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Metallurgical Extraction of Copper in Ancient Egypt

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ABSTRACT

The origins of chemistry in ancient civilizations can be traced back to the initial human endeavors aimed at producing an elixir and transmuting base metals into gold. The discovery and utilization of metallic elements have played a pivotal part in the advancement of human civilizations, since they have facilitated the production of sturdier and longer-lasting materials. The ancient Egyptians were among the oldest civilizations to engage in metallurgical practices. The primary metallic elements employed in ancient Egyptian civilization encompassed copper, gold, silver, and iron. The utilization of copper in ancient Egypt was widespread and constituted a significant aspect of Egypt's industrial endeavors. The current paper investigates the many modes, procedures, and technologies employed in the metallurgical extraction of Copper in ancient Egypt.

Keywords: Egypt, Copper, Metallurgy, Ore, Furnace

INTRODUCTION

The field of chemistry has been concerned with the systematic exploration of materials found in the surrounding environment, encompassing the tasks of material identification, manipulation, and utilization throughout history.

The intertwined nature of civilization's growth and the historical progression of chemistry is evident. Throughout the course of history, a multitude of instances may be observed wherein various materials have been unearthed, modified, and harnessed for the betterment of mankind. The early Homo sapiens lacked awareness of the methodologies employed in the alteration of substances. It can be inferred that the origins of chemistry can be traced back to the early stages of human evolution.[1] The potential correlation between the utilization of fire for culinary purposes and the advancement of chemistry has been posited by British anthropologist Richard Wrangham. The archaeological findings of charred bones in East Africa have been determined to have an age beyond 1.5 million years, therefore establishing them as the earliest evidence of the utilization of fire. [2] A recent study has provided evidence indicating that Israel employed fire as a tool more than 8 million years ago. [3]

The development of chemistry occurred concurrently with the emergence and growth of various civilizations across the globe. Evidence exists of the evolution of chemistry within three ancient civilizations, namely Egypt, China, and India. Legend has it that the term "chemistry" was derived from the ancient Egyptian word "Kemet," which referred to the land of Egypt. The term "Kemet" in Arabic translates to "black soil." Marco Beretta asserts that the ancient Egyptians demonstrated remarkable proficiency in the field of chemical arts. [4]

The development of lead-based cosmetics pigments and the inorganic colour known as Egyptian Blue is commonly associated with Egyptian culture. During the period of ancient Egypt, the predominant metals utilized were copper, gold, silver, and iron.

This paper examines the historical progression of copper metallurgy in ancient Egypt.

Metal Resources

Due to its elevated copper composition, the ancient Egyptians actively pursued four primary mineral sources: azurite, a copper carbonate exhibiting a blue hue; chrysocolla, a copper silicate displaying a distinctive green-blue shade; malachite, and pyrites, commonly referred to as fool's gold, characterized by its metallic yellow coloration and tetragonal crystalline arrangement.[5]The regions of the Eastern Desert and the Sinai Peninsula in Egypt exhibited the highest levels of copper concentration.[6] Although copper ores are widely distributed throughout the Eastern Desert, there are some regions that have gained recognition for their significant copper mining activities. These notable places include Gebel Atawi, Hammash, Wadi Dara, and Um Semiuki. The primary mining locality on the Sinai Peninsula is Serabit el-Khadim, along with its surrounding territory, which includes the Wadi Maghara and Wadi Nasb.

IMAGE 1 shows the location of various Copper mining sites in ancient Egypt.[7]

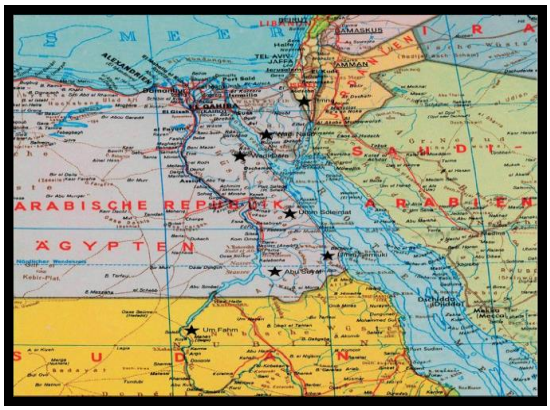


IMAGE 1

Mining in Ancient Egypt

The open pit mining technique was employed by the ancient Egyptians to extract copper from natural resources. Open pit mining is a method employed for the extraction of copper ore near the Earth's surface. [8] The fundamental architecture of the pit mine is most effective during the initial stages while minerals are still readily accessible. Once the surface resources of mineralized silt were exhausted, ancient miners were faced with the decision of selecting between two primary access methods.

If minerals are readily accessible from a vertical face, such as the rock face of a cliff or valley wall, miners may employ a technique wherein they extract the minerals, resulting in the formation of cave-like depressions in the rock Image 2. The technology in question was predominantly utilized by miners at the Wadi Dara mining location.[9] Furthermore, it is possible to excavate deeper cavities, so creating shafts that can facilitate the exploration and extraction of previously untapped mineral reserves. Upon the discovery of deposits, the shaft underwent lateral expansion to form an underground gallery situated at the same level as the mineralization. This gallery was designed to facilitate the collection of the available resource. Ancient miners utilized rudimentary tools such as the pounding stone, wedge, chisel, and gad (sometimes referred to as a pick or spike) to carry out the excavation of tunnels, galleries, and shafts **Image 3.** [10],[11]

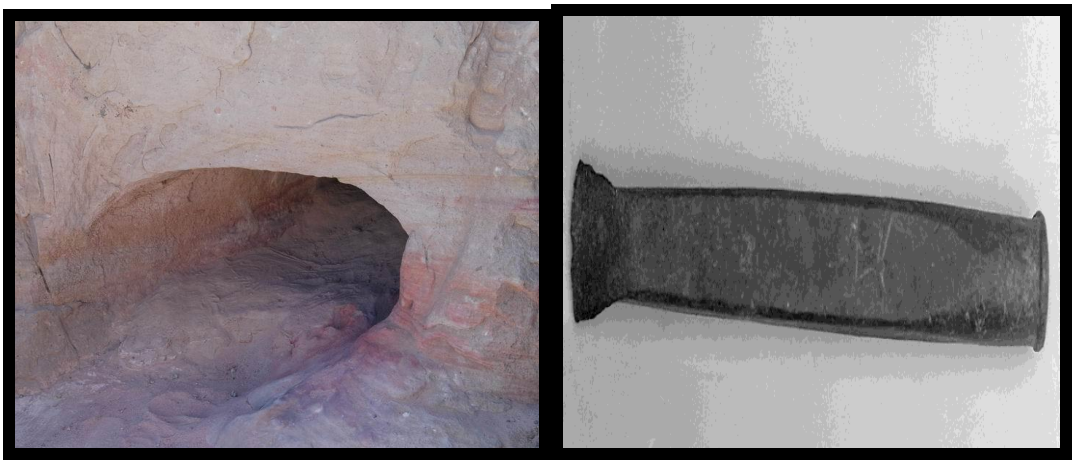


IMAGE 2 **IMAGE 3**

Ancient miners utilized natural resources to simplify the extraction of desired commodities. The rock surface has the potential to undergo accelerated erosion with the application of wood, water, or fire. In various regions of the ancient world, the practice of "fire-setting" was employed as a method to deliberately induce fractures and imperfections in rock formations through the controlled application of fire. [12]

Timna is an expansive park spanning an area of 60 square kilometers, renowned for its geological formations, natural landscapes, and historical significance. Situated to the north of Eilat, this park offers a rich tapestry of geological wonders, showcasing the intricate interplay between nature and history. Within this park, one can find remnants of a bygone Egyptian and Israelite copper mining enterprise. [13]

These remnants encompass various structures like as workshops, furnaces, tunnels, shafts, temples, mining camps, and rock drawings. Within the Timna highlands, the Egyptian miners engaged in the practice of excavating the copper ore by means of cutting into the hills. **Image 4** shows the sought-after substance in question pertains to a greenish powder, discreetly concealed among deposits and veins interlaced throughout the geological formations.[13]

The region in question served as a prominent hub for the manufacture of copper in ancient Egypt, with its origins traced back to the 12th and 13th centuries BC. Image 4 exhibits as enclosed space located at the front of the premises which serves as a designated place for conducting workshop activities and storing various materials. Positioned immediately behind this area is a furnace specifically designed for the purpose of smelting copper.[13]

IMAGE 3 **IMAGE 4**

BENEFICIATION

The beneficiation process was initiated upon extraction of the material from the mine. During the beneficiation process, the ore underwent a more intensive procedure involving sifting and grinding.[14] Simultaneously, the waste rock was transported to a designated disposal site, often resulting in the filling of previously utilized areas.

Once the extraction of copper minerals from the rock was completed, it became necessary to subject them to a purification procedure referred to as smelting. The process of smelting necessitates a high-temperature atmosphere. Before delving into the primary copper processing technique known as smelting, it is imperative to examine three key ancillary technologies: charcoal, ceramics, and ventilation equipment. Each of these technologies contributed to the generation of the necessary heat for the successful implementation of copper smelting. Charcoal emerged as the initial dependable source of fuel for high-temperature combustion processes.[15] The minerals containing a high concentration of copper were combined with charcoal and afterwards inserted into crucibles located within the furnace. During the process of heating, the carbon present in the charcoal would undergo a chemical reaction with the oxygen found in the copper crystals

SMELTING

Ceramic crucibles were utilized for the purpose of conducting the smelting process. Most crucibles were traditionally characterized by a bowl-shaped structure. During the heating procedure, specific depictions of metal working scenes from the Old Kingdom era exhibit crucibles that bear a resemblance to conventional sock or stocking forms, positioned near one another. In order to facilitate precise pouring of the liquid, the "toe" section of the crucible was afterwards opened or uncorked.[16] Moreover, ceramics were employed in the production of tuyeres, which functioned as heat-resistant nozzles affixed to the ends of blowpipes or bellows, facilitating the circulation of air within the furnace during the smelting process.

The presence of oxygen is important for the combustion of materials, and in the early stages of smelting, wind-powered furnaces and flames were utilized to attain elevated temperatures.[17] Nevertheless, this approach exhibits a deficiency in terms of uniformity and regulation, hence potentially resulting in perilous consequences. To effectively mitigate this risk, the utilization of blowpipes and bellows, which were safeguarded by tuyeres, was implemented.[18] Pot bellows, an ancient Egyptian metalworking tool, consisted of a ceramic cylindrical jar enveloped in pliable leather featuring one-way flaps. The bellows were operated by the user's lower extremities and featured a tether for the purpose of re-inflation **Image 5.** [19]

IMAGE 5

The process of smelting involves the first purification of metal using heat, which converts minerals and ores into a form that can be utilized. The procedure entails the classification of materials, the loading of a furnace with charcoal, the combustion process lasting many hours, and the introduction of a combination of charcoal and minerals referred to as a charge. Bellows and blowpipes are utilized to sustain temperatures surpassing the melting point of copper, so guaranteeing the maintenance of a molten charge and the elimination of any residual substances. A flux facilitates the chemical separation of

mineral components. Fluxes have an affinity for undesired substances, thereby forming bonds and thereafter remaining buoyant on the surface of the molten metal. When Malachite is the ore charcoal is used as both a fuel and a flux, whereas alternative minerals necessitated the use of iron oxides, sulphides, or manganese as fluxing agents.[20] These agents are responsible for the release of metallic substances and the subsequent binding of impurities, resulting in the formation of ingots. The copper prills became entrapped within the slag matrix, and subsequently, liberation was achieved by means of mechanical processes such as crushing and grinding.

During the initial stages, the process of smelting was carried out using furnaces of the pit-style variety. However, as the New Kingdom era unfolded, a significant shift occurred, with most furnaces being erected using the more advanced design known as the shaft furnace.[21]

The implementation of design adjustments facilitated the enhancement of the furnace's thermal capacity, enabling it to sustain higher temperatures over extended durations, primarily using airflow management technology. To enhance the oxygen supply within pit furnaces, metalworkers either utilized natural air currents or employed downward-facing blowpipes directed towards the charge. The extent of segregation between the slag and the purified metal was found to be directly influenced by the duration and temperature of the smelting procedure employed for a given ore. [22]

Shaft furnaces, employed a technique known as tapping, which involved the removal of a plug from a hole located on the side of the furnace wall slightly above the level of the refined metal. This method bears resemblance to those utilized throughout the New Kingdom period.[23] As a result of variations in viscosity, the impurities, commonly referred to as slag, exhibit buoyancy and consequently rise to the surface of the molten metal residing at the lowermost region of the furnace. Subsequently, the slag is discharged through a designated aperture located on the side of the furnace, ultimately accumulating, and undergoing cooling within a designated receptacle. The metal has the potential to undergo cooling at the lower region of a furnace without experiencing deformation, so enabling it to be solidified within a mould to determine the specific shape and dimensions of the resulting ingot. Timna's Site 2 offers substantial evidence pertaining to the smelting process and the accompanying technology that facilitated it.

The Ha'aretz museum in Tel-Aviv exhibits a copper smelting furnace that dates back to the 12th century BC **(Image 6**).[24] The furnace is surrounded by elongated stone blocks. Located in the posterior wall, there exists a tubular nozzle that facilitates the introduction of air into the smelting furnace. The slags, which are a residual material resulting from the process of copper extraction by smelting, can be observed adjacent to the furnace, including copper pellets that have become caught within them. The presence of a slag pit is observed in the vicinity of the furnace.

IMAGE 6

REFINING

The process of copper manufacture and refinement commenced with smelting. The enhanced purification of slag and impurities in successive melting processes, often requiring the utilization of crucibles, resulted in an enhanced quality of the produced copper ingots. The metallurgy scene depicted in the tomb of Rekhmire provides evidence that crucibles were commonly employed in conjunction with

open pit furnaces. This is evident from the portrayal of multiple groups of metalworkers heating crucibles using pot bellows over flames **IMAGE 7.**[23]

IMAGE 7

The metal underwent a process of conversion into ingots, The two main classifications of ingots produced under the New Kingdom are commonly referred to as "bun" and "oxhide" ingots. The objects in question have a weight range of three to five pounds and often possess a rectangular shape with a plano-convex structure as shown in **Image 8.**[24] Bun ingots, in comparison to oxhide ingots, have a lower size. Oxhide ingots, were measured to weigh between 24 and 30 kilograms **(Image-9).** [25]

IMAGE 8

IMAGE 9

The observed disparity in weight between the two distinct categories of ingots utilized by metalworkers during the New Kingdom period is likely indicative of their respective intended functional roles. The archaeological discovery of the Ulburun shipwreck revealed the presence of 121 copper bun ingots and 354 oxhide ingots.[26] The inference can be made that the presence of a greater quantity of oxhide ingots on a long-distance commerce vessel suggests their intended use in facilitating transactions involving big quantities of products. The utilization of compact bun ingots offered various benefits in the manufacturing process of items that necessitate tiny amounts of material, including as jewelry and tools

USES OF COPPER IN ANCIENT EGYPT

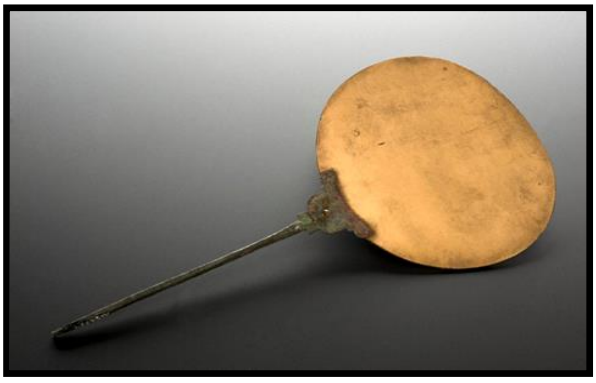
Non-precious metals, such as copper and bronze, were widely employed in the development of military technologies due to their exceptional effectiveness.[27] The axe, spear, and dagger were the principal combat weapons employed by the military forces of the New Kingdom.[28] The utilization of copper greatly enhanced the efficacy of carpentry tools. The adze, often known as the ant, held significant utility in ancient times. Copper tools, including awls and knives, were commonly employed in the craft of leatherworking to effectively cut and shape the leather.

During the New Kingdom era, copper emerged as a significant material utilized in the manufacturing of both essential household items and extravagant luxury goods. Various commonplace items that utilized the abundant copper resources included mirrors, razors, tweezers,

containers, jewelry, and even measuring weights. Mirrors, historically, were crafted through the process of hammering or casting a sheet of copper or bronze into a circular configuration, featuring a tab or handle protruding from one side.[29] The utilization of copper and bronze proved advantageous in the development of razors which were among the various toiletry items that experienced improvements. Razors have dual functionality, serving as both personal grooming implements and vocational tools, particularly within the context of the established barber profession in ancient Egypt.[30] During the New Kingdom, another notable artefact within the realm of cosmetics and toiletries was the tweezer, crafted from materials such as bronze or copper. Bronze has also been utilized in the production of kohl tubes and applicators, with a few instances serving as notable examples. Kohl, a cosmetic substance mostly composed of charcoal, galena, and malachite, was historically utilized for application around the eye, resembling contemporary practices of using eye-liner and eye-shadow.[31] Jewelry, like to other luxury commodities, predominantly comprised of valuable materials, with gold being particularly prominent in ancient Egypt. Copper ores, as well as copper and bronze, were employed in the production of jewelry. Malachite, azurite, and turquoise were highly sought after due of their vivid hues. Tiny fragments of these minerals have the potential to be embedded within ornamental components and objects, with the purpose of imparting vibrant hues.[32] Copper ores were widely utilized as a pigment in the New Kingdom for the purpose of coloring paints, glazes, and cosmetics

Sword made of Copper Alloy
British Museum, UK

Metal adze blade attached to a wooden haft
Met Museum of Art, New York



Bronze Egyptian Toiletry Mirror Science Museum Group Collection, UK

Cosmetic implements including a kohl tube, a razor a whetstone a pair of tweezers and a mirror
Metropolitan Art Museum New York

CONCLUSION

While copper did not possess the same level of recognition as gold and silver in terms of being a widely accepted form of wealth storage, its abundance made it the most dependable metal for acquisition, exchange, and utilization, Copper holds significant importance within Egypt and plays a crucial role in the country's economy. The utility of copper is evidenced by its impact on craft production, cultural and economic development, as well as technical innovation, highlighting the significant power and value it generates. While gold tends to attract more attention compared to copper, it is worth noting that copper had a more major role in facilitating improvements throughout Egyptian history, surpassing both gold and silver.

Declaration by Authors

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REFERENCES

1. Wrangham, Richard W.; Jones, James Holland; Laden, Greg; Pilbeam, David; Conklin-Brittain, NancyLou (Dec 1999). "The Raw and the Stolen". *Current Anthropology*. 40 (5): 567–594
2. Yolanda Fernández-Jalvo , Laura Tormo , Peter Andrews , M. Dolores Marin-Monfort, Taphonomy of burnt bones from Wonderwerk Cave (South Africa), Quaternary International Volume 495, 30 November 2018, 19-29
3. Zohar, I., Alperson-Afil, N., Goren-Inbar, N. *et al.* Evidence for the cooking of fish 780,000 years ago at Gesher Benot Ya'aqov, Israel. *Nat Ecol Evol* **6**, 2022, 2016–2028
4. Marco Beretta, A Cultural History of Chemistry: In Antiquity, Bloomsbury Academic, London, Dec 2021
5. Castel, G., B. Mathieu, G. Pouit, M. el-Hawari, G. Shaaban, H. Hellal, T. Abdalla, and A. Ossama. 1995. "Wadi Dara copper mines." In *Proceedings of the first international conference on ancient Egyptian mining & metallurgy and conservation of metallic artifacts: Cairo, 10-12 April 1995*. Edited by Feisal A. Esmael. Cairo: Egyptian Antiquities Organization Press: 15-31.
6. Dietrich Klemn, Rosemarie Klemn, Encyclopaeidia of the History of Science, Technology &Medicine in Non-Western Cultures,1685-1698
7. Dietrich Klemm, Rosemarie Klemm, Encyclopaedia of the History of Science, Technology & Medicine in Non-Western Cultures,1685-1698, Springer, 2008
8. Craddock, P. T. 1995. *Early Metal Mining and Production*. Washington D.C., SmithsonianInstitution Press
9. Castel, G., B. Mathieu, G. Pouit, M. el-Hawari, G. Shaaban, H. Hellal, T. Abdalla, and AmOssama. 1995. "Wadi Dara copper mines." In *Proceedings of the first internationalconference on ancient Egyptian mining & metallurgy and conservation of metallicartifacts: Cairo, 10-12 April 1995*. Edited by Feisal A. Esmael. Cairo: Egyptian Antiquities Organization Press: 15-31
10. Shaw, Ian. 2001. "Quarries and Mines" in The Oxford Encyclopedia of Ancient Egypt – Volume 3. Edited by Donald Redford, Cairo: American University in Cairo Press: 99-104.
11. https://www.metmuseum.org/art/collection/search/544301
12. Craddock, P.T.1995, Early Mining and Production. Washington D.C. Smithsonian Institution Press 33
13. https://www.biblewalks.com/timna
14. Craddock P.T.1995, Early Mining and Production. Washington D.C. Smithsonian Institution Press 68
15. Castel, G., B. Mathieu, G. Pouit, M. el-Hawari, G. Shaaban, H. Hellal, T. Abdalla, and A. Ossama. 1995. "Wadi Dara copper mines." In Proceedings of the first international conference on ancient Egyptian mining & metallurgy and conservation of metallic artifacts: Cairo, 10-12 April 1995. Edited by Feisal A. Esmael. Cairo: Egyptian Antiquities
16. Davies, Norman de Garis. 1922. *The tomb of Puyemrê at Thebes, vol. 1.* New York: Metropolitan Museum of Art.
17. Betancourt, Philip P. and James D. Muhly. 2006. "The Pot Bellows" *Hesperia Supplements*, Vol.36, The Chrysokamino Metallurgy Workshop and Its Territory: The

American School of Classical Studies at Athens: 125-132
18. Ogden, Jack. 2000. "Metals" In *Ancient Egyptian Materials and Technology*. Edited by Paul T. Nicholson and Ian Shaw. London: Cambridge University Press:151.
19. Rothenberg, Beno and Alexandru Lupu. 1966. "Excavations in the early Iron Age copper industry at Timna (Wadi Arabah, Israel), May 1964 (Preliminary archaeological report)." *Zeitschrift des Deutschen Palstina-Vereins (1953-)*, Bd. 82, H2: 125-135.
20. Craddock, P.T.1995, Early Mining and Production. Washington D.C. Smithsonian Institution Press 147-148.
21. Scheel, Bernd. 1989. *Egyptian Metalworking and Tools.* Shire Egyptology 13. Princes Risborough: Shire Publications.16.
22. Rothenberg, Beno and Jonathan Glass. 1992. "The beginnings and the development of early metallurgy and the settlement and chronology of the western Arabah, from the Chalcolithic period to Early Bronze Age IV." Levanti 24:141-157
23. Scheel, Bernd. 1989. Egyptian Metalworking and Tools. Shire Egyptology 13. Princes Risborough: Shire Publications.
24. https://www.worldhistory.org/image/7262/copper-oxhide-ingot-uluburun-shipwreck/
25. https://www.biblicalarchaeology.org/daily/ancient-cultures/ancient-near-eastern-world/copper-ingots-ancient-shipwreck-turkish-coast/
26. Gestoso Singer, Graciela. 2007. "El barco naugragado en Ulu Burun y el intercambio de bienes en el Mediterraneo oriental." in DavarLogos, 7.1: 19-32.
27. Partridge, Robert. 2002. Fighting Pharaohs: Weapons and warfare in Ancient Egypt. Manchester: Peartree Publishing.
28. Shaw, Ian. 1991. Egyptian Warfare and Weapons, Shire Egptology16. Princes Risborough: Shire Publications
29. British Museum Online Collection
30. Lichtheim, Miriam. 2006. Ancient Egyptian Literature: Volume II: The New Kingdom. London: University of California Press.
31. Lucas, Alfred. 1930. "Cosmetics, Perfumes and Incense in Ancient Egypt" The Journal of Egyptian Archaeology, Vol. 16, No. ½. Egypt Exploration Society: 41–53.
32. Rehren, Th., E.B. Pusch, and A. Herold. 2000. "Glass Coloring Works within a Copper-Centered Industrial Complex in Late Bronze Age Egypt." In The Prehistory and History of 112 Glassmaking Technology. Edited by Patrick McCray. Westerville, OH: The American Ceramic Society: 227-250.

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