Copper From Giza: the Latest News

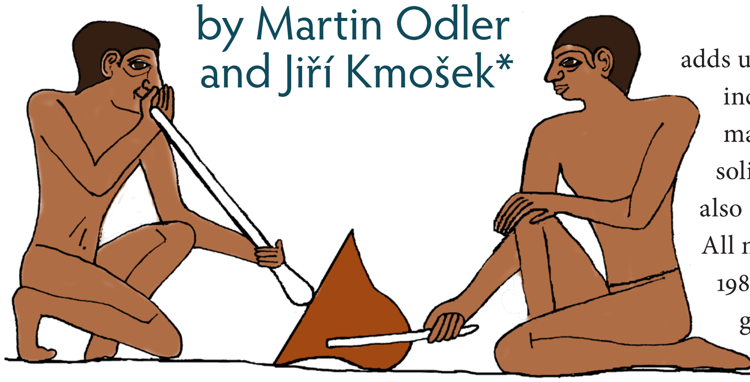
2 authors:

Martin Odler
Newcastle University

Jiri Kmosek
Akademie der Bildenden Künste Wien

Copper at Giza: the Latest News

by Martin Odler and Jiří Kmošek*



There is only one Giza, the largest excavated site of the Old Kingdom. Giza provides the basis of our archaeological knowledge of the period, only slowly being complimented by excavations on other sites. While early large-scale excavations focused on pyramids and other tombs, more recent excavation uncovered areas where ancient workmen actually lived. Thus, both ends of the past reality are represented, real lives of the Old Kingdom people, but also their eternal homes—tombs—with the objects destined to be used in the afterlife.

Information available at Giza holds the keys to many questions about past Egyptian lives. One of them, which we are trying to answer in an ongoing project, is about Old Kingdom procurement, use, and discard of copper. We apply modern scientific analytical techniques to uncover more information about this topic, long neglected in Egyptian archaeology. Many studies were done in the past, including on the material from Giza,[1] but these were all case studies of small groups of material. A systematic approach is what is needed now and in the future.

Many Questions, First Answers: Results of the Current Research

Copper was the most important metal of Old Kingdom Egypt, the Early Bronze Age. Oddly enough, the ubiquitous material of this age in the ancient Near East was not copper alone, but a specific alloy of copper with another chemical element, arsenic. More about the material below, but if your immediate thought was that arsenic is toxic … indeed, it is. But small doses are not lethal, and an addition of just a few percent of arsenic to copper causes the material to be harder, very similar in properties to the later-used tin bronze.

The main task of our project in Giza is to find out how local copper production and artifacts fit into this wider picture. In April 2019, archaeologist Martin Odler visited the AERA field lab at Giza and surveyed the available material, which had been recovered from AERA excavations. The so-called "industrial waste," including copper fragments, slag from the production processes, fragments of the smelting vessels (crucibles), adds up to more than 250 bags, including large bags with many fragments, but also solitary fragments and, finally, also copper artifacts themselves. All material excavated since 1988 is available and gives us good information about the amount of the metallurgical remains from the uncovered archaeological structures and deposits. It may seem to be not that much, but this is actually the largest known corpus of the metallurgical remains from the Old Kingdom in the whole of Egypt.

The 4.D17x Copper Workshop

The most important part of the corpus was found in the workshop denoted 4.D17x situated in the back chamber of Gallery III.8 at the Heit el-Ghurab (HeG) site (see sidebar, next page). Bread molds were used as crucibles for melting the copper, and probably also producing small items, such as needles and fishhooks. This is no coincidence, as bread molds were used for copper production in the Old Kingdom town of Buhen (Nubia), and such use of a bread mold is depicted in a tomb relief in Saqqara, in the tomb of Niankh-khnum and Khnumhotep (shown above). Special molds for the production of copper objects dating from the Old Kingdom are known only from Buhen.[2] Larger tools were cast as copper slabs, and later formed by hammering and annealing (repeated heating and cooling of the metal) to its final shape and function. Smaller objects, such as those produced in the 4.D17x workshop, were most probably shaped from cast metal rods, again going through processes of hammering and annealing.

Samples for Study

From the material at hand, 23 samples were selected, representing the layers of workshop 4.D17x and scattered slag pieces from other areas of HeG, as well as from the Kromer Dump site (KRO) and the Khentkawes Town (KKT)[3] (see table, page 17). These samples were documented and packed for

(continued on page 13)

Above: Copper-working scene in the tomb of Niankh-khnum and Khnumhotep at Saqqara shows a man holding a large bread mold at an angle (with sticks?), while another man uses a blow pipe to heat whatever is inside the bread mold. Redrawn after *Das Grab des Nianchchnum und Chnumhotep. Old Kingdom Tombs at the Causeway of King Unas at Saqqara*, Archäologische Veröffentlichungen, Deutsches Archäologisches Institut, Abteilung Kairo 21, by A. Moussa and H. Altenmüller, Mainz am Rhein: Philipp von Zabern, 1977, Plate 63, detail.

* Martin Odler just completed his PhD at the Czech Institute of Egyptology, Charles University, Prague. Jiří Kmošek is a researcher in the Department of Chemical Technology, University of Pardubice, Pardubice, Czechia, and is also a PhD candidate at the Institute of Science and Technology in Art, Academy of Fine Arts, Vienna.

The 4.D17x Copper Workshop

Map of Heit el-Ghurab showing the location of the 4.D17x copper workshop. Map by Rebekah Miracle, AERA GIS.

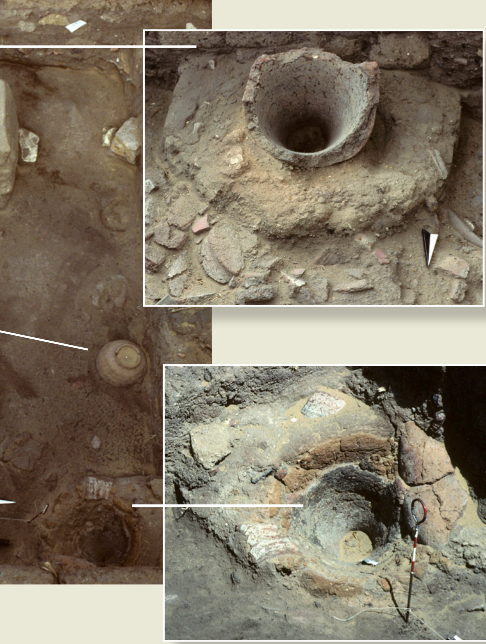
Left: A copper needle and copper fish-hook. The eye of the needle is at the bottom. Photos by Yukinori Kawae.

Above: Square 4.D17x, the copper workshop. North is to the right. Insets: the two bread molds used as crucibles. Note the three large jars implanted in the floor. Photos by Mark Lehner.

AERA uncovered the workshop in 1998 at Heit el-Ghurab while excavating in an area we later discovered was part of the Gallery Complex, a large block of long galleries. In Square D17 (later renamed 4.D17 when we extended our original grid), we discovered walls scorched by a hearth and bright orange deposits nearby. We suspected the hearth had been used for copper working, as many fragments of copper slag turned up in the heavy fraction from flotation samples collected here. In the hopes of uncovering more evidence of copper working, we expanded the excavation diagonally into the adjoining square, which we designated D17x.

Our efforts were rewarded. Here, in a chamber roughly 2 × 4 meters, copper-working appears to have been the principal activity, as indicated by abundant traces of

Square 4.D17x (outlined with red dotted line) during excavations in 1998. The man on the right is excavating through the uppermost floor. Note the hearth in the northeast corner and the three jars that were discovered embedded in the upper floor layer. View to the north. Photo by Mark Lehner.



metallurgy. Two unusual hearths consisting of bread molds had been plastered in place against the walls of the chamber, one at the center of the south wall, the other, in the north-east corner. They were held in place by "collars" of large sherds and mud that had been hard-fired like redbrick from the heat.

The bread mold hearths had been used as crucibles to hold molten metal. Small bits of corroded green copper were embedded in the bread mold walls. We found pieces of spouts and little clay tubes that would have been used to blow air into the "furnace," as well as sherds vitrified by the heat. Copper slag was scattered through the ashy dirt fill and in the floor deposits.

Metal workers probably made small implements, such as the copper fishhook and thin copper needle we found here. Once the tools were heated in the bread mold crucibles for pounding, they could have been quickly cooled by dunking them in water in the large jars implanted in the floor (the so-called process of annealing).

(continued from page 11)

transport to the laboratory of the Institut français d'archéologie orientale (IFAO) in Cairo, which possesses all the necessary equipment for preparing the metallographic cross-sections from the samples and metallographic microscopes for their study. The transfer of samples was kindly allowed and enabled by the Ministry of Tourism and Antiquities. This research at Giza is part of a wider research framework.

Restarting Archaeometallurgy in Modern Egypt

The IFAO supported our project "Restarting Archeometallurgy in Modern Egypt, action spécifique no. 19463" in both 2019 and 2020. The principal investigators of this project are the authors of this article: archaeologist Martin Odler, and an archaeometallurgist, Jiří Kmošek. With our joint expertise, the project is attempting to demonstrate the feasibility of the scientific study of metals in Egypt. It is focused especially on the 3rd and 2nd millennia BC, the Early and Middle Bronze Age, gathering data on ancient copper from different missions working in Egypt, with our base at the Czech Institute of Egyptology, Faculty of Arts, Charles University, Prague, and its Egyptian concession at the Abusir pyramid and cemetery field south of Giza, where the initial corpus was examined.

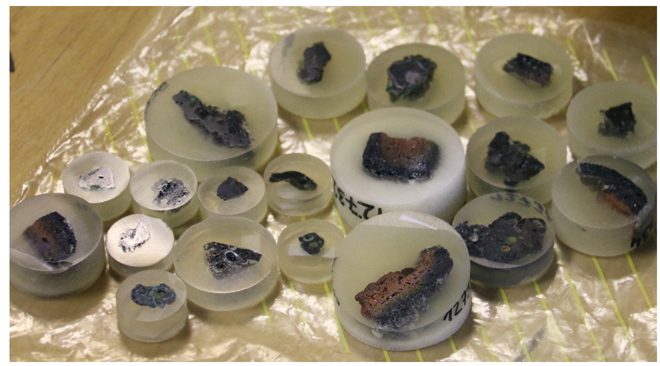
As already mentioned, systematic effort is needed, as the past case studies focused on a limited number of artifacts and the "big picture" is still lacking. Another problem is that not all currently used methods are available in Egypt, and the export of samples is theoretically possible, but legally extremely difficult. Therefore, we are trying to apply the range of available methods in Egypt on the material currently found there, comparing these results with more fine-grained methods used on the samples from provenanced Egyptian and Nubian objects in the museums abroad (see below). This will allow us to pursue research and produce comparable results both in Egypt and outside of Egypt.

Lab Work

In November 2019, Jiří Kmošek prepared cross-sections from the Giza samples (photo, next page, second from top) and all were studied under the microscope and analyzed

In the AERA field lab Martin Odler photographs the samples of metallurgical remains that he prepared for transport to the Institut français d'archéologie orientale (IFAO) lab in Cairo. Photo by Mark Lehner. (Samples shown in photo on page 14, top.)

with a portable X-ray fluorescence spectrometer Bruker Tracer III-SD, one of the most precise (and most expensive) machines for this type of research. The spectrometer gives information (spectra) about the chemical composition of the analyzed material (photo, facing page and page 16). A cross-section cuts the sample in half; the polished sample cut thus enables us to examine the internal structure of the metallurgical remains (photos, page 15). The spectra (page 16), together with the observations of the sections under the microscope, produced the first solid results about the type of material worked in 4th Dynasty Giza. They revealed smelting/melting and probably also alloying slag fragments, and fragments of crucibles, almost all with small prills (metallic globular particles), composed of copper, arsenical copper, and extremely high arsenical copper. These preliminary results will be further studied and compared with other material.



Enigmatic Arsenical Copper

The use of arsenical copper for tools and weapons of the Old Kingdom was confirmed long ago by a range of independent studies on the objects from Egypt in the collections of several museums: the Ashmolean Museum, Oxford, by Hugh McKerrell in the 1970s; the Louvre, Paris, by Félix Michel in the 1960s and 1970s; and the British Museum, London, by Michael Cowell in the 1980s.[4] But it seems that many Egyptologists did not notice, or even internalize this fact in their research, and arsenical copper remained a rather mysterious material of ancient Egypt, until quite recently.

Experimental work on arsenical copper by Heather Lechtman, professor at MIT, demonstrated how it compared with tin bronze: the two metals "may be used interchangeably for specific functions within rather broad alloy ranges: ≈ 2–7 weight-percent arsenic; ≈ 2–7 weight-percent tin."[5] Thus, this less-known, but widely used material, offered similar practical properties as would later tin bronze. Even in the Old Kingdom, tin bronze was not completely foreign to ancient Egyptians, as the earliest tin bronze objects—vessels—occurred already in the Early Dynastic Period. But arsenical copper was the material of choice for tools and weapons before the end of the Middle Kingdom. This was almost all that we knew until recently.

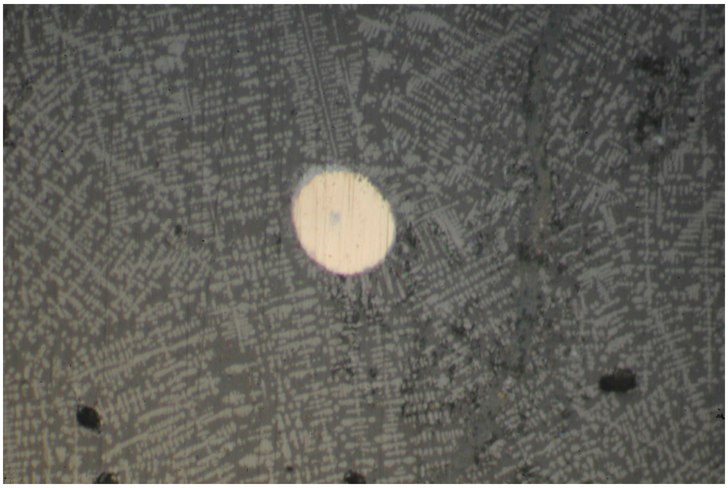
Two articles, published in August 2018 in the *Journal of Archaeological Science*, tackled the questions of the provenance and use of

From top down: The copper samples set for transport. Note only a small amount of the sample is needed for analysis.

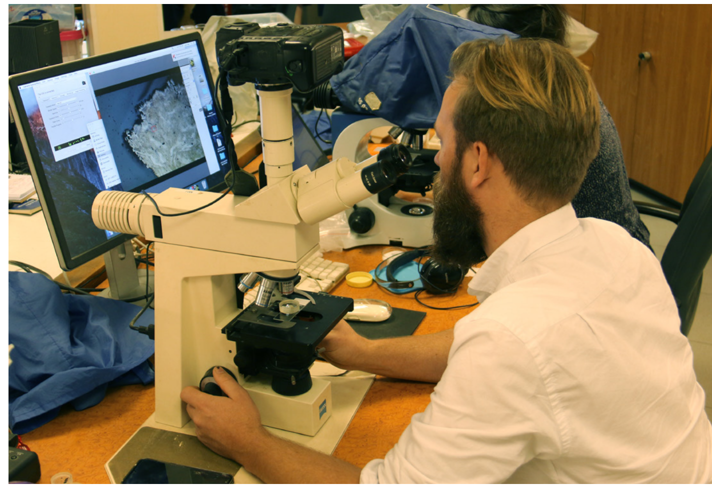
In the IFAO lab, mounted cross-section samples prepared for X-ray fluorescence analysis and microscopy.

For safety reasons, Jiří Kmošek covers the sample for X-ray fluorescence analysis.

Jiří Kmošek analyzes the sample with the portable X-ray fluorescence spectrometer. Photos by Martin Odler.



Microstructure of an iron-rich compact slag fragment with a micrometer-size bright arsenical copper prill in the center, as documented by the metallographic microscope. Photo by Jiří Kmošek.



Jiří Kmošek documents the samples under a metallographic microscope. Photo by Martin Odler.

copper in Early Dynastic and Old Kingdom Egypt. The papers were the result of the project of the Czech team (led by Martin Odler and Jiří Kmošek)[6] and a Belgian team (led by Frederik Rademakers and Georges Verly),[7] both independently working on Egyptian material from the two museums, the former on the artifacts from the Egyptian Museum of Leipzig University, the latter on the material in the Royal Museum of Art and History, Brussels. Following the current focus on provenance and chemical composition, both studies identified the prevailing use of arsenical copper. Concerning the origins of copper, a rather surprising evaluation of the lead isotope results points to the main ore source areas in the Eastern Desert and the Sinai Peninsula. Some researchers supposed that a high quantity of copper in Old Kingdom Egypt was coming from the Early Bronze Age copper "factory" at Khirbet Hamra Ifdan (in Wadi Feynan, contemporary Jordan), but not a single piece has yet been demonstrated to have come from there. However, only about 60 artifacts were analyzed in both studies (and they were the hard-earned results of projects running for several years!), thus we might still be missing Feynan copper.

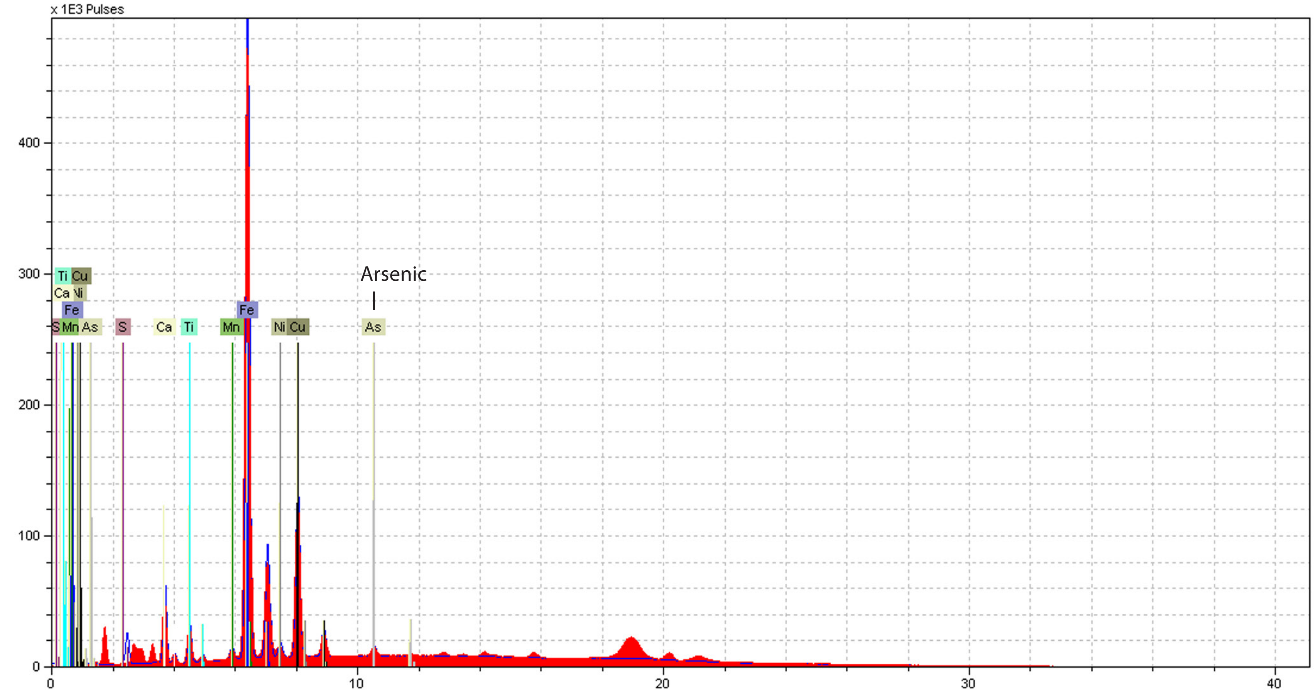
The research of the Czech team also sought further knowledge of the microstructure of the metals and their practical properties.[8] Among the studied assemblage were artifacts from Giza, West Field, where the German mission, led by Georg Steindorff, worked a century ago. We found that the contents of arsenic oscillates in the materials used and that hardness was achieved mainly by hammering the objects into the final shape. Full-size functional tools were, of course, harder than the model tools, which prevail in the known Old Kingdom archaeological contexts. The main difference between full-size functional tools and the model tools is in the amount of arsenic present, the working hypothesis being that the models might have been produced from already recycled material. Nevertheless, the studies of models demonstrated that they were produced by craft operations very similar to the production of full-size tools.[9]

As for the tool kits represented, among the model tools are especially blades of the artisan tool kit: chisels, adzes, axes, and saws. Moreover, often these models involved also razors and needles, besides a range of copper vessels. Full-size tools are much scarcer and thus less frequently analyzed, but one important corpus of artisan tools was found in the Menkaure Valley Temple and is now in the Museum of Fine Arts, Boston. In the 6th Dynasty, full-size mirrors became popular in burial equipment. More on these tools and their analyses can be found in Martin Odler's *Old Kingdom Copper Tools and Model Tools*.[10]

The Old Kingdom is also remarkable for the absence of metal blades of weapons. We know from the iconographic sources that such weapons must have existed, but because of social and religious rules and practices, they were not deposited amongst the burial equipment. Much more metal weaponry is preserved from the First Intermediate Period and Middle Kingdom.

Future Prospects

The project is to be continued in 2020 or in 2021, as the international and local situation will allow. We would like to study more fragments and artifacts from Giza with the help of portable X-ray fluorescence, in order to gain information about the composition of all fragments, selecting more to be studied as samples, with an eventual objective to publish this important material. We plan to analyze selected samples in detail by using the scanning electron microscope equipped with an EDS (Energy Dispersive Spectroscopy) analyzer, in order to get exact information about the composition of specific microstructural phases and metallic copper or arsenical copper prills. Even a tiny bit of a copper prill or slag can give vital information under the microscope, thus it is important to collect everything. Giza is the most important site for the 4th Dynasty. It must also be considered one of the most significant copper-processing centers in the heart of the Egyptian



Analyzed elemental spectrum of one of the samples. The horizontal axis is kiloelectron volts (keV), a unit of energy used in diagnostic radiography. Different elements have different characteristic energy values. The vertical axis reflects count rate (cps), the number of counts for each analyzed element per second. The concentration of the analyzed elements is then calculated from the area of the individual peaks.

state, based on the number of the known copper-processing workshops.

Only a handful of copper-processing workshops are known from 3rd millennium BC Egypt and Nubia (e.g., at Buhen, Elephantine, Edfu, and el-Kab). Three of them were identified in Giza. The workshop excavated by Abdel-Aziz Saleh in 1971–1972,[11] located south-east of the Menkaure mortuary temple, was the most complex, yet it is also the least known, as only a single, not very detailed, report was published on the results of the excavations. Later on in the 1970s, indications of metallurgical activity were found in the trash midden of 4th Dynasty settlement debris excavated by the team of Austrian archaeologists led by Karl Kromer.[12] And the third workshop was identified in HeG, in Square 4.D17x, as already mentioned. Saleh's work might deserve revisiting in the future, as it is most probably the largest copper-processing facility in the area. Paradoxically, we currently know much more about the smaller installations.

Kromer's material is being enriched currently by the recent excavations in and around his original trenches.[13] Part of the material excavated in 1970s was brought to Austria and ended up in the collection of the Institute of Prehistory at the University of Vienna. Among the objects were also the archaeometallurgical remains and copper artifacts, already being studied by our Czech team.

Since the range of methods available in Egypt is rather limited now, the projects there ought to be complemented by the more detailed analyses of the objects in the museum and university collections. The results of the research of Kromer's material, deposited in Austria, will be published soon. Right now we can say that the tools found were made of arsenical copper (including needles and fish-hooks) and the copper itself came either from the Eastern Desert or Sinai, Feynan being again absent.

1.Maddin, R., T. Stech, J. D. Muhly, and E. Brovarski, "Old Kingdom Models from the Tomb of Impy: Metallurgical Studies," *Journal of Egyptian Archaeology* 70 (1), pages 33–41, 1984.

2. O'Connor, D. B. *The Old Kingdom Town at Buhen*, Excavation Memoir/ Egypt Exploration Society 106, London: Egypt Exploration Society, 2014.

3. The Kromer Dump is a huge midden of trash discarded from two 4th Dynasty sites. The sample in the study was in a garbage layer that probably came from a site near where the Menkaure Valley Temple was later built. See Witsell, A.,"Kromer 2018: Basket by Basket," *AERAGRAM* 19-1, pages 2–9, Spring 2018. Available for free download at aeraweb.org.

The Khentkawes Town includes residences that once housed priests serving the cult of Queen Khentkawes and structures that may have been used during the time that the Menkaure Valley Temple was being built.

4. Michel, F., "Analyse de quarante miroirs appartenant au Département des Antiquités égyptiennes du Musée du Louvre," *Annales (Laboratoire de recherche des musées de France)* 23, pages 34–46, 1972.

Hours, M., and Michel, F., "Scientific Methods in the Study of the Metallurgy of Antiquity at the Louvre," In *Application of Science in Examination of Works of Art: Proceedings of the 3rd International Seminar, June 15-19, 1970*, 1st Edition, edited by W. J. Young, Boston: Boston Museum of Fine Arts, pages 67–72, 1974.

Eaton, E. R., and McKerrell, H., "Near Eastern Alloying and Some Textual Evidence for the Early Use of Arsenical Copper," *World Archaeology* 8 (2), pages 169–191, 1976.

Cowell, M. R., "Scientific Appendix I. Chemical Analysis," In *Catalogue of Egyptian Antiquities in the British Museum. 7: Tools and Weapons; 1: Axes*, edited by W. V. Davies, London: British Museum Publications, pages 96–118, 1987.

5. Lechtman, H., "Arsenic Bronze: Dirty Copper or Chosen Alloy? A View from the Americas," *Journal of Field Archaeology*, 23 (4), page 506, 1996.

6. Kmošek, J., M. Odler, M. Fikrle, and Y. V. Kochergina, "Invisible Connections. Early Dynastic and Old Kingdom Egyptian Metalwork in the

Table showing results of analysis for each sample.

IFAO sample number	AREA	YEAR	DESCRIPTION	WEIGHT (Grams)	MATERIAL DETERMINED BY XRF
12732	D17x	1999	vitrified pottery fragment	5.4	vitrified ceramic sherd with no added fluxes or metal
12733	D17x	1998	vitrified pottery fragment	3.4	vitrified ceramic sherd with no added fluxes or metal
12734	D17x	1998	vitrified pottery fragment	3.6	vitrified ceramic sherd with small arsenical copper prills
12735	D17x	1998	slag nodules	0.5	silica rich slag fragment with arsenical copper prills
12736	D17x	1998	vitrified pottery fragment/ crucible	6	vitrified ceramic sherd with arsenical copper prills
12737	D17x	1998	slag fragment	3.3	iron-rich slag fragment with completely corroded arsenical copper prills
12738	D17x	1998	slag fragment	2.4	iron-rich compact slag fragment with small arsenical copper prills
12739	D17x	1998	slag fragment	1.5	silica-rich compact slag fragment with small arsenical copper prills
12740	KRO	2018	slag fragment	0.9	slag fragment with small arsenical copper prills
12741	SWI	2018	copper mineral	1.5	copper mineral with high portion of iron
12742	KKT	2008	slag fragment	0.4	silica-rich compact slag fragment with small arsenical copper prills
12743	AA-S	2015	slag fragment	1.2	silica-rich compact slag fragment with small arsenical copper prills
12744	WD	2005	slag fragment	0.5	iron-rich compact slag fragment with small arsenical copper prills (in photo, page 15)
12745	WD	2005	vitrified pottery fragment/ crucible	1.1	vitrified ceramic sherd with arsenical copper prills
12746	SWI	2016	clinker	7.2	iron mineral with high portion of calcium and silica
12747	EOG	2005	burnt soil	8	burnt soil with no singularity
12748	RAB	2002	charred coal	2.8	porous charred coal with high portion of iron, sulphur, and calcium
12749	D17x	1998	slag fragment	0.6	silica-rich compact slag fragment with corroded arsenical copper prills
12750	D17x	1998	slag fragment	0.8	silica-rich compact slag fragment with no metallic prills
12751	D17x	1998	slag fragment	0.3	iron-rich compact slag fragment with small arsenical copper prills and copper sulphides
12752	D17x	1998	slag fragment	4.4	iron-rich compact slag fragment with small arsenical copper prills
12753	D17	1997	slag fragment	2.4	silica-rich compact slag fragment with big arsenical copper prills
12754	TBLF	1998	vitrified pottery fragment	2.8	vitrified ceramic sherd with no metallic prills

Egyptian Museum of Leipzig University," *Journal of Archaeological Science* 96, pages 191–207, 2018.

7. Rademakers, F. W., G. Verly, L. Delvaux, and P. Degryse, "Copper for the Afterlife in Predynastic to Old Kingdom Egypt: Provenance Characterization by Chemical and Lead Isotope Analysis (RMAH Collection, Belgium)," *Journal of Archaeological Science* 96, pages 175–190, 2018.

8. Kmošek et al. 2018, see footnote 6.

Kmošek, J., M. Odler, T. Jamborová, Š. Msallamová, K. Šálková, and M. Kmoníčková, "Archaeometallurgical Study of Copper Alloy Tools and Model Tools from the Old Kingdom Necropolis at Giza," In *Old Kingdom Copper Tools and Model Tools*, 1st edition, edited by M. Odler, Archaeopress Egyptology 14. Oxford: Archaeopress, pages 238–248, 2016.

9. Maddin et al. 1984, see footnote 1; Kmošek et al. 2016, see footnote 8.

10. Odler, M., *Old Kingdom Copper Tools and Model Tools* (With Contributions by Jiří Kmošek, Ján Dupej, Katarína Arias Kytnarová, Lucie Jirásková, Veronika Dulíková, Tereza Jamborová, Šárka Msallamová, Kateřina Šálková and Martina Kmoníčková) 1st edition, Archaeopress Egyptology 14. Oxford: Archaeopress, 2016.

11. Saleh, A.-A., "Excavations Around Mycerinus Pyramid Complex," *Mitteilungen des Deutschen Archäologischen Instituts, Abteilung Kairo* 30, pages 131–154, 1974.

12. Kromer, K., *Siedlungsfunde aus dem frühen alten Reich in Giseh: Österreichische Ausgrabungen* 1971–1975. Vienna: Österreichische Akademie de Wissenschaften, 1978.

13. See footnote 3.

AERAGRAM

Volume 20 Number 2 Fall 2019

Executive Editor: Dr. Mark Lehner
Science & Arts Editor: Dr. Wilma Wetterstrom
Managing Editor: Alexandra Witsell

AERAGRAM is published by AERA, Ancient Egypt Research Associates, Inc., a 501(c) (3), tax-exempt, nonprofit organization.

Ancient Egypt Research Associates
26 Lincoln St. Ste. 5, Boston, MA 02135 USA
E-mail: info@aeraweb.org

Sign up for AERA's E-Bulletin
Please e-mail: info@aeraweb.org.
In the subject line type: "E-Bulletin."

AERA's website: aeraweb.org