall had been damaged in antiquity as part of the normal operating procedure when the copper load was removed after it had cooled. Slag had coated in the interior walls of the clay lining within the furnace, but the bulk of the molten refuse had been tapped into a 70 centimeter by 120 centimeters slag pit that had been lined with stones to contain the material.[128] Another furnace, designated Furnace I, was identified at Area E. It was more well-constructed with a wall built around the upper section and showed signs of repeated reuse with multiple smelting floors, slag pits and slag layers of differing consistency.[129] Further excavations in Area G revealed that the site had previously been used as a metallurgical processing site with different strata showing distinct signs of slag and furnace pits separated by layers of sterile sand, representing a period of absence of metallurgy operations.

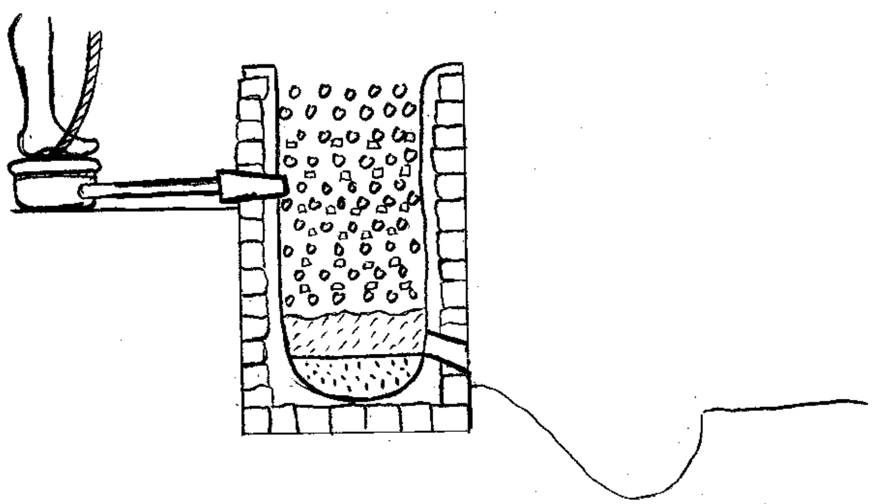

Figure 4.2 Example of Shaft Furnace with slag pit and pot bellows after Scheel

[127] Van Lorkeren 2000: 275-276.
[128] Rothenberg and Lupu 1966: 129, 131.
[129] Rothenberg and Lupu 1966: 130.

While the furnaces and evidence of smelting is important to our understanding of metallurgical practices, Site 2 at Timna also has evidence that the supporting technologies discussed above also were prepared on site. In Area B an installation for the manufacturing of charcoal was discovered with significant layers of carbon dust and charcoal *in situ*. The area also contained a workshop with evidence of crushing and grinding operations in the form of crushed copper ore along with grinding and hammering stones.[130] Area D contained additional storehouses and workshops that contained additional stone tools, clay for furnace linings and tuy*è*res, copper ore, and flux. Rothenberg postulates that one building in the area, measuring ten by six meters, served as a center for preparing the charges that would be smelted within the furnaces.[131] Rothenberg dated Site 2 to no later than 1100 BC, a timeframe that is concurrent with the New Kingdom in Egypt.[132] Thus, this site could be seen as a typical late New Kingdom center for the metallurgical operations that took place near mining expeditions.

Ingots

The two main types of ingots produced during the New Kingdom are the so-called bun and oxhide ingots.[133] Bun ingots are similar in shape to modern ingots. They are roughly rectangular and plano-convex, weighing roughly 3 to 6 kilograms.[134] Bun ingots are smaller than oxhide ingots, which weighed between 24 and 30 kilograms, and whose shaped resembled depictions of flayed animal skins in Egyptian art (Fig. 4.3). They had what could be referred to as handles or tabs on the corners (the equivalent of where the legs of an animal would have been, had this been a skin), which aided in their transportation on the shoulders of

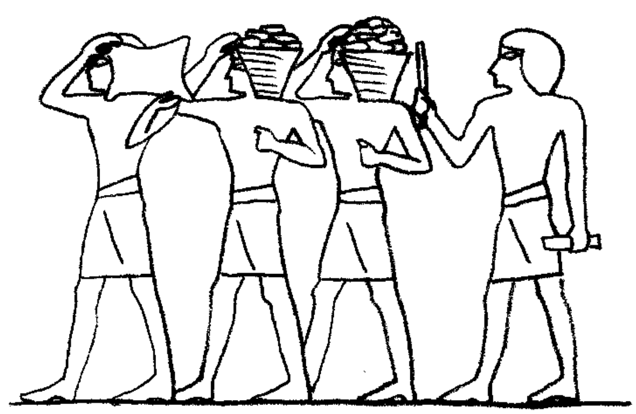

Figure 4.3 Metalworkers from TT100 after Davies – The worker on the left carries an oxhide ingot while the two middle workers carry baskets of bun ingots or fluxing agents.

[130] Rothenberg and Lupu 1966: 127.
[131] Rothenberg and Lupu 1966: 128.
[132] Rothenberg and Lupu 1966: 133.
[133] Van Lokeren 2000: 275.
[134] Hauptmann 2002: 17

metalworkers and porters.[135] Oxhide ingots, due to their size, required copper from multiple smelts to create. Crucibles were of extreme importance in this process as they allowed the metalworkers to contain and control the liquefied metal without sustaining heavy injuries.[136] If gathered and purified correctly, copper ingots could be of high quality and density, resulting in less refining being necessary during the shaping and casting processes.[137] The copper recovered from the Ulburun shipwreck contained impurities in the form of slag, residual flux and sulphides due to improper refining methods that led to poor quality copper in the ingots.[138] Thus, it is probable that ingots were of different qualities resulting from the refining methods that were used.

The discrepancy in the weight of the two types of ingots used by New Kingdom metalworkers likely relates to their intended use. The shipwreck of Ulburun contained 354 oxhide ingots and 121 bun ingots of copper.[139] The presence of significantly more oxhide ingots on a vessel engaged in long distance trade implies that these ingots were designed to be used in high capacity exchanges. The tomb of Rekhmire shows one such oxhide ingot, along with materials possibly including smaller bun ingots of tin and lead, being used in the construction of large bronze doors to be installed at the temple of Karnak.[140] The copper being used is identified as "Asiatic copper" and its depiction as an oxhide ingot reinforces the idea that these ingots were reserved for either international trade or high capacity projects.[141] The bun ingots, because of their small size, would have been useful for the production of objects requiring smaller amounts of the material, like jewelry and tools, as they would have required less work to cut down and reshape than that required in the refining and reshaping of oxhide ingots.

Transforming the metal into ingots like those described above created an easy way for the metal to be transported from the mining site and to establish standards in their trade. While, with an appropriate heat and duration, small ingots could be created from a single smelt, most ingots that have been found show evidence of multiple meltings to achieve the size and consistency necessary for the two standard ingot styles used in the New Kingdom. Experiments suggest that in an early small-scale furnace, which did not employ tapping to free the copper from its slag,

[135] Ogden 2000: 150; Gestoso Singer 2007: 24.
[136] Scheel 1989: 22-23.
[137] Hauptmann 2002: 7. Referencing the quality of copper ingots produced at Timna and Wadi Fainan.
[138] Hauptmann 2002: 2.
[139] Gestoso Singer 2007: 24.
[140] Davies 1973: Plate LII.
[141] Scheel 1989: 19.

between 1 and 3 kilograms of refined metallic copper prills could be produced from a single smelt.[142] During the smelt some of these prills would be separated from the slag, but a substantial number of prills would first need to be removed from the slag trapping them before they could be used. The prills, once free from the residual material, would then be melted into ingots. The weight of even a small bun ingot often exceeded the amount of copper prills produced from a single smelt, and oxhide ingots required several times the amount of copper needed in a bun ingot. Greater measures of copper could be obtained from tapped shaft furnaces, but the material was still insufficient to produce large ingots with a single smelt.

Further Refinement

Smelting was only the first step in the production and refining of copper. Further melting, which often required the use of crucibles, raised the quality of prepared copper ingots by the additional removal of slag and impurities. While shaft furnaces proved useful in increasing the efficiency of smelting installations at mining sites, they are not as useful for further melting and processing of copper since they are difficult to use in conjunction with crucibles and the tapping procedure they facilitated was unnecessary at later stages of refinement. The metalworking scene in the tomb of Rekhmire supports the premise that crucibles were used primarily with open pit furnaces, as it depicts multiple sets of metalworkers heating crucibles above fires stoked by pot bellows. Other tombs, like that of Puyemra (TT39), show workers using blow pipes to stoke fires holding curved bottom crucibles nestled in fires or against low walls.[143] Experiments conducted with small amounts of copper ore have demonstrated that copper can be smelted in crucibles, with copper oxide ores producing particularly clean and slag free results. However, the practicality of using crucibles to perform the initial smelt on large quantities of copper remains in question.[144]

Crucibles were absolutely essential in the casting process, not only with copper but other metals as well. Metalworking scenes, and especially those related to casting operations, clearly show the use of crucibles in the handling of heated, and often liquefied, metals.[145] Once again the tomb of Rekhmire provides clear depictions on the process of heating metal, held in crucibles above several fires, and then pouring the metal into molds, in this case for the doors to the temple

[142] Hikade 1998: 47
[143] Scheel 1989: 23, fig. 14.
[144] Rothenberg 1999: 162 & 165.
[145] Davies 1973: Plate LII.

of Amun at Karnak. Because the heated contents, as well as the crucibles themselves, were extremely dangerous, care had to be taken in their handling. As shown in the metalworking scene in Rekhmire's tomb, branches, likely soaked in water to protect them against the heat, were twisted around the crucibles and are one way the ancient Egyptians handled these super-heated containers. The method appears to have required two people to perform and would have ensured greater control, especially during the pouring for the cast. Stones could also be used as insulation against the heat of the crucible and did not necessitate multiple workers coordinating their movements.[146] However, the scenes which depict stones being used this way always coincide with the use of small "sock" style crucibles.

Alloys

An alloy is a combination of metals, or metals with other materials, that alters the structure of the metal to change or modify its attributes. Alloying, the process of experimentation and purposeful creation of alloys, probably began as a result of beneficiation, which allowed naturally occurring deposits of arsenic within Egyptian copper to accumulate to a sufficient degree to give the resulting copper-arsenic blend greater strength than had by pure copper, which is more prone to wear. Truly pure copper was unobtainable in the ancient world as neither the native deposits nor the smelting procedure were of sufficient quality to produce one hundred percent pure copper.[147] However, copper-arsenic was the first alloy exploited by the Egyptians for its mechanical benefits. Old Kingdom examples of axes using alloyed copper and arsenic are found to be 7 percent arsenic by weight.[148] Alloyed copper is more useful and stronger than pure copper, particularly when mixed with arsenic. Copper with an arsenic component of one percent was useful in tool manufacturing as it was easier to cast because of its enhanced ability to flow when molten. This allowed for the clean filling of the casting molds, which resulted in the production of more stable objects. Copper-arsenic was also stronger than traditional un-alloyed copper, which meant that it produced more effective tools that would ultimately require less upkeep and maintenance.[149]

Bronze, an alloy of copper and tin, often receives the greatest degree of attention when discussing archaeometallurgy as it represents a clear technological shift. Perhaps that is why it is

[146] Scheel 1989: 30 & 31, figs 26 & 27.
[147] Ogden 2000: 151.
[148] Ogden 2000: 152.
[149] Tylecote 1976: 8, fig. 2.

the sole alloy that designates a chronological time period in the history of a civilization: the Bronze Age. Bronze is, however, sometimes difficult to identify without proper chemical testing. In Egyptology, this has caused problems when discussing the material construction of metal artifacts. Early Egyptologists often identified artifacts as bronze, when in fact they were copper or copper-arsenic alloys. This has led to muddled understandings of bronze's first use in Egypt. There are examples of high tin levels in Early Dynastic and Old Kingdom vessels and objects, but those examples represent a small minority of the artifacts from those periods. The Middle Kingdom saw increased and apparently deliberate alloying of copper and tin, but even in the early New Kingdom bronze was still not the dominant alloy in use.

It is not until the Ramesside Period that tin becomes present in most copper alloys. This increase in the presence of tin is probably due to the increasing amount of international trade during the Ramesside period. Tin was not an abundant resource in the ancient Near East and there is much dispute as to its origin.[150] It has been suggested that ancient tin used by the Egyptians and other Near Eastern civilizations was sourced from areas of Anatolia, Iran and possibly Armenia.[151] The prevalence of New Kingdom copper-tin bronze artifacts as well as tin-based pigments would have required the acquisition of tin from somewhere, but no clear source has yet been identified.[152]

The shipwreck at Ulburun contained roughly ten tons in copper ingots and another ton in tin ingots. If these amounts are to act as a guide in recreating the recipe for ancient bronze, then it is probable that Egyptian bronze artifacts should contain roughly a nine to ten percent tin content. However, chemical testing has shown that the tin content can fluctuate wildly in ancient Egyptian artifacts, such as the hollow cast figure of a man now kept at the Louvre (E27153) with five percent tin and a *mnit* in the Fitzwilliam Museum (EGA.54.1949) with a 20 percent tin content. This means that it is possible there was no established standard in the production of bronze, and that bronze objects produced in ancient Egypt could vary widely in their make-up.[153] Unfortunately, the necessary testing to identify chemical content is often destructive in nature, which has limited the number of tests performed. Only an increase in the number of tested artifacts can increase our understanding of the ancient recipe for bronze and provide deeper insight into ancient alloying processes.

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[150] Ogden 2000: 171.
[151] Tylecote 1976: 14; Van de Meiroop 2010: 169.
[152] Ogden 2000: 153.
[153] Ogden 2000: 153-154, 171.

Per-Ramesses Case Study

Fortunately, knowledge of the process of metalworking and the production of alloys in the New Kingdom has been enhanced in recent years by the excavations in the Nile Delta near the area of Qantir, in what once was the capital city of Per-Ramesses. Edgar Pusch and his crew successfully excavated the remains of a high-temperature craft industrial complex, where not only metalworking was performed, but also glass and faience production.[154] It is likely that due to the similar nature of the work, namely reliance on high-temperature fires, kilns and copper ores (glazes often required copper and tin for coloring), these industries were housed together in what was almost certainly a state/royally-controlled workshop.[155] The site's importance is partially due to its immensity, covering nearly a space of nearly 30,000 square meters, but the clear evidence of bronze alloy production is also key in helping to establish the technological changes and the emerging standards of metallurgy within the New Kingdom. It also contains evidence of foreign influence in the form of the production of Hittite shields and weaponry alongside Egyptian goods, which give clear dating evidence to place the site's primary usage during the 19th Dynasty and Ramesside period.[156]

The two strata of most relevance to this discussion are B/2 and B/3. These layers contain significant metalworking facilities with three distinct types of heating structures designated as melting channels, melting batteries and cross-furnaces. Their use in many ways follows the patterns described above for melting, and possibly smelting, activities with large amounts of charcoal being used to produce sufficient heat to melt copper ingots, or portions thereof, within crucibles in preparation for casting in prepared molds. The multiple melting channels, measuring approximately 20 centimeters across, run parallel along the floor of the facility for roughly 15 meters each and are thought to have been supplied with forced air via pot bellows, although no clear examples of such have been identified. The melting batteries seem to be reserved for the preparation of metals for use in molds, which were excavated quite near the batteries. The uniquely styled cross-furnaces appear to have contained compartmentalized internal sections, each with a sloping floor leading into a central pit where a large amount of slag was collected. However, there is some degree of confusion around the intended use for the cross-furnaces as the slag still present

[154] Pusch 1990: 100; Herold 1995: 134.
[155] Pusch 1995: 126.
[156] Herold 1995: 137; Pusch 1995: 122.

within the furnaces' inner chambers is distinctly different than the slag on the crucibles found near the furnaces. It has been suggested that the furnace could have acted as an oven to preheat the molds used in casting at the site as well as clean them of residual metals after use, or possibly casting particularly large pieces within the furnace itself.

The center for heating at the site represents only one part of the metalwork performed in this industrial style complex. Nearby, on the south side of the enclosure wall, workshop areas are designated and filled with material for the production of goods relying on metal, stone, glass, faience, leather and even bone. While there is no definitive evidence, it is likely that this facility operated similarly to a more modern factory with the raw metals being prepared in the furnaces, poured into molds on the "furnace room" floor, and cooled products being removed and refined in nearby workshops.

The true value these furnaces and melting stations serve in the present discussion related to the economic value of copper during the New Kingdom, is that they demonstrate the amount of work required to create and maintain them. Pusch and his team suggest that the large melting chambers are likely to have operated simultaneously. One partial section of a single melting channel roughly seven meters in length is reported to have contained thirty-nine tuyères, many of which were found *in situ* within the low wall of the channel. If we extrapolate this data out to first to one complete channel, with at least forty people working on heating crucibles, and then taking into account the multiple channels, six separate melting batteries, three cross-furnaces, along with those attending to the molds and castings, an estimate of several hundred metalworkers employed on just the "furnace-room floor" is easily believable. That is not taking into account those working on the goods and products elsewhere on the complex. While this site shows periods of inactivity between the 18th and 19th Dynasties, the complex shows heavy signs of continuous use for roughly sixty years (1320-1250 BC) during the later New Kingdom and especially during the reign of Ramesses II.[157]

Recycling

Due to the work required to produce useable copper, and other metals, it was often recycled from previously prepared batches or by recycling used tools and artifacts.[158] In the case of the

[157] Pusch 1995: 126.
[158] Ogden 2000: 156-157.

bronze production centers at Per-Ramesses, some of the copper being recycled has been identified as Cypriote in origin.[159] This makes establishing material standards, especially those related to alloying, difficult for archaeologists as the makeup of material components can fluctuate within a single artifact, let alone between locations, workshops, or time periods. Thus, the requirements for considering a material to be alloyed on purpose often are quite low, sometimes needing no more than a one percent inclusion of the secondary element.[160] This is partly why bronze is often cited as the material of an artifact. To combat this ambiguity most of the scholars engaged in archaeometallurgy have called for increased chemical analysis of artifacts in an effort to establish comparative data for future finds.[161]

Required Workforce

Before discussing the goods produced through the use of copper or their impact on Egyptian economy, it is fundamentally vital to discuss what the acquisition and processing of copper ore represented in terms of workload and resources. The lack of any relevant mechanized systems to ease the workload for these activities meant that all these endeavors, and their supporting technologies, were necessarily performed by people. This labor performed by these individuals represents the unifying element between the extraction and processing of copper as a resource and the larger New Kingdom economy.[162] Two unique features significantly impacted both the social and economic structure of ancient Egypt: the Nile River with its yearly inundation and the authoritarian control exerted over Egypt's large population.

In comparison to most other river basins, the Nile Valley is unique in two respects: its pathway takes it through the otherwise completely barren landscape of the Sahara Desert and its yearly flooding was predictable and non-threatening. Without the Nile River, Egyptian civilization would never have formed. The yearly cycle of its inundation was likely the foundation of Egypt's religious beliefs and practices, with their focus on rebirth and resurrection. This inundation supplied the valley with fresh rich soil and divided the abundantly fertile black land, *kmt*, from the desert regions inhospitable to human life, *dšrt*. The inundation and simple irrigation techniques also made grain farming easier than anywhere else in the world. The flooding lasted for roughly

[159] Rademakers 2017: 50.
[160] Ogden 2000: 152.
[161] Ogden 2000: 154.
[162] Cooney 2007: 162.

four months of the year and during this time there was little work for farmers to perform on their crops. This freedom from labor intensive crop production allowed the population to be used for state and religiously funded projects like pyramid and temple building and mining expeditions. The labor conscripted for such projects is classified as corvée labor.[163] While there are few clear records that outline the policies governing the practices, recruitment or schedules of corvée work groups, they nevertheless represented significant available resources for Egyptian royal and religious institutions.[164] From the few examples of administrative documents discussing corvée labor groups Egyptologists believe that their recruitment and use varied depending on the expedition or activity with which the group would be involved. However, it does seem logical that such groups would be gathered and used when not involved in other subsistence activities. Therefore the inundation would have been provided the best season for gathering large numbers of workers, but this assertion is still subject to speculation.

Egypt has always had a significant population in comparison to its neighbors in the Near East.[165] That population provided Egypt with a substantial workforce that facilitated in Egypt's early rise as a civilization.[166] It was expected that the populace would support royal and religious institutions through taxes. Because money was not a developed concept of most ancient civilizations, these taxes were most often collected through payments of grain or conscripted labor programs, otherwise known as corvée labor or *bḥ* to the ancient Egyptians.[167] The ability to conscript labor for state projects, usually during the inundation when farming communities were largely inactive, is a resource not to be underestimated.

Each of the steps in the processes of mineral extraction and processing described above required the attention and skill of at least one person to achieve, and more realistically several people, particularly if the activity was performed as part of a large-scale operation/production. People were needed to make and fire the ceramics used in the crucibles and tuyères. Someone had to prepare the charcoal from the available wood sources, while others had to stoke the fire and make sure it was the appropriate temperature and then to maintain that temperature, and finally taking constant precautions to ensure the safety of the camp. People were needed to prepare the

[163] Shaw 2002: 246.
[164] Cooney 2007: 164-165.
[165] Trigger 2001: 30-31; Spalinger 2002: 147.
[166] Spalinger 2005, 148.
[167] Cooney 2007: 165-166; Faulkner 1962: 83.

charge for smelting. Others had to prepare the molds for the eventual castings. Individuals or groups of administrators had to keep track of the stores and supplies needed for supporting life in remote areas. At the mines, workers had to be fed, so teams of people had to cook for them and provisions, including water, often had to be brought into the site. Medical care was also a concern, although this likely was considered a secondary duty.[168] Several Egyptian mining and processing sites also demonstrate evidence of security forces present for at least some periods of the mining operations, either as a protective or policing force.[169] Fortifications along routes involved in metal trade and near mining centers, like those at Wadi Maghara and Ras Budran, further signified the value of copper to the New Kingdom Egyptians, since people do not defend that which is of no value.[170] The unskilled labor forces present at the site were the result of seasonal corvée labor, requisitioned by the royal and religious authorities.[171] It is unclear whether the craftsmen who provided the skilled labor were conscripted or not. The administrative force was most often directly connected to the institution maintaining the mining operation. The scale of such operations, and the number of people employed by them, provide good indications of the relative value that copper held in Egypt.

It is estimated that a single mine shaft in the Sinai required at least ten workers to maintain; three to create the tunnel or shaft, two to carry away the detritus, two to sort the ore into useable and un-usable fragments, one assisting with the vertical ascension of the material, one prospector, and one overseer required to document the haul.[172] Given that each mining site dated to the New Kingdom in the Sinai, Timna and elsewhere contained multiple shafts, and using royal documents to establish the size of expeditionary groups to these mining locations, it is probable that mining excursions employed several hundred people to assist in the mining, processing, transportation and administration surrounding copper.[173] One expedition, in the 38th regnal year of Senusret I (1927 BC), to the Wadi Hammamat, known for its gold deposits and specially hard stone, employed 17,000 people.[174]

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168 Černý 1954: 919.
169 Cooney 2007: 167.
170 Nigro 2014: 39; Mumford 2015: 10.
171 Cooney 2007: 166-167.
172 Hikade 1998: 126.
173 Shaw 2002: 247.
174 Cooney 2007:166; Shaw 2002: 250; Eggebrecht 1980: 66 – suggests more than 20,000 men employed as part of the expedition.

While the workforce required at both mining and workshop sites would have been substantial, several categories of archaeological data, including layers of inactivity at metalworking sites, expedition inscriptions and proclamations and scribal literature, support the conclusion that these sites were used for relatively short time periods and likely only during certain seasons.[175] The site at Qantir likely had a period of no more than 60 years of productivity. During that period its production focus shifted from general bronze goods to chariot manufacture and maintenance. These transformations are possibly the result of political change in the Ramesside Period and the war with the Hittites coming to an end.[176] The lack of any permanent dwellings and documents from the New Kingdom indicate that mining expeditions were seasonal or episodic, relying on the king's direction, and therefore no permanent towns or settlements were established at the sites.[177] This transitory nature likely facilitated the transport of the processed copper, at least to or from areas within the Nile Valley, as the workers returned to their respective homes as the summer period of inundation, lasting roughly three to four months, came to a close.

Inscriptions and graffiti left at the mining sites also give clear indication that most of these sites were exploited only periodically by royal excavation teams. Shaw suggests that during the Middle Kingdom the average time between major mining expeditions to the Sinai was somewhere close to 30 years.[178] However, during the New Kingdom the mining sites appear to have been used more frequently, especially Timna, with large camps supporting the metal processing. Such camps were equipped with living arrangements prepared for the workers as well as objects used to support their daily lives, including cooking utensils and various pot types.[179] Even this more frequent use does not suggest that these expeditions were regular occurrences as they are often touted as great achievements by the king in royal inscriptions. Hatshepsut's trading expedition to Punt preserved on the walls of her mortuary temple at Deir el-Bahari, while not directly concerned with metal trade, serves as a good example of the status that such trading and mining endeavors held within the New Kingdom royal mindset. The mining expeditions were not as celebrated as the trading or military exploits of most Egyptian Kings, probably because they were seen as more supportive or important to infrastructure rather than spectacle. In some ways it was the rarity of these expeditions

[175] Pusch 1995: 126.
[176] Herold 1995: 135-136.
[177] Mumford 2013: 6163.
[178] Shaw 2002: 251.
[179] Rothenberg and Lupu 1966: 132.

that made them effective as symbols of the power, authority and ability of the king to sustain Egypt.

One other type of evidence that mining was considered more of a short-term arrangement actually comes from what is considered a classical piece of ancient Egyptian literature: *The Satire of the Trades*. This piece lists out many of trades with which the ancient Egyptian people were involved including farming, fishing, weaving, baking, haircutting and smithing among others. What is important about this list is that there is no mention of mining as a profession. The author of the ancient text goes to great length to decry the various hard labor jobs of the day explaining to his son that their drawbacks make them inferior to the exalted occupation of the scribe.[180] Given the poor and potentially dangerous working conditions, desolate locations, and the high levels of back-breaking labor involved with mining, it seems unlikely that the author would not have anything negative to say about mining as a potential occupation. It is possible that the exclusion of such work from the *Satire of Trades* is because it was not designated as an official profession. It is likely that ancient Egyptians would have viewed it in similar light to any other type of corv*é*e labor required by the state institutions, rather than a regular trade.

The inclusion of metalsmiths within this list might be broadened to include mining, but it seems unlikely since the author's critique of the smith, in some translations more specifically the copper-smith, is that his hands smell like a crocodile. This complaint has little connection to mining processes, although it could be related more to a more socially construed status. The smell probably refers to the smoke generated by the smelting furnaces and the odors produced from burning flux and metal slag, although it remains unclear. The status of miners, as a profession, therefore was likely either a non-issue as it was considered a part of the corv*é*e labor required by the state on, at most, a seasonal basis. The work also might have been performed by prisoners of war and/or criminals and therefore not a position appropriate for law-abiding Egyptian citizens.[181]

The status of miners and metalworkers helps to frame the further discussion about the role copper played in Egypt and its economic value. Professions dedicated to the acquisition of copper and the status of those involved in related activities provides contextual information about how the society at large valued the people engaged in the procurement of raw materials and commodities. As is the case in most civilizations, the Egyptians seem to have placed higher value on those

[180] Lichteim 2006: 186 & 188.
[181] Cooney 2007: 173.

engaged in the crafting of goods over those involved in gathering the raw materials for such goods to be made. In the subsequent chapter those goods will be discussed along with the modes of their production.

Chapter 5 – Copper Artifacts

Artifact overview

Copper was a key component in many types of objects produced by the ancient Egyptians in all walks of life. These artifacts held significant value: for the material from which they were made, for their usefulness or beauty as objects in their own right, as well as for their socio-ideological function. These objects, explored below in greater detail, include weapons and military gear, tools, household goods and jewelry. Copper was also used as a material in medicines and pigments. The social value of such objects and uses is often difficult to measure and was subject to wild fluctuations in prevalent tastes. However, social value can have significant impact on economic exchanges, especially in domestic exchanges. The value given to copper is especially important when evaluating grave goods, since the inclusion of the material within the objects left with the dead indicated their expected usefulness to the deceased. Each artifact type introduced below will be presented with its most standardized characteristics. Variations in decoration, size and medium were common in ancient Egypt, but each of these objects included herein required the use of copper in some substantial way. Photographs of examples of the artifacts can be found in Appendix A.

General Aspects of Production

Most of the general shaping of the tools and artifacts would have been accomplished either through hot or cold working methods by the use of stone pounding hammers and shaped anvils of various materials or through casting. The materials necessary for metallurgical activities are well established in the archaeological and pictographic material of the New Kingdom and some have been introduced above.[182] In the case of hammering methods, sheets would be prepared from metal ingots, or portions thereof, through a process called chasing. Chasing is performed by pounding the metal with a curved stone along a flat anvil made of either wood or stone. In the hands of a skilled craftsman, the curvature of the stone stretches and thins the metal, pressing it in the desired direction.[183] This combination of flat anvil and pounding stone seems to have been used in the early preparation of copper and copper alloys, but not in shaping the metal into any form other

[182] Davies 1973: Plate LII.
[183] Scheel 1989: 36.

than flat sheets. Anvils used for shaping vessels and other household goods appear to be primarily constructed of wood, which would soften the hammering marks resulting from working the metals. These shaping anvils were little more than wooden rods supported by a bi-pod or lashed to a post.[184] (Fig. 5.1) In the case of large objects being produced, sometimes a core of wood would be used that would provide a form on which to bend the metal and to which the shaped metal could be affixed. The life-sized copper statue of Pepi I was possibly created using this method, but Eckmann debates the use of such techniques.[185] Such a large artifact required multiple shaped pieces to be joined. This joining would be accomplished by fixing each metal sheet to the core, or through soldering sheets together. The soldering technique was commonly used for vessels since they needed to be hollow to be functional. The soldering process required heat to be applied to the metal sheets, usually once they had been roughly shaped, so the materials could be bound together with additional metallic elements.[186]

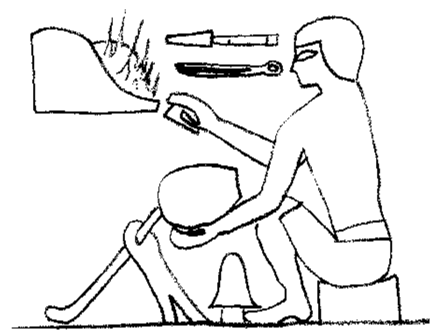

Figure 5.1 Metalworker from TT100 after Davies

Heating copper while working it, a process called annealing, greatly increases the ductility and general strength of copper goods. The heat allows the poly-crystals in the metal to reorient more freely and reduces the cracking that can occur through cold working the material. This process seems to be well understood as metalworkers are often shown with small furnaces near their shaping stations (Fig. 5.1)[187] As part of the annealing, the part would be left to cool naturally, although rapid cooling in liquid can also assist in the process. Once the process was complete, objects that would be used as tools or that needed increased strength would then be further hardened through more cold work. Work-hardening, as the process is called, greatly increased the durability of copper objects.[188]

Unlike the hammering methods, casting can only be performed with molten metals. One of the oldest methods of casting, and one which allowed for the most detail to be transferred to the object, is that of the lost-wax cast. To use this technique a model in the final shape of the desired

[184] Scheel 1989: 36.
[185] Eckmann and Shafik 2002: 12.
[186] Scheel 1989: 34.
[187] Davies 1973: Plate LII
[188] Poole et. al. 1996: 560.

object was prepared in malleable bee's wax, which allowed for a high level of detail to be preserved.[189] After the model was prepared, a ceramic coating was applied to the outside of the model. The model and the ceramic were then fired within a furnace or kiln to set the ceramic while the wax was allowed to melt out. The result was an empty ceramic mold that held the detail of the original model and could withstand the heat of molten metal poured inside. The mold would then be filled with the desired metal and both were then allowed to cool. Once the metal had hardened, most ceramic molds needed to be broken to remove the finished product.[190] However, due to the ease with which these molds could be prepared, this additional work of preparing new molds did little to hamper the fabrication of metal goods. Because of the efficacy of the method, lost-wax casting is still used in the prototyping and machining practices of some industries today. Ancient examples of objects made using this method include the myriad votive statues that began to be produced at the end of the New Kingdom and throughout the Late Period.[191]

For larger or more substantial objects, a stone or ceramic core could be used, which would limit the need for the large amounts of metal. In this case, the wax would be sculpted around a prepared core. Then an additional layer of ceramic material would be applied to the external surface of the wax model as normal. The wax would again be melted out as the ceramic mold was fired and prepared for the molten metal. However, because the core was also inserted into the mold, the final piece would end up hollow. This significantly reduced the weight and the required amount of metal for these objects while still allowing for a high level of detail in the final product.

The types of molds used in the casting process greatly impacted the products created. Open molds, which only had one shaped or finished side and were usually prepared in stone, did not allow for high levels of detail.[192] Open molds are often found near smelting furnaces and could be used in the preparation of ingots, which did not require detailed components. These molds did not need to be broken since the metal was largely exposed on its upper surface and could be continuously re-used. Such molds have been tested in experimental projects with a high degree of success.[193] Most objects that used open molds in their preparation usually required a fair amount of additional processing and finishing before the objects were ready for their intended use. Even

[189] Ogden 2000: 157.
[190] Scheel 1989: 41
[191] Ogden 2000: 158.
[192] Scheel 1989: 40.
[193] Van Lorken 2000: 275.

axes and chisels, which relied heavily on open molds in their production, required refining and sharpening through the hammering methods discussed above. Closely related to open molds were the two-part molds. These molds were designed so that the object could be prepared in matching pieces that could be fit or soldered together.

These general processing methods produced the vast majority of ancient copper goods, including the ones discussed below. While the technologies they employed seem simple to the uninitiated, the careful manipulation and training required to produce the artifacts currently housed in museums around the world clearly show the high level of skill held by ancient metalworkers. The techniques discussed above are applied generally to all forms of metalworking, but hereafter the focus will shift to the production of copper based objects.

Military Goods

Non-precious metals, and specifically copper and bronze, were among the most effective materials used in warfare technologies.[194] For many of the same reasons that tools benefit from the use of metal in their construction, military items gain properties that enhance their efficacy. Both copper and copper alloys provide a durability that other materials of the ancient world lack. While copper's use is most commonly apparent in weapons, it was also useful for items that were to receive constant wear, like the bit placed in the mouth of the horse, or horses, pulling a chariot and along the hubs of wheels.[195]

Weapons and royal metallic body armor required large amounts of copper for their construction. The primary melee weapons of the army of the New Kingdom were the axe, spear and dagger.[196] Ranged weapons utilizing copper were primarily restricted to the bow and arrow. Arrows employing copper tips have been recovered, but the amount of copper required for such small elements would not have demanded vast stores of metal to produce.

The axe, used as a weapon, was possibly the earliest attested bladed weapon with clear examples dating to the Old Kingdom[197]. While the style of the axe blade changed over the course of Egypt's history, by the New Kingdom the blade of the axe was commonly trapeziform with a convex cutting edge and large extended lugs, which allowed for easy attachment of the blade to

[194] Partridge 2002: 24.
[195] Herold 1995: 135.
[196] Shaw 1991: 37, 42-43.
[197] Partridge 2002: 47.

the haft using leather thongs. (Fig. 5.2)[198] This style of axe is prevalently seen in depictions of warfare as a common weapon wielded by soldiers of the Middle and New Kingdoms. New Kingdom examples of soldiers and their gear can be found at Karnak Temple where scenes of warfare from the reigns of both Seti I and Ramesses II cover the exterior walls.[199] Luxor temple and the Ramesseum also display the military feats of Ramesses II. These scenes are dominated by the exploits of the King as he rides in his chariot, but mixed into the scenes are soldiers with wielding various weapons. On the northern interior wall of the Hathor shrine attached to Hatshepsut's mortuary temple at Deir el-Bahari a particularly clear example of soldiers in procession with their weapons, most notably axes like those described above, can be seen.

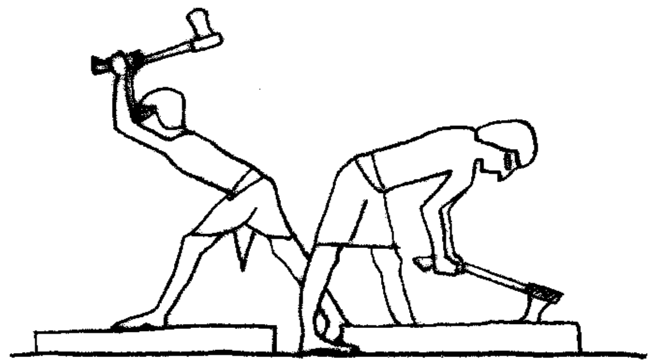

Figure 5.2 Carpenters from TT100 after Davies, Similar axes were used by New Kingdom soldiers

Axes used in combat were likely to have shorter hafts than woodcutting axes. These hafts had elliptical cross-sections that allowed for a more comfortable grip and increased the military effectiveness by limiting the chance that a glancing blow might disarm the soldier wielding the axe.[200] The blade design used in the New Kingdom allowed the wielder to reach over or around shields used by the enemy by extending the blade in a perpendicular direction from the haft. The cutting design also increased the penetration ability, thereby making the enemies' shields and armor potentially less effectual. Shallow axe-blades were occasionally attached to longer hafts and operated in a similar manner to a polearm. The length and weight of such weapons meant the wielder was required to use two hands and was thus restricted from using a shield.[201] Such designs could have been useful when wielded from a chariot, but it is unclear if they were used in such a manner. There are also several axes of ceremonial design dated to the New Kingdom. These axe-blades often have open-worked designs displaying figures or scenes.[202] The open design would

[198] Scheel 1989: 47.
[199] Epigraphic Survey 1986: Plate 3, 5.
[200] Partridge 2002: 48; Shaw 1991: 36.
[201] Shaw 1991: 38, fig. 28 - The scene depicts this style of axe used in a 5th Dynasty siege of a Palestinian fortress.
[202] Partridge 2002: 47.

have greatly reduced the weight of such axes, but would also have made them less effective in combat.

New Kingdom spears were comprised of long wooden poles and tipped with straight blades, often made of metal. The blades were often leaf-shaped and not necessarily thin. These design elements kept the blade from becoming trapped inside an enemy or shield and allowed for some degree of slashing in addition to piercing attacks.[203] The profile of spearheads changed little over the course of Egyptian history but followed the style of being roughly triangular in shape with a narrow aft section where they were attached to their poles.[204] In the New Kingdom, the standard method of attaching the spearheads to their hafts was to prepare a socket in the metallic head that wrapped around the pole and allowed either piece to be replaced with relative ease.[205] The spear came in two varieties, the short spear used for stabbing and the long spear used for thrusting.[206] Spears filled the middle ground between melee and ranged weaponry; they could be used for both since they could be held or thrown with accuracy. Spears can be used quite effectively when paired with a shield, but their piercing style of damage and relatively light weight would have also made shields an effective defense against them. Middle Kingdom models of soldiers show spears and shields were common, possibly the most common, weapons for army personnel.

The final weapon reviewed here will be the knife/dagger and their variations. Knives can be produced in a variety of materials, but metal double-edged blades with a slightly thicker center proved the most useful in the New Kingdom. The short blade lengths, 30 centimeter or shorter, ensured that these weapons were reserved for close-quarter combat only and they would probably have been ineffective against a shielded enemy.[207] The inclusion of a pommel officially changes a knife into a dagger and made the weapon better balanced.[208] Blades extending beyond 30 centimeter are more often classified as swords, but these were rarely used by the Egyptian soldier.

Often associated with knives and daggers is the sword-like khopesh or khepesh. These semi-sickle-shaped blades were longer than daggers and were Asiatic in origin, entering Egypt

[203] Partridge 2002: 39.
[204] Partridge 2002: 39.
[205] Petrie 1917: 31; Shaw 1991: 37; Partridge 2002: 38.
[206] Gilbert 2004: 58-63; Petrie 1917: 31. The difference in the two styles relates to the type of damage caused by the weapon. The *Oxford English Dictionary* says that a thrust is a force designed to push or move something away (1.a.), but to stab is to make a hole through something (2.d.), in this case an enemy.
[207] Reeves 1990: 177.
[208] Partridge 2002: 50.

during the late Second Intermediate Period.[209] Although the khopesh is commonly thought of as a sword or dagger a cross-sectional view of the blade shows it had a wedge-shaped design, with only the outside of the bulging convex curve being sharpened.[210] This singular wedge-shaped cutting edge means these weapons are more closely associated with axes in the purpose they served in combat. During the New Kingdom, they are often seen replacing the traditional mace in kingly "smiting scenes" and wielded by the king while battling from his chariot.[211] It is possible that this is due to the efficacy of curved blades from an elevated or mounted position. As an attacker swings the blade down while riding by in a chariot, the curved blade slashes through the enemy and is simultaneously pulled out as the attacker continues passing the target without becoming stuck in it. This ability is well documented and nearly all cavalry swords contained some curve to them all the way through the 20th Century, when mounted armed combat ceased.[212]

The bit, used as part of the chariot gear and referenced above, was a metallic, jointed element placed in the mouth of the horse and attached to the harness that allowed charioteers a high degree of control of the animal as it pulled them into war. This piece of technology, likely introduced along with the chariot by the Hyksos in the Second Intermediate Period, pulls on the tender areas of the mouth of the horse producing quick response times required in combat situations.[213] Without it, the horses pulling the chariot would have reacted slowly and would not have been effective in combat scenarios. The bit's production in copper or bronze ensured that the chewing of the animal would not destroy it, nor would it leave dangerous and painful shards of material in the harnessed animal's mouth.

Copper, and during the New Kingdom bronze, greatly enhanced the military capability of the ancient Egyptians. The size of Egypt's armies necessitated that massive numbers of these weapons and gear be produced and maintained. If the average weight of copper employed in the armament of one soldier was 400 grams, which does not seem unreasonable given that surviving examples of weapons range between 1 kilogram and 100 grams, then Egypt would have needed to have roughly 8,000 kilograms of copper, or 87,900 *dbn* according to their own system of measurement, in order to supply the soldiers who participated at the battle of Kadesh.

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[209] Shaw 1991: 43.
[210] Gordon 1958: 23.
[211] Epigraphic Survey 1986: Plate 4, 6, 13, 17b. Also, the entrance pylon of Medinet Habu depicts Ramesses III engaged in the traditional smiting scene using a khopesh blade.
[212] Gordon 1958: 25.
[213] Darnell 2007: 63.

Tools

Some of the tools requiring metal as part of their construction have been listed above, but specific examples will be provided here for clarification and comparison. Tools will be presented primarily in accordance with the main occupation with which they are associated. Because of the large number of special occupational tools and because in some instances tools could serve in multiple professions or as military weapons, for example, the axe and knife, care has been given to place each tool in the most appropriate category.

Farming

Farmers had little need for metal tools. The only metal farming implements that were used regularly in the New Kingdom were the hoe and the plough.[214] These devices are used to break up chunks of firmly packed soil, and prepare the soil for planting. Sickles and scythes used for the harvesting of crops were primarily made of wood with flint chips embedded within the cutting edge. Such flint could be easily procured and replaced should the tool need maintenance. Metal sickles and scythes only came into use during the Graeco-Roman period.[215]

Figure 5.3 Carpenter with adze from TT100 after Davies

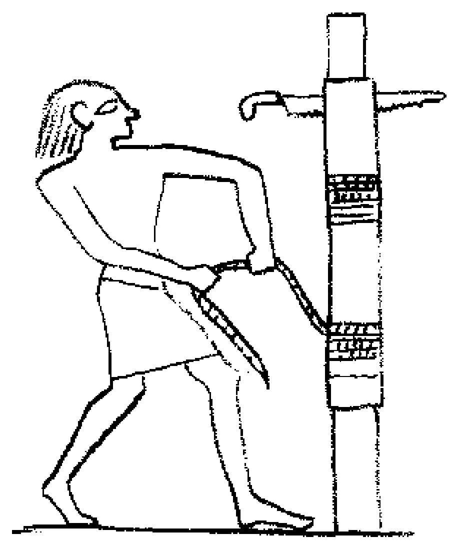

Figure 5.4 Carpenter with saw from TT100 after Davies

Carpentry

Carpentry tools were among the types of tools that most benefitted from the use of copper. The adze (*ʿnt*) was one of the most useful tools to the ancient Egyptian carpenter and is easily recognizable as a carpentry tool in Egyptian crafting scenes.[216] The closest approximate modern tool is the plane, but the designs differ substantially. Unlike a hatchet, which is built

[214] Scheel 1989: 56.
[215] Scheel 1989: 56.
[216] Lichtheim 2006: 186. – In the Satire of the trade the adze is the identifying tool for the carpentry trade.

similarly to the axe with its blade running parallel to its haft, the adze held the blade at an acute angle away from and perpendicularly twisted to the handle of the tool. (Fig. 5.3) The adze was considered a fairly versatile tool and served as the primary shaping implement of the carpenter's toolkit. It was primarily used to split, plane and chisel lumber with the blade being scraped along the grain of the wood toward the workman, while the axe and saw could be used to cut wood across its grain. Only the blade of this tool would have been made of copper or one of its alloys.

The ancient Egyptian saw was comprised almost entirely of a sheet of copper, no wider than half a centimeter, manipulated with either one or two hands via its handle or handles.[217] (Fig. 5.4) Saws could be prepared with teeth, most often positioned to cut on the draw stroke, or without any teeth, in which case sand could be used as an abrasive between the material being shaped and the copper blade.[218] Saws allowed for straight flat planes to be fashioned across the grain of the wood, something the adze was unable to perform. While saws were used most often within carpentry they could also be used in the quarrying and shaping of stone.[219] The sarcophagus of Khufu, within the Great Pyramid at Giza, and other sarcophagi from the Old Kingdom show clear signs of being shaped with a saw.[220] The sarcophagus of Khufu actually shows adjustments in the cutting angle.

Bow drills of the New Kingdom used copper for either drilling bits or as a type of tubular saw to cut circular holes in both wood and stone.[221] The bit was placed at the end of a short wooden shaft, around which was wound a thread or rope attached to a bow that pulled the thread tight. As the workman would manipulate the bow perpendicularly to the shaft, the tension in the string would spin the shaft being held in place by a capstone in the workman's alternate hand. The pressure applied from the cap stone would drive the shaft into the material being drilled and the bit would cut and grind a hole. Similar drills could be used in the course of hollowing out stone vessels. Metal bits could be placed across the main drilling post to enlarge the inner area of the container being shaped.[222]

[217] Arnold 1991: 267.
[218] Scheel 1989: 50 & 51.
[219] Scheel 1989: 51-52.
[220] Arnold 1991: 267.
[221] Scheel 1989: 53; Arnold 1991: 50.
[222] Wild 1939: plate 173.

Stonemasonry

Metal chisels or spikes (*ḫ3*), discussed above as part of the discussion on mining, were used abundantly for various stone shaping activities in the New Kingdom.[223] During that period, the chisels used in stonemasonry projects, often called spikes in ancient texts, weighed between seven and eight *dbn*.[224] They were handheld and used in conjunction with a pounding stone. They were normally rectangular in construction, being prepared in open molds or in two-part molds with a narrowed edge originally made by hammering and then sharpened with a whetstone.[225] Chisels employed by carpenters usually had wooden handles due to the necessity for greater control as well as their smaller size, while spikes used in stonemasonry were bulkier and did not require handles.[226] This difference is largely due to the different materials being worked, as the inclusion of a soft wooden handle in the stonemasonry tools would absorb some of the force applied with the pounding stone and would ultimately break down the handle faster than the rock being mined or quarried.

It is difficult to calculate the amount of copper needed for stonemasonry activities in Egypt. However, given the scale of stonework within Egypt, including tomb construction, statue sculpting and mining expeditions, it is not unreasonable to speculate that at any given time there were several thousand copper/copper alloy spikes in use. The acquisition of copper stores to facilitate in the production of said spikes also would have required the use of the spikes themselves. It is easy to see why New Kingdom institutions began trading for additional copper to meet their needs.[227]

Leatherworking

In leatherworking, copper tools such as awls and knives were used to cut and shape the leather, though bone tools might also have been used to great effect. An awl is similar to a spike but smaller and capped with a wooden handle. It allowed the leatherworker to punch holes through leather of varying thickness through which thread or rope could be strung. Copper and bronze knives also proved useful in cutting leather to shape for use as sandals; chariot gear including harnesses and protective facing; and straps, which were largely used as binding elements for

[223] Arnold 1991: 257.
[224] Janssen 1994: 94.
[225] Scheel 1989: 51-53.
[226] Scheel 1989: 52, Fig 58.
[227] Van de Mieroop 2010: 169.

weapons, tools and structures. Leatherworking knives in the New Kingdom had broad convex cutting edges with wooden handles, and some have been found with broad T-shaped blades.[228]

Copper could also be used in the production of needles, a useful tool for the trades of leatherworking and tailoring.[229] Needles are among the first tools to use copper, with examples being found dating to the Predynastic Period of Egypt.[230] This is likely due to the small amounts of metal needed in their construction, which would have been easily obtained from native copper deposits found near the surface. Metal needles would have required little to no maintenance since their tips would have been used against extremely soft material in comparison to other tools that employed copper.

Metalworking

Ironically metalworkers were among the craftsmen who most needed metal tools to assist in the production of their goods. The first depictions of tongs, likely made of metal, to handle crucibles and red-hot metals being worked in the furnaces of the metalsmiths, appear in the New Kingdom.[231] These tools can be seen being carried along with tuyères by the workmen in the upper registers of the metalworking scene in the tomb of Rekhmire. (Fig 5.5) Tongs were likely used in the annealing process to reheat sections of the metal objects being pounded into shape. The annealing helped to ensure the metal would not break down and crack during the shaping process.[232] Tongs were also likely used when separate metal components were soldered together to create a final product. Stone handling devices, like those described above and used during the Old Kingdom, would have required extremely careful movements to ensure that shaped metal sheets were not damaged, but tongs would have provided greater control of the hot metal and safety.

Figure 5.5 Metalworker with tools from TT 100 after Davies

[228] Scheel 1989: 54.
[229] Scheel 1989: 55.
[230] Items: BM 01.4.41; BM 11.151.89; BM 11.151.91.
[231] Davies 1973: Plate LII.
[232] Scheel 1989: 30.

Household Goods

During the New Kingdom, copper also became a primary resource for the production of household and luxury items. Some of the everyday goods to make use of available copper were mirrors, razors, tweezers, vessels, jewelry and even weights of measurement. Each of these products would have been created to enhance the daily lifestyle of Egyptians in the New Kingdom either by making tasks easier or by providing a more durable and long-lasting version of a pre-existing tool or instrument. All of these items existed in previous periods of Egyptian history, but their increase in occurrence within the archaeological record suggests a rise in the standard of living for Egyptians during the New Kingdom.

Toiletries

Mirrors (*ꜥnḫ*) were made by hammering or casting a sheet of copper or bronze into a circular shape with a tab or handle extending from one side. Mirrors were handheld with either wooden or metal handles often including some form of stylized hand guard, with the overall length usually between 20 and 30 centimeters, although the size and weight could fluctuate greatly.[233] Handles were often decoratively carved during the New Kingdom. Common motifs include naked women, falcons or falcon heads, or deities, most often the head of Hathor. While not as effective as 21st Century mirrors, the surface of the mirror would have been polished with soft stones and possibly coated with electrum or silver leaf to enhance its reflectivity, although this would not have been required and only a few luxury examples contain this modification, such as the mirrors belonging to the foreign wives of Thutmosis III.[234] These devices would have served primarily a cosmetic function assisting in the application of makeup. While examples are found in Egypt dating to the Old Kingdom, they are rare.[235] In the Middle Kingdom images of mirrors appear in funerary contexts, which perhaps reflect an increase in their use and distribution during that period. The use and availability of mirrors grows substantially during the New Kingdom. The British Museum lists fifteen such mirrors in their collection dated to the New Kingdom. Price comparisons from Deir el-Medina suggest an average value of 6 *dbn* for a mirror despite substantial variation in their weight with examples ranging from 117 grams to 2.8 kilograms.[236]

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[233] Gathered from information from the British Museum's Online Collection with examples given in Appendix A.
[234] Metropolitan Museum of Art Accession number: 26.8.97, 26.8.98.
[235] Metropolitan Museum of Art Accession number: 19.3.93; and BM Item: EA57570.
[236] Janssen 1975(b): 301, 302.

Razors (*mẖʿḳ*) were another toiletry item that benefited from the use of copper and bronze. Razors could be used both as a personal item as well as an occupational tool, as barbers were an established profession in Egypt.[237] The primary benefits of these blades, like the blades of knives and axes, were their ability to be sharpened with a minimal reduction in the material of their construction and their durability. Stone blades have been produced and used by humans for several thousand years, but these blades required either comparably large portions of material to be removed from the core blade in order to be sharpened or a complete replacement of the stone shards that made up the blade, as in the case of sickles. Razors were sharpened with the use of whetstones, which are sometimes found along-side razors in deposits. While obsidian and chert shards were used as blades in medical procedures, especially those involving surgery, their extreme sharpness made them too dangerous to be used as razors. Instead, metal blades were made in a variety of shapes to trim and shave the hair of Egyptians in the New Kingdom. The three primary blade styles, each of which receives an example in Appendix A, include long fixed blades, shorter curved blades similar to those of knives, and rotating blades equipped with a curved handle.

Another cosmetic and toiletry item made of bronze or copper in the New Kingdom was the tweezer. This thin instrument was usually constructed of a single piece of metal bent over on itself in a U-shape with little tabs on the ends to facilitate in gripping. Unfortunately, they are not widely referred to in either Egyptian texts or shown in scenes, but it seems little has changed in their usage and design over the past few thousand years. Tweezers did not have to be made of copper, but copper's ability to retain a shape bestowed on it through the hammering and annealing process likely ensured longer lasting versions. Copper's natural anti-bacterial properties also would have led to fewer infections if used to remove foreign material from the skin or open wounds.

There are also a few examples of kohl tubes and applicators being produced in bronze and copper. These small containers, usually no taller than 10 centimeter, were made in a wide range of mediums, including wood, ivory, glass, faience and metal, and with an array of stylistic variations.[238] Kohl was a cosmetic, largely made of charcoal, galena and malachite, designed to be applied around the eye, similar to how eye-liner and eye-shadow are used today.[239] If copper was

[237] Lichtheim 2006: 186.
[238] Cooney 1975: 235.
[239] Lucas 1930: 41.

included in the production of kohl containers, it likely would have increased its effectiveness as protection against eye-infection due to its anti-bacterial properties.

Vessels

Vessels were most commonly produced in silt or clay. The use of ceramics made vessels resistant to heat, a quality useful when cooking food, and yet cheap and easily replaceable should one become damaged. Metal vessels were produced in similar styles to existing ceramic patterns, but the enhanced durability and luster ensured that these items were considered luxury goods. Their status as luxury items and increased value is attested by their inclusion as offerings to temples and administrators as well as by their presence within foreign offerings brought to Egypt by Syrian merchants.[240] Most luxury vessels offered to the temples and as royal mortuary items would have been produced with precious metals, but bronze and copper vessels (*dydy* and *ḳbw*) could be found among the household items available for purchase at Deir el-Medina.[241] While such vessels are uncommon, their frequency within the archaeological record does increase during the New Kingdom over earlier time periods.

Luxury Goods

Jewelry, as with most luxury items, was mostly produced with precious materials, and in Egypt this especially included gold. The Egyptians used more than just gold in the creation of jewelry. Copper ores, copper and bronze were all used in making jewelry. Malachite, azurite and turquoise were all desired for their vibrant colors. Small pieces of these minerals could be inlaid in decorative elements and items to provide color. This technique ensured the longevity of the jewelry and increased its value. When ground into powder, these copper ores could also be used to in the production of blue faience and glazes.[242] Copper and bronze were also inexpensive substitutes for more precious metals in decoration. Rings (*šꜣḳw*), used both for administrative purposes and adornment, sometimes made use of copper. One example is currently held in the British Museum. The ring, whose finger-loop is constructed out of a bronze or copper alloy, contains a small scarab seal that is allowed to rotate around its longitudinal axis.[243] On one side,

[240] Davies 1947: Plate XV.
[241] Janssen 1975(b): 243.
[242] Rehren 1998: 227.
[243] Item EA64919, pictured below in Appendix A.

the customary scarab pattern can be seen carved into a glazed piece of steatite. When rotated to the opposite side, which would normally be against the skin of the finger, a seal is visible. The example likely acted as a signet ring for the official to whom it belonged. Such rings seem to have cost very little since they required only tiny amounts of copper for their construction.[244] Other types of rings including bracelets and anklets have also been produced with copper alloys.[245] Copper could also be used for a counterpoise to offset the weight of beaded necklaces. The re-alignment of weight would have drastically reduced the neck pain incurred by wearing such heavy adornments and helped to ensure that they stayed in place.

Trade Uses

That Egyptians had and used weights and scales is well documented by their inclusion within religious texts and vignettes, most predominantly in the weighing of the heart scene within the Book of the Dead, as well as scenes of trading, as in the case of the visit by Syrian merchants recorded in the tomb of Kenamun.[246] (Fig. 5.6) While weights used in exchanges could be prepared in any material, most often in stone, there are a number of examples of both detailed and plain weights being prepared in copper and bronze.[247] Weights could be prepared in the shape of animals or parts thereof, including calf's heads, ibexes and panthers, and also in geometric shapes like octagons. The British Museum contains examples of each of these.[248] To facilitate in fair trade within marketplaces, standardized metal weights were created to be used in conjunction with scales. These standardized weights helped develop fixed values for goods within the Egyptian economy. Unfortunately for those involved in discussions about value and economy, the units of weight and the units of value used by the Egyptians were one and the same. With regard to the units associated with the weighing of metals, the standard

Figure 5.6 Merchant at Stall with holding scales from TT162 after Davies

[244] Janssen reports a bronze ring costing roughly ½ *dbn*.
[245] Janssen 1975(b): 309.
[246] Davies 1963: Plate XV.
[247] Weigall 1908: XIV-XV.
[248] Items: EA59286, EA11580, EA59287 and EA50094 respectively.

unit was the *dbn*. A single *dbn* weighs 91 grams in 21st Century terms. Smaller subdivisions included the *ḳdt* and the *šnˁtj,* which represented a tenth and a twelfth of a *dbn* respectively.

Model Tools

In the early stages of the field of archaeology, the focus was on finding valuable treasures, usually those that contained or used precious materials, hidden within ancient tombs. However, copper is not a precious metal, neither anciently nor in more modern times. Its primary value stems from its utility as a material, not its wealth storage or social connotations, like those associated with gold. Despite this difference, copper artifacts are commonly found within the funerary goods of those who lived in Egypt during the New Kingdom. Each of the aforementioned objects above has been found in and associated with two types of archaeological environs; those sites concerned with the daily living of ancient peoples and those located within the necropolises of Egypt. So far one has focused the discussion on the artifacts involved with daily living. However, there is little to change when discussing the copper and bronze artifacts found within the tombs and funerary deposits of the New Kingdom. Because the Egyptians conceptualized the afterlife as an extension of daily life, they believed that an individual needed the same types of accoutrements. Thus, archaeologists have found that many of the goods buried with the deceased were everyday objects, including those discussed above, or modifications thereof.

The most common modification was to produce the goods as models of the original items. This practice extends back to the Old Kingdom where tombs of elite women in the Memphite necropolis contain model tools related to craft production that they either participated in or were patrons of.[249] Models still use the same materials and construction styles but sizes could, and often would, fluctuate with models being so significantly reduced from the original that using the model for any type of work was impractical at best. Model tools were also often replaced tool blades with thin sheets of copper to limit the amount of copper wasted on such funerary items. The belief was that the materials and scenes prepared for the deceased would have been made whole and perfect in the afterlife and therefore any deficiencies in the goods would not matter in the eternities. Likewise, the inclusion of offering lists in tombs and coffins throughout Egyptian history was designed to magically renew and supply the tomb owner even if the goods being offered were only

[249] Odler 2015: 55.

pictured or inscribed on the walls. The lists sometimes included tools and goods not present in the physical offerings to the deceased.

Pigments and Medicine

Copper was also an ingredient in various technologies and practices. While copper ores, especially malachite, are also recorded as being used for both medicinal and cosmetic functions, such uses were largely discontinued by the New Kingdom and therefore fall outside the range of this discussion. However, copper ores were used extensively as a colorant for paints, glazes and makeup during the New Kingdom. The classic “Egyptian blue” color of faience and paints was achieved by use of copper carbonate ores, most likely malachite and azurite.[250] The color was important in a religious setting as ceilings of sacred spaces were often painted with yellow stars on field of blue. The vast amount of pigment required to produce the myriad examples of blue glazed and painted objects along with the decorations within tombs and temples likely required substantial quantities of raw copper and copper ore. The New Kingdom saw a distinct rise in the abundant use of the pigments.[251] Researchers have reconstructed possible ways to produce this pigment, despite no ancient recipe being preserved. Unfortunately, the missing recipe hinders the analysis on how the production of such pigment would have impacted the acquisition and trade of copper and copper ores since it is difficult to identify which particular commodities were most needed for the pigments. The pigments would have been prepared by grinding the materials providing the color and then mixing them with a medium to ensure smooth transfer and application. Such a transfer medium would have differed depending on the surface to which the pigment was being applied.

[250] Jaksch 1983: 526.
[251] Jaksch 1983: 527-528, (Table 1).

Chapter 6 - The Ancient Egyptian Economy and Copper's Role

Economic Fundamentals

Before discussing the economic theories that can be applied in the analysis of New Kingdom economy, it is vital to define some key terms with regard to economies and their practices. In this work the word *economy* refers to the institutions, processes and supporting ideology and technology that drives the production, distribution and taxation of goods and services within a society. This incorporates most of the organizations that collectively operate as *the state*, but can also include organizations related to religious and other ideological institutions or social structures, many of which are indirectly associated with the state. This broader definition, and its extension to include areas outside of what might be considered traditional governmental infrastructure, is especially appropriate for this discussion of ancient Egyptian economy since there was little to no separation of religious and state organizations in terms of governing or their combined ideological impact on the populace.

Tax will refer to the goods and services compulsorily rendered to administrative organizations, be they religious or governmental. Because the New Kingdom did not have a monetized economy, meaning they lacked standardized currency or coinage, these taxes were collected in kind.[252] *In kind* refers to payments made through bartered goods or most commonly through agricultural yields from worked land. *Redistribution* is the process by which materials or goods gathered by institutions, usually through taxation, are repurposed as payment to individuals employed by administrative organizations. In the case of Egypt, this meant that taxes in the form of grain would be collected and placed into granaries and temple storehouses, and then partially given back in the form of wages or possibly their equivalent in terms of usable goods, to the people involved in the various projects, including construction, mining and military expeditions that were commissioned by Egyptian royal or temple institutions.[253] These wages are most often recorded as amounts of beer and bread; resources considered staples in the diet of ancient Egyptians.[254] However, because of the high numbers of these goods offered to administrative officials for their

[252] Katary 2011: 3; Bleiberg 1989: 181.
[253] Cooney 2007: 161; Černý 1954: 916.
[254] Miller 1991: 257.

services, it is unlikely that wages would have been paid solely in bread and beer and therefore other goods would likely have augmented the use of foodstuffs as secondary forms of payment.[255]

The term market is used in two ways when discussing economics. First, *a marketplace* can refer to a physical location where exchanges of goods and services take place. Second, *market*, in a larger sense, refers to a self-sustaining and regulating system that ensures fair but maximized value in both domestic and foreign exchanges. This second definition is most often implied when historians and economists discuss market economies, as the system described in the second definition sustains the formation of larger economic forces evident at the national scale. The market system dominates the 21st Century financial world but it did not have as great an impact in the ancient world, since markets of both definitions heavily rely on the use of standardized currency. Specific weights of metals, in the form of coins, usually act as the common medium for currency, but coins were not introduced into Egypt until the 26th Dynasty (c. 600 BC). These first examples of currency were produced in Greece and it was not until the 29th Dynasty (c. 300 BC) that Egypt began minting its own standardized currency.[256]

During the New Kingdom standardized weights were used to establish the value of certain commodities, which would have been used in the place of currency in a form of money-barter system. The common weights used for metals included the *dbn*, roughly 91 grams, the *ḳdt* (kite) was a tenth of a *dbn,* and a special weight for silver called a *šnʿtj* that was a twelfth of a *dbn* or roughly seven and a half grams.[257] The small weights of the *ḳdt* and the *šnʿtj* were primarily reserved for precious metals since these materials held a much higher value on average than the goods for which they were being exchanged. Grain was measured by volume rather than weight with the standard size being the *ẖꜣr* or "sack," which was 76.56 liters. These sacks could be subdivided into smaller portions of the *ỉpt*, one quarter the volume of a *ẖꜣr*, and the *ḥḳꜣt*, one quarter the volume of a *ỉpt*.[258] Rates of exchange between commodities will be addressed below as they pertain to the different economic theories.

The final economic term needing attention here is exchange. *Exchange*, in this work, will refer to the act of transferring ownership of property, goods, and materials, either on a domestic or foreign level, from one party to another. Exchanges taking place on a large scale, primarily with

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[255] Cooney 2007: 167.
[256] Muhs 2016: 9.
[257] Muhs 2016: 113; Haring 2013: 8.
[258] Haring 2013: 8.

foreign partners, will usually be identified as *trade* or *trading* since the reciprocal nature of the exchange is more evident from the contemporary documents, especially the Amarna letters, which provide direct examples of copper trade between Cyprus and Egypt during the reign of Akhenaten in the 18th Dynasty (c. 1275 BC). In Amarna letters EA 33-36, which primarily deal with the trading of copper, the two leaders refer to each other as "brother" suggesting a respectable level of equality between them and a level of diplomatic friendship.[259] These large-scale exchanges are fairly well documented as the Egyptian royal courts required two sets of records to be prepared. One set was sent along with the goods being transferred while the other was kept in the Egyptian administrative centers in charge of the exchange. The records indicate that trading at this scale was often presented as a gift to the recipient accompanied by requests for gifts of similar value.

Unfortunately, small scale exchanges, like those made by households acquiring everyday goods, did not require any form of written documentation, although some scholars argue that the oral testimonies of witnesses could have acted as contemporary documentation. In any case, without texts, these small exchanges are nearly impossible to properly study.[260] The collection of documents involving small scale exchanges from Deir el-Medina carried out by Janssen (1975b) is useful in that it provides examples of exchange rates between various commodities and goods. However, Deir el-Medina cannot be considered a traditional Egyptian village or town as nearly all of the citizens were almost exclusively involved in the construction and maintenance of the royal tombs at the Theban necropolis and Valley of the Kings. Although their wealth fluctuated greatly, the citizens of the town were likely among the most elite and wealthy workmen of the New Kingdom. Therefore, using contemporary data about their daily or small scale exchanges to model the rest of Egypt could lead to skewed statistics and evaluations of the role copper played within the economy of the time. Deir el-Medina further alters interpretations of copper's value and role within Egypt at large since so many of the citizens of the village relied on it as part of their occupation. Furthermore, the majority of copper tools the workmen used were owned and supplied by the state.

The dearth of other contemporary sources is possibly due to low literacy rates among the general populace of Egypt and the lack of written receipts for small transactions, although such an

[259] Moran 1992: 38-40; EA 16 demonstrates this relative equality well since the Assyrian king complains that the gift given to him by the Egyptian king is not enough to balance the gifts provided to him. Translation by Grayson.
[260] Muhs 2016: 6.

absence may be an accident of archaeology.[261] Thus, we have limited evidence of the daily purchasing habits of most New Kingdom Egyptians, but many surviving documents on the collection and administration of state revenues and taxes. More important transactions and exchanges, like the transfer of land ownership, were handled and recorded by local administration and scribes who stored them at the *knb.t* courts.[262] Any disputes regarding state revenues or the improper administration thereof were resolved at one of two "great" *knb.t* courts, one in the north at Memphis and one in the south at Thebes. Local villages and towns could also have knb.t courts that resolved minor disputes. It was courts like these at Deir el-Medina that provide some surviving documentation on the value of copper at the local level.

Hieratic ostracon 5631 in the British Museum from Deir el-Medina relates the grievance of an individual whose servants were taken away from him because he did not return a sizable number of royally-owned copper tools to a certain temple official. According to the account, these copper tools, many types of which are unclear due to deterioration of the text and numbering between 200 and 700, were worth 12 servants.[263] While this record is useful in establishing a comparative value of copper, it does little to demonstrate the small local exchanges that were likely a part of everyday life for the Egyptians. With regards to exchanges involving copper, the documentation suggests that only those who directly benefited from or needed copper, either as a tool or material required as part of their profession, received it from royal or temple administrative centers as part of the redistribution aspects of the Egyptian economy or sometimes as a mark of royal "favor."[264]

The exchange of metals can be used to demonstrate the impact of market economy systems within the New Kingdom economy. The lack of coinage, used below as evidence to support the Substantivist theory, did not mean that Egypt lacked methods of standardized exchange.[265] In fact, exchange rates between goods from different periods within the New Kingdom have been identified in contemporary sources and show fluctuations in the value of commodities.[266] These rates are identified by Formalists to be evidence of money-barter systems, meaning the barter of

[261] Baines 1989: 584.
[262] Muhs 2016: 96.
[263] Muhs 2016: 93.
[264] Janssen 1994: 96.
[265] See Chapter 1, as well as below, for the use of these terms.
[266] Janssen 1975(b): 116.

goods and service with reference to fixed units of value.[267] This fixed value is somewhat established and influenced by the idea that certain materials or commodities hold intrinsic value, primarily determined either by their scarcity, attributes or utility.

Intrinsic Value

The three types of commodities that are commonly believed to hold intrinsic value in the ancient world are land, foodstuffs and metals. Two of these commodities are intertwined with one another, namely land and food. Land, specifically arable land, is valuable because of what it can produce. The primary farmland available in Egypt is found in the Nile Valley and Fayum, although the Fayum was not likely used abundantly during the New Kingdom. It is estimated that during the Ramesside period, Egypt had roughly 22,400 sq. km of arable land with a population of 2.9 million.[268] While this amount of fertile land meant that land was not exactly scarce on a per capita basis, the food produced yearly on each square kilometer of that land would have needed to provide enough sustenance for 130 individuals.[269] The Egyptians grew barley and emmer wheat as their staple cereal grains. These grains constituted the primary ingredients in the bread and beer used as payment for general services rendered to the governing institutions and as the main foods within the ancient Egyptian diet.

Land was also needed to maintain cattle herds. During the Predynastic Period and the Old Kingdom, cattle was considered a valuable commodity as evidenced by the bi-annual cattle count that operated in conjunction with tax collection. Foreign cattle were brought to Egypt in the Middle and New Kingdoms from Syria Palestine but such trading endeavors were often small in scale and foreign breeds do not seem to have been bred on a large scale as a result of these transactions, although this is debatable. In the tomb of Kenamun (TT 162), a scene depicting foreign traders, or possibly a Syrian group offering tribute, includes two such cattle. The cattle being brought to the High Priest of the Temple of Amun, along with a substantial quantity of jars containing oil or wine, are bulls with large shoulder humps, identified today as zebu.[270] It is important to note that these are the only examples of clearly identifiable foodstuffs being traded within this particular scene. While the transportation of the cattle would have necessitated the inclusion of grains or grass for

[267] Haring 2009: 5.
[268] Butzer 1976: 83.
[269] Haring 2013: 2.
[270] Davies and Faulkner 1947: 45.

their consumption, these goods do not appear to have been worthy of foreign trade. Unfortunately, in the ancient world many types of food were difficult to transport because of inadequate methods of preservation, which meant that food had to be locally sourced for most communities. There is evidence of luxury foodstuffs being transported to and from Egypt during the New Kingdom, including dried fish and foreign wines.[271] However, all these types of foodstuffs were traded in relatively small measures and did not represent large-scale trading operations. Despite the evident trade in foodstuffs, these goods do not appear to have accounted for the bulk of long distance exchanges in the ancient Near East until the Roman Period. Therefore, both land and food were primarily locally transferable commodities with intrinsic value, requiring the purchaser to either relocate or already reside in a close proximity to the site of production.

In contrast to land and food, metals, both as ingots and as small goods, were easily transportable over large distances. This meant that the intrinsic value of metals was also more transferable and useful as a medium of exchange between cultural groups. Metals stand apart from other production mediums available to ancient peoples because they are durable, malleable and relatively resistant to deterioration. In comparison to other ancient materials, such as stone, leather or cloth, metals were better able to retain a given shape at very fine thicknesses. Gold and silver, two of the most lustrous metals accessible to ancient peoples, are unfortunately very soft, so their low durability makes them unsuitable for the production of tools, but their luster made them valuable for other reasons and useful as luxury items. Much of their perceived value is based on ideological and social contexts, such as the Egyptian belief that the flesh of the gods was made of gold, or local scarcity, as in the case of silver since it had to be imported into Egypt due to a lack of significant local deposits.[272] These qualities made gold and silver perfect materials for luxury or ceremonial items and are why world civilizations, both ancient and modern, consider them precious metals.

Until the 1970s most of the major world civilizations used gold as the foundation of their currencies. This reliance was referred to as the gold standard and meant that each coin or paper bill could be directly traded for its printed value in gold. Just like modern societies, gold was considered by ancient Egyptians to be vastly more valuable than other available metals, but this high level of value made it unsuitable as a medium of exchange for small local transactions. The

[271] Lichtheim 2006: 227-228, The Report of Wenamun.
[272] Ikram 2000: 279.

following table, based on Černý's work, presents some of the rates of exchange within the New Kingdom. These exchange rates demonstrate that silver was roughly half the value of gold, while copper's value fluctuated between a hundredth and a sixtieth of the value of silver.[273]

One *dbn* of Gold			
Time period	*Silver equivalent*	*Copper equivalent*	*Barley Equivalent*
18th and 19th Dynasties	1.6 *dbn*	Averaged to 166 *dbn*	166 *ẖꜣr*
Early 20th	2 *dbn*	120 *dbn*	60 *ẖꜣr*
Mid 20th	2 *dbn*	120 *dbn*	30 *ẖꜣr*
Famine periods in 20th	2 *dbn*	120 *dbn*	15 *ẖꜣr*
Late 20th	2 *dbn*	120 *dbn*	60 *ẖꜣr*

Table 6.1 - Exchange rates of commodities during different phases of the New Kingdom displaying the equivalent value of one *dbn* of gold in different commodities, based on Černý's work

Similar to gold and silver, copper's lustrous qualities contribute to its intrinsic value, but it also has greater durability and the ability to be alloyed into stronger metals for use in tools. Its luster encouraged its use in jewelry and ceremonial objects in the Predynastic Period and into the early Old Kingdom, but its relative abundance and lower degree of reflectivity, when compared to gold, made it a secondary commodity in the production of such goods.[274] Copper's utility as a material within tools and technology represented its primary contribution to the Egyptian economy and helped develop its perceived value. Granted it would have held more perceived value among craftsmen who needed it, either as a production material or as a tool in their profession, but its value as a commodity was also widely recognized as evidenced by its use as a medium of exchange in local transactions. The direct correlation between a *dbn* of copper and a *ẖꜣr* of barley in the 19th Dynasty also suggests a type of simple conversion rate between goods of intrinsic value.[275] The abundance of copper meant that it could be used as the basic, and therefore the lowest valued, metal used in exchanges. Accounts from many of the ostraca from Deir el-Medina examined by

[273] Muhs 2016: 114; Černý 1954: 906.
[274] Lacovara 2001: 295.
[275] Muhs 2016: 114.

Janssen, Černý, and others express the value of goods in terms of *dbn* of copper.[276] This use of copper as the basic unit of exchange is a precursor to the development of money in later periods.

While the stability in the ancient value of gold was partially due to its desirability as a precious commodity within foreign markets, copper's variable value was an example of its use within, and dependence on, local exchanges. These local exchanges were more susceptible to political and environmental conditions, including institutional changes and drought. Ultimately, by the time money and coinage were introduced into the economy of Egypt, silver appears as the standard method of expressing prices and scholars have stated that the idea of money actually was synonymous with silver in ancient Egypt.[277]

Theoretical Views on the Economy of Ancient Egypt

The following discussion on the economic theories that frame analyses on ancient economies is designed to outline the prevalent ideas surrounding such analyses and provide some comparison to the different approaches economists take when examining the ancient world. The inclusion of economic theories within the present work is intended to give contextual understanding for both the Egyptian economy and the previous discussions surrounding said economy. The complexity of economies, both ancient and modern, allows for different perspectives to be applied simultaneously with a large degree of success. Currently, there are three primary theories concerning the make-up and operation of the ancient Egyptian economy. They are identified as the Substantivist, the Formalist and New Institutional Economic theories. These theories differ primarily in their perspectives on the role that market systems played within the economies of Egypt and how the economy was administered.

Substantivists argue that markets, and particularly self-regulating markets, did not exist in ancient societies because of the more egalitarian nature of ancient peoples and the need for control of ancient economies by governing institutions.[278] The Substantivist viewpoint is the most commonly accepted by ancient historians. Formalists claim that humans by nature desire to provide long-term security for themselves through wealth acquisition and the generation of profits,

[276] Černý 1954: 915; Janssen 1975(b): 4.
[277] Černý 1954: 914.
[278] Polanyi 1957: 249.

and that the free-market system is a natural extension of that desire.[279] Formalists are not common, but their viewpoint seems have been gaining traction in the past few decades and much more so in just the last few years. New Institutional Economists analyze ancient economies from the viewpoint that elements of both redistribution and market systems worked side-by-side, and that changes within the balance between them occurred primarily as a result of institutional manipulation.[280] Because of the clear evidence of gathering taxes in kind and the redistribution of those taxes as wages for services rendered by the Egyptian populace, each of these theories agree that some form of redistribution existed in Egypt during the New Kingdom. The evidence for taxation is primarily found in documents of the New Kingdom that were kept by the religious and administrative institutions of the time. Such documents include the Wilbour Papyrus, tax collection scenes in the tomb of Rekhmire, the Edict of Horemheb, the Turin Taxation Papyrus, Papyrus Louvre 3171, British Museum Papyrus 10447 and others.[281] The agricultural modes of taxation are well discussed by Wolfgang Helck's analysis, which relies on Wilbour Papyrus A, but unfortunately he does not discuss the economic function of metals in his work.[282]

In 1957, Karl Polanyi set the course for most economic histories dealing with ancient civilizations when he theorized that self-sustaining market economies could not exist in the ancient world because the institutions establishing and administrating societies were too inter-connected In other words, control by forces outside those involved in the direct exchanging of goods, namely the control of social, political and religious institutions, was too great to allow a self-regulating market economy to form.[283] Polanyi's ideas provided the foundation for the Substantivist economic theory, which focusses on the premise that ancient economies were primarily concerned with the subsistence needs of their population.[284] This theory dominates much of the discussion on the economy of ancient Egypt because Substantivist theory, and Polanyi's argument in particular, recognizes the role that the king played in Egypt's culture. To ancient Egyptians, the king was a divine being, both the literal offspring of a god and the physical manifestation of the falcon-headed sun god Horus. The inherent divinity of kingship, in both Egypt and its Near Eastern neighbors, is

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[279] Warburton 1997: 73-75.
[280] Muhs 2016: 2.
[281] Katary, 2001: 353-354.
[282] Helck 1963: 541.
[283] Polanyi et. al 1957: 71.
[284] Eyre 2015: 707.

well documented and widely accepted.[285] This ideology of kingship meant that ultimately the king, under ideal circumstances, had complete control over any aspect of Egyptian society. It should be noted that the degree this control was expressly felt by the Egyptians of the New Kingdom is debatable and that religious institutions had gained at least some independence from the king although they still made use of him as a figurehead and focus of temple decoration. However, the power and control of the king should not be summarily dismissed.

For example, Akhenaten's religious and administrative reforms during the Amarna Period of the New Kingdom demonstrate the socially integrated and wide-spread power of the king quite clearly. Although Akhenaten's changes were not considered directly economic in nature, they nevertheless had a huge impact on the infrastructure of Egypt's economy. Changes in construction, art and production would have required the retraining of workmen. The relocation of the capital to a newly built city in Middle Egypt would have shifted commercial centers and altered trade routes, although the Nile River would still have acted as the prime path for most trade. The economic changes are demonstrated in the comparison of different types of goods found in the various areas of the new capital, primarily the southern settlements at Amarna.[286] It is also possible that the religious reforms could have affected foreign contacts and trade with foreign temples as the previously established religious institutions were dissolved and their wealth redistributed to the new royally controlled organizations. The report of Wenamun, from the late 20th or early 21st Dynasties, suggests that religious favors and offerings to Egyptian gods, or rather the priests who represented them, could be considered a form of partial payment for goods and services.[287] The same report also demonstrates how weak kings or high priests could lose favor among foreign trading partners if they did not demonstrate proper respect to the leaders of those foreign powers.

Ultimately, the Substantivist theory argues that the economy of ancient Egypt was governed almost entirely through the redistribution efforts of royal and religious institutions. This redistribution primarily took the form of foodstuff and production goods used as payment of wages for services rendered to the organizations in charge of the redistribution. The mining expeditions discussed above in Chapter Four are a prime example of this process. If there was a need or desire for a particular metal, stone or gem, a large, royally or religiously commissioned group was

[285] Lutz 1924: 453.
[286] Shaw 2015: 146.
[287] Lichtheim 1966: 186.

collected through seasonal corvée labor programs to extract the material; although it is possible those individuals used in such mining expeditions were prisoners of war or other captive slaves.[288] The needs of the skilled and unskilled workers, including food, shelter and tools, were handled by the administrative forces in charge of the expedition in a similar manner to that used with the work crews operating out of Deir el-Medina.[289] These needs were partially met through the payment of wages to the workers often expressed in terms of loaves of bread and jars of beer, but could also include gifts or favors in the form of tools or similar goods for more skilled workmen.[290] Unskilled labor was rewarded with a subsistence level of food, recorded in one Middle Kingdom expedition to the Wadi Hammamat as ten loaves of bread and one-third a jug of beer daily.[291] Skilled workers, in the same expedition, on average received double what unskilled workers did as wages. The overseers also received daily wages for their responsibilities however, the large amounts provided to high-level overseers and scribes, somewhere between 50 and 200 times what an unskilled worker received, were unlikely to have been supplied solely as bread and beer, even if they were expressed in such a manner, since it would have been impossible for such quantities to have been produced and consumed by the individuals set to receive them.[292] Kemp suggests that any wages not consumed during the expedition would have been given to the officials and workers as payment on the completion of the expedition.[293]

In a similar system of redistribution, workmen employed at the royal tomb building village of Deir el-Medina are recorded to have received copper spikes, used in the carving of the tombs, both as "favors" (*ḥsw*) of the king that were considered the private property of the workers, and as general tools owned by the state but set aside for the work the stonemasons performed.[294] When the state-owned tools would fall into disrepair the common practice was to return them to the administration so they could be sharpened and maintained, while the maintenance of tools that were the workmen's personal property were the responsibility of the workmen themselves.[295] The

[288] Cooney 2007: 175.
[289] Černý 1954: 917.
[290] Cooney 2007: 167; Papazian 2013: 83.
[291] Cooney 2007: 167.
[292] Cooney 2007: 167.
[293] Kemp 1989: 125-127.
[294] Janssen 1994: 94.
[295] Janssen 1994: 93 & 97.

providing of copper and bronze spikes to these workmen as well as the recycling of tools is attested in O. Cairo 25629, O. Cairo 25568, O. DeM 693 and O. DeM 625.[296]

In an apparent break from the redistribution methods prevalent in the New Kingdom, Papyrus Turin 1879 vs. II reports that during year six of Ramses VI's reign, the Karnak temple administration, normally tasked with supplying the workmen, demanded the forfeiture of 600 *dbn* (nearly 55 kilograms) of privately-owned copper from the workmen and administration of Deir el-Medina.[297] The reasons behind this demand are not made clear in the text, but it is possible that this request is the result of diminishing wealth in the treasury of the temple of Amun due to overextension of resources during times of low crop yields or economic hardship similar to those experienced during the reign of Ramses III.[298] This text and others like it, as well as different perspectives on human motivations, have led some scholars to suggest that the redistributive model for the Egyptian economy suggested by the Substantivists is inaccurate.

The Formalist viewpoint relies primarily on the works of David Warburton.[299] Much like the thoughts expressed by Polanyi, who operates from a perspective of ancient egalitarianism common among anthropologists, Warburton's argument that the ancient Egyptians used a market economy system relies on certain assumptions about human motivation, namely that the accumulation of wealth and riches is a primary driving force in all humans.[300] He points to the richness of the Egyptian state for evidence of this position, claiming that the taxes collected from the populace facilitated the creation of a more productive economy and enhanced the power and wealth of both royal and temple administrative institutions.[301] The inclusion of rare materials and goods within tombs dating to the Naqada Period (c. 4th Millennium BC) also suggests that wealth acquisition was desirable quite early in the history of ancient peoples in the Nile Valley. Evidence of long distance trade between the Ma'adi Culture and peoples in the area of Syria Palestine and beyond also suggest types of exchanges typical of marketplaces. Marketplaces, according to Formalists, played an important role in the development of economy from the earliest phases of history.[302] Subsistence living leads to stagnation of economic forces and development.[303]

[296] Janssen 1994: 94.
[297] Janssen 1994: 91-92.
[298] Janssen 1994: 95.
[299] Warburton 1997; 1999; 2000.
[300] Warburton 1997: 54.
[301] Warburton 1997: 55 (fig. 1) & 119 (fig. 4).
[302] Warburton 2012: 4-5.
[303] Warburton 1997: 119 (fig. 4)

Warburton claims that it is only through the influence of both private and public sector agents that the levels of richness evident within Egyptian culture and society are possible.[304] He further points to the presence of marketplaces, taxation, salaried and corvée labor as well as the existence and support of a luxury driven elite class as further evidence of the presence of a market-based economy in the New Kingdom.[305]

Barry Kemp also argues that complete reliance on a redistributive economy would have made it impossible to account for and administer to the needs of individuals within Egypt. He asserts that markets were key instruments in meeting these demands and that to deny their existence and importance is folly.[306] He uses an example found in Papyrus B.M. 10052, which recounts the theft of silver and the testimony of those involved, to assert the role that supply and demand could play in local exchanges. One woman charged with theft claims that she earned the money by selling food during a year of famine while another asserts she earned her silver selling garden produce.[307] Kemp uses this example to state that the scarcity of certain commodities, like the example of food during a famine, could greatly increase the relative value of those commodities in the short-term and there is clear evidence that individuals used these situations to increase their livelihood. In a modern sense this practice follows the adage about dealing in the stock market: buy low and sell high.

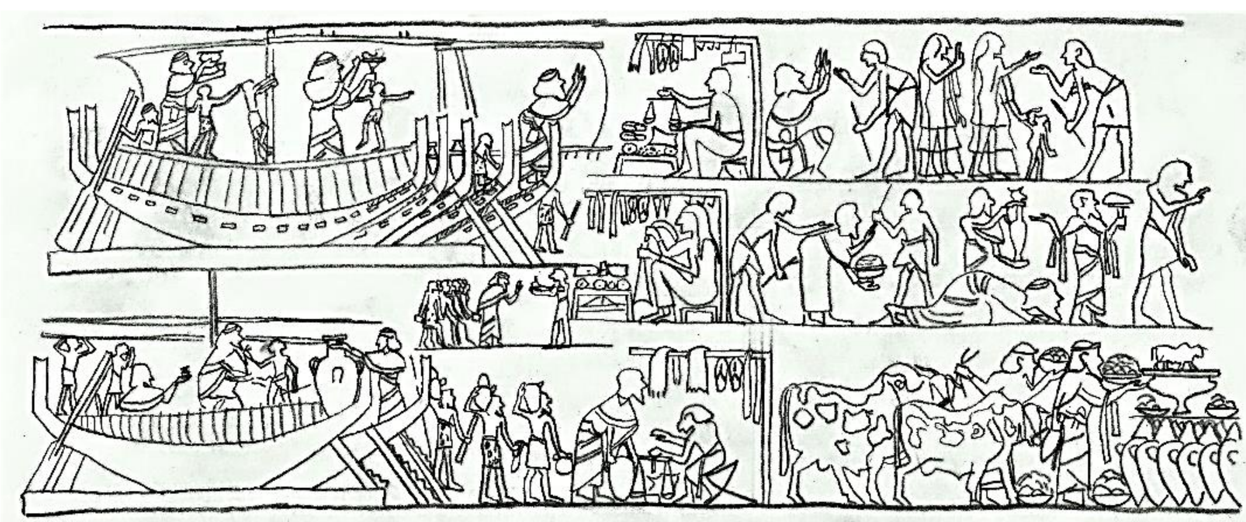


Figure 6.1- Entrance Hall of Kenamun, After Davies, 1963, Plate XV

[304] Warburton 1997: 324.
[305] Warburton 2012: 5.
[306] Kemp 1989: 303.
[307] Kemp 1989: 313-314.

In the tomb of Kenamun (TT 162) who was the overseer of the granary at the temple of Amun, a clear depiction of a marketplace is found in a scene displaying the arrival of Syrian merchant ships. (Fig. 6.1) The scene matches similar market and trading scenes of the Middle Kingdom at Beni Hasan and Old Kingdom market scenes such as the one found along the Unas causeway.[308] The merchants are shown transporting people, possibly as slaves, vessels containing wine and oils, exotic bulls, vessels of precious metals, and other materials. They are met by Egyptians in stalls offering sandals, cloth and other goods. The two male Egyptians in the stalls hold scales before them suggesting that exchanges between the foreigners and the Egyptians relied on fair trade. The only administrative official placed in front of the "merchant" stalls is one who is documenting the people, possibly sailors, brought by the Syrian traders.[309] Other officials greet the traders and appear to be introducing them to the tomb owner, not pictured in the image above.[310] The scene is problematic from an economic standpoint in that it is unclear to what level this encounter represents a free and self-sustaining marketplace as opposed to a religious institution overseeing the receipt of tribute offerings, and if a marketplace is intended, it raises the question as to how common such mercantile activities were. Janssen demonstrates that local exchanges and trade along the Nile was commonplace but since most marketplace tomb scenes involve large land-owners or administrators they therefore fail to capture the extent of trading among the rest of the population.[311] That such marketplaces existed at all partially supports the Formalist theory.

Evidence for the ability and desire to store wealth, a common feature in market economies, can be found at Amarna, where a cache, called the el-Till Hoard, of precious materials was found buried within a dwelling. This deposit contained 37 *dbn* of gold in the form of small bars and another 12 *dbn* of silver in the form of rings and figurines.[312] Using the exchange rates for the 18th Dynasty listed in the table above this amounted to roughly 7,390 *dbn* (672.5 kilograms) of copper or 565,550 liters of barley. This cache seems to represent a sizable stockpile of wealth. Lack of contemporary documentation about the cache make it impossible to identify how such a sizable amount was acquired, but it does lend credence to the idea that the principles of wealth accumulation did exist in the Egyptian mindset. The lack of copper within the deposit suggests

308 Harpur 1987: 112.
309 Davies 1947: 46.
310 Davies 1947: 45.
311 Janssen 1961: 98, 101.
312 Muhs 2016: 115.

that it was not considered nearly as valuable or as useful as a means of storing wealth as the more luxurious and costly metals of gold and silver.

The New Institutional Economic model was originally developed by Ronald Coase, but is currently championed by B. Muhs, who points to the tendency for oversimplification on the part of both the Substantivists and the Formalists. New Institutional Economics (NIE) argues that economies are by nature extremely complex and involve nearly every aspect of a civilization in their development and maintenance. NIE acknowledges elements of both market and redistributive models and claims that they co-existed and that the choice to use one system over the other in any given exchange was determined through a comparison of the costs associated with each economic system and how it would impact the transaction.

These costs, designated transaction costs, could come in the form of searching for available transaction partners, policing and enforcing agreements, or the costs of negotiation, information and research. There were also social costs, especially in the area of foreign trade. Since Near Eastern ideologies of kingship implied the ruler was divine, and in some cases omnipotent, any dealings with other rulers necessitated a careful formality not required in domestic exchanges. Thus, in the Amarna Letters we see the kings referring to each other as brothers and treating each other for the most part as equals despite the absolute power they held within their own respective states.[313] This social cost is also demonstrated by trading often taking the form of gift exchanges. Despite the connotations of the word gift, it is clear that these transactions were meant to be reciprocal and more in line with the expectations associated with trade. Amarna letters EA 7, 9 and 10 all relate the dissatisfaction of the Babylonian ruler, Burnaburiash, at the amount and quality of gold previously gifted by Akhenaten.[314] Given the compulsion that kings could exert on their own citizens it is unlikely that such formalities and requests would be given by the king in a domestic exchange.

The NIE theory really argues for compromise and an open mindset when discussing ancient economy. It allows for both entrepreneurial activities associated with markets and the institutional control necessary to administer redistributive economies. However, by accounting for the ability of individuals and organizations to choose which system they would participate in, understanding the New Kingdom economy becomes even more difficult. Muhs suggests that the New Kingdom

[313] Moran 1992: 104-110; For examples see EA 33 - EA 36.
[314] Moran 1992: 14, 18-19.

is actually a time of transition as more market-based systems and methods of economic control are put into practice in the first millennium BC.[315]

Of all these theories, it is NIE that can be most successfully applied to the discussion of copper's relative qualitative value. The theory's inclusion of multiple economic systems encourages complex discussions of exchange, value and economy. These discussions are especially useful when addressing one commodity among many. Unfortunately, NIE does not have a strong foothold in economic models and histories. This is partly due to its diversified nature; it is far easier to claim adherence to the stringent structures already existent than asserting a fluidity in economy that is difficult to quantify, qualify and address. One hopes that future studies similar to the one undertaken here will enhance the overall discussions of economy by addressing individual commodities and the forces acting on them in an economic sense. The use of copper as a commodity of exchange and trade as well as the near monopoly that royal and religious institutions held on its extraction are both accounted for in NIE.[316] Without understanding both aspects of copper's role in the New Kingdom little can truly be said about its relative value.

Influences on Copper's Relative Value

Economic discussions, like those above outlining economic theories, about ancient Egypt have, until now, relied almost exclusively on textual evidence and sources. These sources provide examples of exchanges, redistributive models and foreign trade, which is why they have received so much attention and why economic theories focus on these elements. Written sources are the only clearly expressed and enduring link to the perceived value of commodities and goods that are not subject to speculation and subjective evaluation. A good textual source simply states the items exchanged and by so doing, theoretically, indicates the relative value between those items or commodities. At first glance, the simple and direct statements contained within textual sources relaying what occurred in ancient transactions seem to provide all the information necessary to evaluate commodities and their roles. However, this reliance on only one type of source, and a rare type at that, creates an enormously biased interpretation of the value and role of the goods and commodities being exchanged. This bias is clearly seen when we begin applying other types of sources in an economic analysis.

[315] Muhs 2016: 11.
[316] Muhs 2016: 133.

Taking copper as an example, textual sources identify it as the least valuable of the metals used by ancient Egyptians. Copper was the most common of the metals available to ancient Egyptians. As such, it was used as the basic metal commodity in exchanges with an average exchange rate during the New Kingdom, taken from textual sources, of 100 copper *dbn* to 1 silver *dbn*.[317] No doubt copper was more commonly used as a standard for exchange over gold or silver because it was more available. Before the concept of money, or a monetized economy, copper was being treated as the standard medium of value in local Egyptian exchanges. This does not mean that copper itself was regularly traded but rather that prices or values were expressed in terms of *dbn* of copper. Once the idea of money did develop, it was associated with silver, which was considered to have a greater degree of wealth storage than copper.

The way textual sources look at the use of copper produces a fairly clear picture of the quantitative value that copper held in Egypt, or in other words its exchange value. In accepting that basic and low exchange value for copper, it could be taken, and seems to be assumed, that copper had little real impact on the economy of Egypt. However, these sources fail to address other considerations that impact economy and economic development and therefore misrepresent the importance and role that copper held within the New Kingdom economy.

Like all resources, the value of copper was determined by a number of factors including scarcity and availability in local and foreign markets, difficulty of procurement, modes of consumption, social connotations and, as stated above, overall utility. The majority of these factors are not addressed in textual sources at all, especially those texts directly relating to the exchange of commodities or goods. However, these elements are demonstrated through the analysis of archaeological reports, detailed examination of artifacts, comparative studies and archaeological reconstructive and experimental projects. Furthermore, it is these factors that contribute most heavily to the discussion of copper's value and role within Egypt's economy.

Scarcity has always been a well-established principle in determining value. The rarer a certain material is, the greater its perceived value. For instance, ceramic pottery was commonly available to ancient Egyptians. Because it was so widely used, and cheaply produced, it was often thrown away if a piece was damaged or fell out of style, similar to the way paper plates are used today. This was done to such a degree that pottery and pottery sherds represent the most numerous category of artifact unearthed by archaeologists. In many archaeological projects pottery sherds

[317] Lacovara 2001: 295.

are not catalogued in detail unless they have distinctive markings or are diagnostics. Ordinary sherds can provide scientific insight and readily available sources of comparison to other sites, but they often fail to provide much in the way of aesthetic or social value. On the other hand, the metallic treasures discovered within the tomb of Tutankhamun are quite rare, not only because of the material wealth they represent but also because of the rarity of these types of objects found through archaeological endeavors.

Copper was not an especially scarce commodity in the New Kingdom, but it was in high demand during this period. In the Sinai, in the areas of Wadi Kharig and Wadi Nasb, Flinders Petrie claimed to have found nearly 100,000 tons of slag from the smelting processes of nearby copper mines.[318] Such a quantity of slag would have been produced by the processing of nearly 5,000 tons of usable copper. This amount of copper is the equivalent of 500 ships with cargo similar to that of the shipwreck at Uluburn.[319] It is impossible to date the slag since the area has inscriptions ranging from the Old to the New Kingdoms, but given that this was not the only Egyptian site to mine copper, it is unlikely that copper was considered a scarce commodity. The mines at Timna also show significant amounts of copper being produced, with nearly 1,000 tons being produced during the Ramesside Period.[320]

While the archaeological reports show clear evidence for massive copper exploitation on the part of the Egyptians, the long-distance foreign trade of copper, especially from Cyprus, also supplied Egypt with abundant quantities of the material. It is reported in Amarna Letters EA 33 – 36 that a total of more than 920 talents of copper weighing roughly 28 kilograms each, the equivalent of nearly 283,080 *dbn*, were transferred from Cyprus to Egypt during the reign of Akhenaten.[321] The trading of such large quantities of copper indicate that Egypt's demand and consumption of copper was beyond its own capabilities to meet. The increasing demand for copper during the New Kingdom likely points to a change in copper's status from a luxury commodity to a necessary one.

This change in status is further exemplified by the inclusion of copper within a substantial number of goods produced during the New Kingdom. Copper and bronze are evident in many different types of weapons, tools, household goods, including vessels, toiletry utensils and knives

[318] Petrie 1906:
[319] Hikade 1998: 46.
[320] Hikade 1998: 48.
[321] Moran 1992: 104-110.

and even within funerary offerings such as those listed in Chapter Five and the Appendix. The use of copper as the primary material within these artifacts represents the normal production of many of these goods. The copper present in such common and household artifacts, especially mirrors and razors, demonstrates its availability to even the less privileged population of Egypt.

Further increases in the demand of copper can be traced to the development of a standing military force within Egypt during the New Kingdom, which necessitated the production of vast numbers of weapons and equipment. To model the amount of copper necessary to supply a standing military force, one will use the battle of Kadesh, during the reign of Ramesses II, as an example. A division within the Egyptian army consisted of roughly 5,000 men, each of which would have required at least one metal, or metal tipped, weapon.[322] Four divisions were used during the battle of Kadesh, totaling 20,000 soldiers. The battle would have therefore required an equivalent number of weapons. Axes and spears were among the most common weapons in the New Kingdom. An axe used roughly 5 *dbn* (450 grams) of copper in its construction and a spearhead could range between 1 and 3 *dbn* (91 – 273 grams) of copper depending on its size. Taking these measurements into consideration and assuming an average use of 3 *dbn* (273 grams) of copper per soldier, in order to supply the soldiers present at the battle of Kadesh with one weapon each, at least 5,460 kilograms of copper would have been required.[323] It should be remembered that the army divisions present at Kadesh did not represent the entirety of the Egyptian army, and that copper was used for more than just weapons. Bronze scale armor, an object that required significant copper to create and was reserved for the king, bits and hubs used for the chariot gear, arrows and medicine all would have required copper in their construction and use in military ventures.[324]

It is likely that the affluence of Egypt as a nation during the New Kingdom also contributed to the rise in copper consumption within luxury items and household goods such as toiletries including razors, mirrors, tweezers, and metal vessels to meet the demands of elite households. The prices of these goods, as established by Janssen, is often stated in terms of *dbn* of copper.[325]

[322] Partridge 2002: 88. Nearly all weapons by the New Kingdom contained a cutting edge of bronze or copper, including arrows.
[323] Numbers based on the weight of British Museum axe head (EA 68878) and Metropolitan Museum of Art spearheads (Accession numbers 30.8.116 and 12.180.5). The estimated weight of the spear heads were calculated using the density of bronze and the measurements of the indicated items.
[324] Shaw 1991: 42; Partridge 2002: 56-58.
[325] Janssen 1975(b): 4.

There is some confusion as to whether the use of *dbn* in these cases refers to the weight or value of the items. Since there are frequently discrepancies between the weight of the object and its listed price, it seems there was an increase in the value of an object brought about through the work required to produce it.[326] This extra value, above that of the material itself, seems to be accounted for in increased prices in the lists compiled by Janssen.

The production of craftsmen's tools also required significant consumption of copper. Each spike provided or gifted to the stonemasons of Deir el-Medina weighed between 6 and 8 *dbn*. While many of these spikes were recycled when they needed maintenance, the administration was responsible for ensuring that workmen had enough tools on hand to accomplish their tasks. This meant that each stonemason would need *at least* two chisels or spikes on hand; one for use on the tomb wall and one in reserve to use while returned chisels were being maintained and repaired. With an average workforce of somewhere close to 50 workmen, this would require close to 700 *dbn* worth of copper, and it is likely that much greater stores of copper tools were available.[327]

The value of such tools, weapons, and luxury items is obviously greater than that of the raw material. This is true even more so among those engaged in the crafting of metallic objects, from whose perspective the copper would have been absolutely vital. Papyrus BM 10068 lists many of the occupations held by Egyptian citizens of Amarna and gives some indication as to their relative position and frequency. Although this document likely misrepresents the number of priests within Egyptian society, it is important for our discussion here that coppersmiths represented nearly five percent of the professionals listed.[328] This means that for nearly five percent of the population of Amarna copper was considered a necessary commodity and directly contributed to their livelihood.

When discussing the role of copper within the Egyptian economy it is crucial to also remember the number of people engaged in the mining, processing or production of copper based objects and technologies, or the use of such products. The proposed figures at the end of Chapter Four suggest that at times mining expeditions could employ up to one percent of the entire

[326] Janssen 1975(b): 299. Janssen frequently makes the argument that weight and price are not necessarily equal when discussing copper based objects. The price is usually greater likely to account for the manufacturing process.
[327] P. Turin 1879 verso II records a request made for 600 *dbn* from the administration and workmen in the village to be delivered to the Amun Temple treasury, Translation Janssen, 1994.
[328] Shaw 2015: 136.

Egyptian population, although this number was not common.[329] Records at Serabit el-Khadim show an expedition workforce of the Middle Kingdom usually varied between 168-734, but could include more than 1000 workers and support personnel.[330] This is not insignificant to the overall economy of Egypt. While the professions of mining and smithing themselves were not lauded anciently, the social importance of the work produced by metalworkers, and specifically coppersmiths, likely increased the overall value of copper within Egypt's economy.[331] This is demonstrated by the bronze production centers found by Pusch at Qantir, which, as discussed in Chapter Four, appear to have employed several hundred workers during portions of the Ramesside Period.

All of these factors lead to a significant qualitative value and role for copper within the Egyptian economy. While it was a fairly common material, copper stimulated economic growth and technological advancements by providing a commodity with a somewhat stable intrinsic value to use as a means of exchange as well as developing and supporting industries to use it. Its processing and use provided employment for skilled craftsmen. Copper's durability and resilience improved tools, increasing the longevity of products and facilitating more advanced metalworking techniques. Goods normally produced with other materials were considered to be of greater value when made with copper or its alloys. Copper and bronze increased the effectiveness of weapons and armor in addition to facilitating the training and control of horses through the use of metal bits. Copper and bronze were the primary metals that allowed Egypt to defend its borders and expand its territorial influence. This successful expansion also brought in booty from conquered lands and further enhanced the New Kingdom economy. Without the technological advantages of copper and its alloys, Egypt would have been unable to maintain its control over vassal states. This reliance on adequate technology is evident as in later periods Egypt's failure to adapt and progress into an Iron Age contributed to its waning power in the region.

[329] This is based on the Middle Kingdom expedition addressed in Chapter Four. The suspected population of the time was nearly 2 million and the expedition is thought to have contained 20 thousand individuals.
[330] Shaw 2002: 247.
[331] Shaw 2015: 136.

Chapter 7 – Conclusion

The discussion of copper's material attributes, the processes involved in its extraction and refinement, its importance to and use in the material culture of Egypt and its role within the economic context of the New Kingdom, seems to suggest that copper was an essential material to Egypt's technological and economic development. Copper appears to have provided the Egyptians with a useful and abundant metallic resource whose utility made it a suitable material for functional work. While it was not as socially significant or valuable as silver or gold to Egypt or other Near Eastern societies, copper served as the metal of practicality. Its comparatively low luster did not make it suitable for ceremonial or luxury jewelry pieces when gold or silver were available as alternatives. It was considered the most basic of anciently accessible metals that lent itself to useful alloying. Egyptians' use of copper and copper alloy tools helped to produce some of the greatest ancient marvels still observable today, including the pyramids and temples for which Egypt is known, and demonstrates the technological advantage that copper could grant. Copper kept Egypt competitive, both economically and militarily, with its Near Eastern neighbors from the Predynastic Period until the Third Intermediate Period, when the rise in the use of iron by other Near Eastern civilizations gave Egypt competition, and a technological and military disadvantage.

While the techniques of mining used in Egypt are primitive by the standards of the 21st Century, both in terms of mining styles and tools used, ancient miners were nevertheless successful in extracting huge amounts of raw material from copper-rich geologic layers. The use of fire in weakening the hard rock surrounding deposits of desired material demonstrates innovative problem-solving techniques. The method of shaft creation and placement reveal a significant understanding of geologic formations. Clearly the Egyptians had a developed understanding of mineral and metal-rich geological formations, as well as strategies by which to extract these valuable materials.

Although Egyptians had access to copper locally, regional access increased dramatically in the New Kingdom due to Egypt's enhanced power and influence. This allowed Egypt to both exploit natural deposits within its borders and trade for metals with foreign kingdoms, especially Cyprus, to great effect. The increasing demand of copper during the New Kingdom, at least partially based on the formation of a standing army, ensured these trade relations were important to Egypt. Egypt also controlled numerous copper-rich deposits in its outlying regions, beyond the

Sinai, in areas of Syria-Palestine. The acquisition of copper from these areas, far away from the cultural centers in the Nile Valley, represented a sizable investment on the part of royal and temple institutions. These organizations were solely responsible for the mining expeditions that acquired copper for Egypt, as they were the only groups with the available resources necessary for such undertakings. The expeditions themselves in some cases created sizable temporary settlements to maintain their operation, such as those near Serabit el-Khadim. Fortresses along the Way of Horus, in northern Sinai along the Mediterranean Sea, were built in part to guard trade routes supplying copper and other tribute to Egypt. The amount of copper brought to Egypt and the effort spent in its acquisition are testaments to the significance of Egypt's copper requirements and the strength of its economy within the region.

The processing involved with transforming the raw material into usable quantities and qualities of copper suggests continuously improving technologies and methods, some of which may have been acquired from regional neighbors. The transmission of such techniques is most apparent at the site of Timna, but it is possible that the sharing of technologies has not left clear archaeological indicators elsewhere. Without the supporting technologies of ceramic and charcoal production copper smelting and refining could not have been possible. The technologies of the New Kingdom showcase the advancements in industry and the use of industrial complexes in the production of high temperature goods. These technological developments are most clearly identified by the purposeful alloying of metals with the rise in the use of bronze and other copper alloys during the New Kingdom. The size of the industrial complex at Per-Ramses further demonstrates the scale that copper and bronze held in matters of craft production and the perceived benefits from having industrial centers using these materials located in the heart of a capital city.

The quantity of copper artifacts produced by the Egyptians was substantial. Copper was used primarily for its utility and increased functionality within weapons, tools and everyday objects. While many of these artifacts have been researched individually, the present work has sought to discuss their importance to the value of copper as a commodity within an economic framework, rather than examining them as object types. A more detailed breakdown of the copper elements within artifacts would have greatly facilitated this discussion as it would have allowed for greater comparison, and perhaps clarification, as to whether prices listed in New Kingdom documents are fundamentally based on the weight of metal within the object or on other economically driven parameters. However, measurements, especially weights of different materials within discovered goods, are not always taken for composite artifacts, especially if an artifact is severely damaged. While industrial complexes appear to have been used in the New Kingdom, there appears to be little that would suggest a concurrent standardization of artifacts. The processes of ancient production, to a large extent, prohibit standardization as molds were prepared and broken with some degree of regularity. Molds today are designed to be re-usable for mass production and therefore exhibit a high degree of standardization. While ancient metalworkers did follow certain patterns in production, the lack of industrial standardization among the individual artifacts is further evidenced by the variable quantities of tin and arsenic in copper alloys like bronze. This variability probably had an impact on the value of goods produced by certain ancient Egyptian metallurgists. In much the same way that the most skilled stonemasons and artists were reserved for royal projects, it is likely that the more skilled metalworkers also were sought after by powerful institutions and individuals. It seems feasible that this desirability would have impacted the value and cost for goods produced by these metalworkers, but this is largely speculative.

Because so many of the previous works on ancient economies sought to explain or address differing theoretical models and viewpoints about ancient economies, it was important to provide a brief overview so that this work may be placed in an academic context. The ultimate intention was not to support one theory over any others, although the approach associated with New Institutional Economics did lend itself to the methodology proposed for this type of analysis. In the past, the prevailing theorists on Egyptian economy have tended to base their arguments on opposing viewpoints about the power and control of institutions in economic arenas, the presence and importance of marketplace exchanges and recorded rates of exchange between commodities. Each of these factors relies heavily, and sometimes exclusively, on textual sources. These sources can provide contemporary comparative values when discussing commodities in ancient economies, but the reliance on only one type of source inherently creates bias in any analysis that does not directly relate to language. Because the role commodities play within societies can be complex it is best to use as many types of sources as possible. The exchange value for copper fluctuated throughout the course of the New Kingdom possibly due to political, technological and environmental factors only some of which may be gleaned from textual sources.

Although copper does not appear to have served as a well-established means of wealth storage, as was the case with gold and silver, its availability ensured its status as the most reliable metal to acquire, exchange and use, especially for smaller scale trading. The discussion of the qualitative value for copper within the New Kingdom Egyptian economy is about more than giving a quantifiable rate of exchange for the commodity. Resources are not only valuable for the wealth that they store, but for the changes that they make in the societies which use them. In this regard, copper is one of the most influential resources within Egypt and Egypt's economy. Its impact on craft production, cultural and economic development, and technological innovation demonstrate the power and value generated by copper's utility. While gold will always capture more attention than copper, copper facilitated in significant advancements throughout Egyptian history to a much greater degree than gold or silver. Records indicating copper's exchange rates within the New Kingdom are rare in comparison to other types of texts. The heavy reliance on texts has created a significant bias in the arguments made for the application of certain economic theories and has hampered economic discussions which seek to rely on other types of sources. The earlier economic studies, in the author's opinion, downplay the value and role of copper by only focusing on its exchange value with other commodities.

However, the number of people employed in copper's acquisition, or who benefited from its use in profession-based tools and weapons, clearly point to its implicit, if not explicit, economic influence. Furthermore, the level to which it enhanced objects normally created in other mediums, increasing their relative value compared to the original designs and materials, communicates the worth of copper within Egyptian civilization. In these ways, the exchange value of copper as a commodity is vastly overshadowed by the value generated by the role copper played within Egyptian economy as a whole. This extra value and upsurge in the desirability of copper objects is demonstrated by the increased frequency of copper artifacts found in connection with New Kingdom sites in comparison to other periods and can only be seen through archaeological findings. The impact on the production of other goods and supporting technologies is best exemplified when reconstructive archaeological projects are analyzed. Likewise, scenes and art model the activities of ancient craftsmen in a way texts cannot clearly portray. It is only through the use of multiple source types and when steps are taken to place a commodity within its complete context, including environmental, technological, political, processual and economic factors, that an understanding of commodity can be realized.

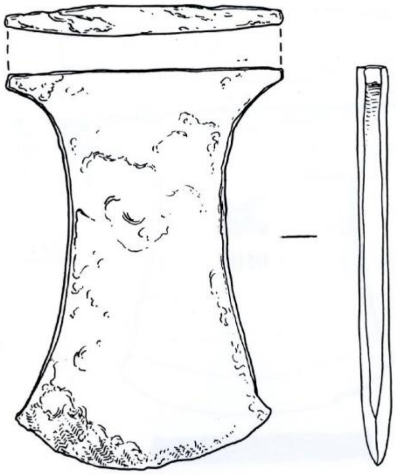
Future economic analyses and discussions of singular commodities will provide unique perspectives on those commodities and their roles within various societies both ancient and modern. Such research encourages cross-disciplinary studies. The current discussion would have benefited from further investigation and analysis on the role trade relations and foreign merchants played in Egypt, but effort to appropriately address such topics would have distracted from the overall purpose of analyzing copper's role in the New Kingdom. This topic and others – including the impact of quality wood on metallurgy, the viability of various land and water trade routes in the ancient world, an in-depth analysis on charcoal production in its own right especially in desert regions, further studies and comparisons on the chemical make-up of artifacts, and experimental and ethnographic projects testing and recording production and processing methods involved in metallurgy and copper-smithing in particular – are suggested as areas for further study. Each of these areas would expand our understanding on the impact copper had as a commodity within Egypt. This understanding could also help us be more aware of the social and economic factors at play with modern commodities, such as aluminum or diamonds, beyond the traditional aspects of wealth-storage and exchange values. If a holistic methodology, like the one proposed in this work, is followed in such studies, analyses would provide better contextual understanding for their readers and would encourage academic cooperation and transmission of information across traditional educational boundaries.

Appendix A: Selected Catalogue of Objects

All images have been taken from online museum catalogues that make their content freely available for academic purposes. Items listed in the Metropolitan Museum of Art collection can be found at http://www.metmuseum.org/art/collection. Items listed in The British Museum collection can be accessed at http://www.britishmuseum.org/research/collection_online/search.aspx.

1.) Carpenter's Adze
The Metropolitan Museum of Art: 96.4.7
New Kingdom – 18th Dynasty
Thebes - Deir el-Bahari, Foundation Deposit 1 (A)
Medium: Wood, bronze or copper alloy, leather
Length of handle: 19.6 cm
Length of blade: 15.7 cm
Width 5.3 cm

2.) Axe Head
British Museum: EA68878
New Kingdom – Possibly 18th Dynasty
Provenance unknown
Medium: Arsenical copper
Length: 12.9 cm (maximum)
Width: 9.06 cm (butt)
Thickness: 1.07 cm
Weight: 468.8 gm



3.) Ornamental Axe with Handle
British Museum: EA36766
New Kingdom – Possibly 18th Dynasty
Provenance unknown – Possibly from Thebes
Medium: Bronze or copper alloy, tamarisk wood, leather
Length: 43.5 cm (haft)
Height: 4 cm
Width: 16.5 cm (blade)
Weight: 260.5 gm

4.) Stonecutting Chisel
British Museum: EA15740
New Kingdom
Thebes
Medium: Bronze
Length: 12.7 cm

5.) Carpenter's Chisel
The Metropolitan Museum of Art: 12.180.344
New Kingdom – 18th Dynasty
Thebes – Malqata Palace
Medium: Bronze
Length: 16.2 cm

6.) Stonemason's Chisel
The Metropolitan Museum of Art: 27.3.12
Middle Kingdom – 11th Dynasty
Thebes – Deir el-Bahari
Medium: Bronze or copper alloy and wood
Length: 15.9 cm
Width: 2.2 cm

7.) Cosmetic Set
The Metropolitan Museum of Art: 26.7.837
New Kingdom – Early 18th Dynasty
Thebes – Asasif Tomb, CC 37
Medium: Bronze or copper alloy, ivory, stone and wood

Mirror (26.7.837a):
Length: 9.1 cm
Width: 6.8 cm

Razor (26.7.837b):
Length: 18.4 cm
Width: 2.2 cm
Thickness: 0.1 cm

Tweezers (26.7.837c):
Length: 7.2 cm
Width: 1.3 cm
Height: 0.7 cm

Whetstone (26.7.837d):
Length: 9.9 cm
Width: 1.8 cm
Height: 1 cm

Kohl tube (26.7.1447):
Height 7.8 cm

8.) Menat Necklace with Counterpoise
The Metropolitan Museum of Art: 11.215.450
New Kingdom – 18th Dynasty
Thebes – Malqata Palace
Medium: Faience, bronze or copper alloy, glass, agate, carnelian, lapis lazuli, turquoise
Length of counterpoise: 14.7 cm

9.) Cup
The Metropolitan Museum of Art: 10.130.1348
New Kingdom
Provenance unknown
Medium: Bronze or copper alloy
Height: 8 cm
Diameter: 12 cm

10.) Harpoon
British Museum: EA59226
New Kingdom
Provenance unknown
Medium: Bronze or copper alloy
Length: 13.7 cm
Width: 3.2 cm
Height: 1.4 cm

11.) Small knife with handle
Egyptian Museum, Cairo: JE61279
New Kingdom – 18th Dynasty
Thebes – Valley of the Kings
Medium: Copper alloy and wood
Length: 19 cm

12.) Mirror with handle in the shape of a woman holding a papyrus umbel
The Metropolitan Museum of Art: 1972.118.30
New Kingdom – 18th Dynasty
Provenance unknown – Possibly Thebes
Medium: Bronze or copper alloy
Height: 29 cm
Diameter: 15.5 cm
Weight: 1.2 kg

13.) Mirror with Handle
The Metropolitan Museum of Art: 26.2.18
New Kingdom – 18th Dynasty
Saqqara
Medium: Bronze or copper alloy
Height: 20.5 cm

14.) Razor (knife)
British Museum: EA5597
New Kingdom – 18th Dynasty
Thebes – Temple of Isis
Medium: Bronze or copper alloy
Length: 11.7 cm
Width: 2.2 cm
Thickness: 0.2 cm

15.) Razor (fixed)
British Museum: EA26262
New Kingdom
Provenance unknown
Medium: Bronze or copper alloy (blade) and copper
Length: 19 cm

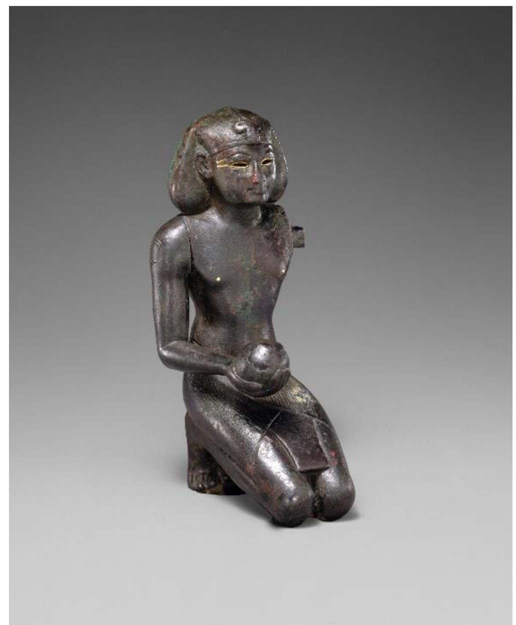
16.) Razor (rotating)
British Museum: EA37198
New Kingdom – 18th Dynasty
Thebes – Deir el-Medina
Medium: Bronze or copper alloy and wood
Height: 11 cm
Width: 16.8 cm
Weight: 0.05 kg

17.) Ring with scarab
British Museum: EA64919
New Kingdom
Provenance unknown
Medium: Bronze and glazed steatite
Diameter: 2.9 cm

18.) Egyptian Ring found in Cyprus
British Museum: 1897,0401.355
New Kingdom
Cyprus – Enkomi, Tomb 67
Medium: Bronze or copper alloy
Length: 2.1 cm
Width: 1 cm
Height: 0.7 cm

19.) Saw
The Metropolitan Museum of Art: 25.3.120
New Kingdom – 18th Dynasty
Thebes – Deir el-Bahari foundation deposit
Medium: Bronze or copper alloy and wood
Length: 38 cm
Width (blade): 4.1 cm

20.) Ritual Statue of Thutmosis III
The Metropolitan Museum of Art: 1995.21
New Kingdom – 18th Dynasty
Provenance unknown
Medium: Black bronze with gold inlay
Height: 13.1 cm (16.2 cm w/ tang)
Width: 6 cm
Depth: 7.6 cm



21.) Weight in the shape of a bull's head (2 dbn)
The Metropolitan Museum of Art: 68.139.2
New Kingdom – 18th Dynasty
Provenance unknown
Medium: Bronze or copper alloy
Height 3.1 cm
Width: 4.3 cm
Weight: 181.22 gm

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