ANCIENT IRANIAN STUDIES

پژوهشنامهٔ ایران باستان

Revision of the History of Smelting and Mining of Copper in the Center of the Iranian Plateau Based on the Evidence and Petrographic Tests of the Slag of Gazanak Zarandieh Tepe

Author(s): Mojtaba Baghershahi & Fatemeh Heidary Samet

Source: Ancient Iranian Studies, July 2023, VOL. 2, NO. 6: 35-49.
Published by: Tissapherness Archaeological Research Group
Stable URL:
https://www.ancientiranianstudies.ir/article_170964_b5e8ea0b05905b8fc61290f8fc978330.pdf?lang=en

Ancient Iranian Studies
2023, VOL. 2, NO. 6: 35-47. OPEN ACCESS
https://doi.org/10.22034/AIS.2023.385300.1034

ANCIENT
IRANIAN
STUDIES

RESEARCH ARTICLE

Revision of the History of Smelting and Mining of Copper in the Center of the Iranian Plateau Based on the Evidence and Petrographic Tests of the Slag of Gazanak Zarandieh

Mojtaba Baqershahi[1], Fatemeh Heidary Samet[2]

Abstract

In a survey carried out in the Sadrabad area of Zarandieh in June 2020, in addition to the whole village of Sadrabad, its satellite areas were also examined and identified, which led to remarkable results in the archaeological studies of the Iranian plateau, which in addition to other archaeological survey, metal slags were also studied and analyzed there. Slag is the residue of minerals from the smelting, which occurs naturally as a molten silicate or as a mixture of several silicate minerals with compounds of oxides, sulfides, and metals. To detect metal minerals in slag, it is necessary to prepare a polished section from the samples in order to identify its type . The silicate minerals in the slag are studied with passing light using a thin section. Gazanak Zarandieh Tepe is located 85 km from Tehran and 75 km from Saveh in Sadrabad Vilage in Zarandieh city of Markazi province. The oldest settlement phase identified in this area is Neolithic (or Pre-pottery Neolithic) and the newest period identified is related to the Safavid era. In this survey, we obtained evidence of smelting and processing of copper, which included pure native copper and slag from smelting of this metal, which by integrating them for laboratory studies, especially the petrographic elemental analysis, which resulted in amazing results. The purpose of petrographic testing on study samples is to identify the components of the slag, the type of material extracted and, if possible, the host rock mineral. Since the study area lacks Chalcolithic age, and the abundance of plum ware, which appeared in the context of Cheshmeh Ali pottery and the transition period according to the speculation of the 2021 season, led us to the question that melting and extraction copper metal in the center of the Iranian plateau has an older history than the dates presented in this article.

Keywords: Petrography; Slag; Gazanak; Copper.

[1] MA of Archaeology, Tehran, Iran (Corresponding Author). mojtaba.sa65@gmail.com
[2] MA of Archaeology, Tehran, Iran.

Article info: Received: 9 February 2023 | Accepted: 28 April 2023 | Published: 1 July 2023
Citation: Baqershahi, Mojtaba; Heidary Samet, Fatemeh. (2023). "Revision of the History of Smelting and Mining of Copper in the Center of the Iranian Plateau Based on the Evidence and Petrographic Tests of the Slag of Gazanak Zarandieh Tepe". *Ancient Iranian Studies*, Vol. 2 (6): 35-47.
https://doi.org/10.22034/AIS.2023.385300.1034

Introduction

From the semi-finished identification and excavations, French archaeologist De Morgan in the early twentieth century and the excavations of Erich Schmidt in the fourth decade of the same century (1934-36 CE) in Cheshmeh Ali until now, the incoherence of past studies on the central Iranian Plateau, as well as the lack of purposefulness of many research activities carried out in these years, is one of the reasons caused the formation of a vague and incomprehensible image of cultural developments in the region. As such, many questions remain in the context of the sequence of different culture at ages from the 6th millennium BCE in the center of the Iranian plateau (Fazeli Nashli, 2009: 22). For this reason, with the approval of the General Directorate of Cultural Heritage, Handicrafts and Tourism of Markazi Province and with the permission of the team of the Archaeological Research Institute in June 2020, we set out to systematically survey the sites of Sadrabad Zarandieh village. We did not have any chances or sources for initial research, during and after the site work. Therefore, using the readable finding and theoretical foundations of archeology and anthropology, we worked to advance as much as possible. Therefore, we could literally play the role of the author in the report and descriptions in order to lay a solid and correct foundation for the research of the Sadrabad area. First of all, we needed aerial mapping and photography, and a geo-database, geo-reference, which, by placing 21 benchmarks and targets on the ground, determined the flight path of the orthophoto drone. Then, we turned the map into 100 percent square meters and into four squares fifty by fifty. This made us avoid the very tedious,old and incorrect method of marking the ground and conduct methodical survey with centimeter accuracy. In this method, using tablets and software Geo Paparazzi, UTM Geo Map, Sovitet Milito Geo and others, we recorded each piece of pottery and cultural object at our coordinates on the map (Fig. 1). This made no cultural object out of our reach, and according to the texture of the pottery (primary or secondary) and each specific period, we tried to record accurately the mother places of each period. Index pottery was collected to prepare a comprehensive database in the Sadrabad area and transferred to the site for preliminary studies on them. From the study of cultural objects in the 2020 survey and speculation of 2021, it was found that the oldest settlement phase in this area belongs to the pre-Neolithic (no pottery?) phase, and immediately after that, objects and findings of the transition period (Sialk II) along with plum ware in the same context, of non-inhabitation in the Chalcolithic age, Bronze Age, Iron Age and Sassanian period and the latest examples belong to the Islamic era. Therefore, due to the lack of human settlement in the Chalcolithic Age in this area and the lack of material and cultural evidence of that age, this study presents a hypothesis based on experimental and microscopic studies and an analysis to get the most accurate impression. It also deals with the chronology of the history of smelting and extraction of copper by humans in the central Iranian plateau.

Methodology

Thin-section petrography is a method for studying and classifying metal structures (Fig. 2-3). This method is used in the study of a wide range of materials, including rocks, minerals, pottery, slag,

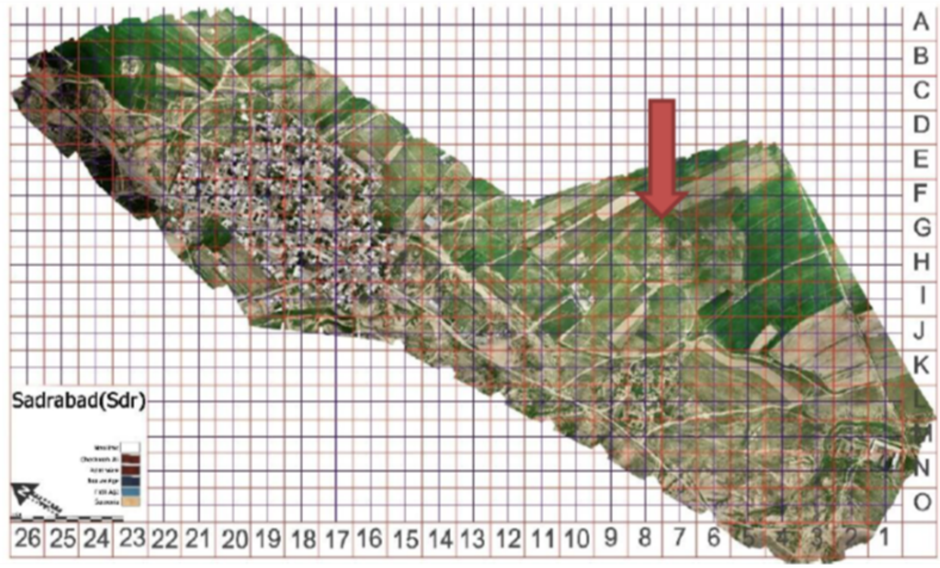


Fig. 1. 250-Hectare Area of Sadrabad Site and the Location of Gazanak Tepe

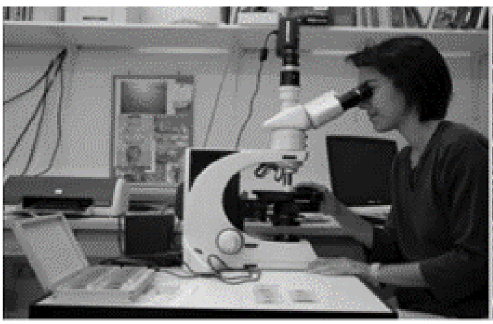
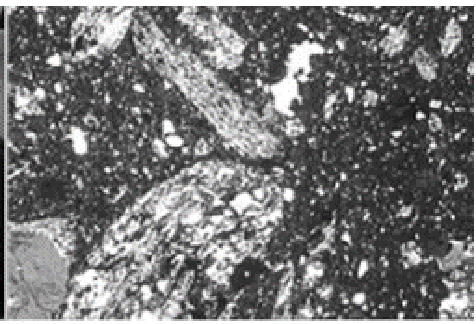



Fig. 2. Microscopic Image of a Thin Section of a Container with a Rough Surface under Polarized Light Showing Large, Aerated Phyllite Components, 4 mm Horizontal (Peterson, 2009).
Fig. 3. Using Polarized Microscope to Study Thin Section of Metal, A Prehistoric Institution of the Aegean in Eastern Crete, Greece (Peterson, 2009)

concrete, brick, plaster (a mixture of lime or gypsum). In this method, a polished section is studied using a binocular polarizing microscope with 40X magnification and polarized light. The information obtained from petrography identifies some important aspects of the study of slag, including the origin and production technique and the minerals used. In this study, we encountered with minerals such as Pyroxene (Fig. 4), iron oxides remaining in the samples (Fig. 4), mineral quartz in copper metal ores (Fig. 5). For example, in the microscopic image of the Experimental Sample 9, the analysis of Olivine and iron oxides can be seen well (Fig. 6, Down). In the Experimental Sample 9, without passing the optical spectrum and cutting the polished surface of the slag, we see the remaining pure copper metal (Fig. 6, Up). However, in the experimental sample 16, it is possible to observe a quantum, which can be seen without passing the light spectrum through the polished section of the samples. Covllite is a derivative and mineral associated with copper in meaning stones that can be well detected in these samples (Fig. 7). Covllite an another mineral that is a residue of smelting and processing of copper is degenerate. This mineral usually appears with copper and its compounds, which can be seen in the Experimental Sample 9 without passing the light spectrum in the polished section taken from this sample (Fig. 8) and the Spanifax texture of slag (Fig. 9). In the experimental Sample 16, olivia mineral and iron oxides can be clearly observed by passing a light spectrum through a polarized microscope, indicating that the melting temperature of these samples was not such that the iron metal was processed (Fig. 9). In Experimental Sample 15, the Spanifax texture and olivine crystals can be clearly seen in the light spectrum passing through the specimens (Fig. 10). In the same experimental sample, without passing the microscopic light spectrum, by observing the harvested and polished surface of the sample, he observed the remains of copper left in the slag, which indicates the melting of copper metal (Fig. 11). However, in the Experimental Sample 17, passing the microscopic light spectrum through the processed slag, the copper residues in the sample can be well detected (Fig. 12). Also in the same sample and by passing the microscopic light spectrum of polarizing, quartz and Diogenite minerals are completely detectable and visible (Fig. 13), which indicates the use of this sample and other samples for smelting and extraction of copper metal, which in all samples is confirmed due to placement of minerals and finally the source metal is extracted. In this study, a thin section is made by cutting a small piece of the sample, then glued to the smooth surface of a glass microscope blade and its surface is polished to a standard thickness (25-30 µm) and finally polished using polarized microscopes At the standard thicknesses, mineral components present in the slag texture appear in different color spectrums and are identified based on specific optical properties (Bambauer, Taborszky, and Trochim, 1979; Deer, Howie, and Zussman, 1996; Nesse, 2004).

The map of Sadrabad and Goznak Tepe shown in Figure 1 is an aerial photograph of the entire Sadrabad village and its ancient sites. The map was taken as an orthophoto and geo-reference by the author in 2020 to provide an up-to-date map of the entire area of Sadrabad, especially Gazanak Tepe.

Petrographic Purposes of Slag

Today, metal slags are studied in relevant studies to obtain a lot of information on various topics, including technology, the type of minerals, the type of microscopic texture, and the extraction of the relevant metal. Metal slag from the Gazanak Tepe was studied to understand the mineralogy and its microscopic texture and the metal that was finally extracted. Petrography of slag is one of the necessary techniques in the field of studying the origin of metal extraction in that area, which is able to identify its texture by microscopic examination of thin section. In this method, the different structures and properties of slag are identified based on micro-structural details that are not easily visible to the naked eye or through small magnifications, and also help researchers identify more details that might otherwise be ignored or misinterpreted by traditional macroscopic methods.

The characteristics identified in thin

Table 1. Results of Petrographic Study of Slags in Sadrabad Village (Gazanak Tepe)

Metal Ores	Silicate Minerals	Location	No.	Sample Number
Iron Oxide - Copper Minerals (Covllite and Diogenite)	Olivine-Pyroxene, Primary mineralization and quartz with Spanifax texture	Zarandiyeh-SadrAbad-Gazanak	01	09-SF-09
Iron Oxide - Copper Minerals (Covllite and Diogenite)	Olivine-Pyroxene, Primary mineralization and quartz with Spanifax texture	Zarandiyeh-SadrAbad-Gazanak	02	99-SF-16
Iron Oxide - Copper Minerals (Covllite and Diogenite)	Olivine-Pyroxene, Primary mineralization and quartz with Spanifax texture	Zarandiyeh-SadrAbad-Gazanak	03	99-SF-01
Iron Oxide - Copper Minerals (Covllite and Diogenite)	Olivine-Pyroxene, Primary mineralization and quartz with Spanifax	Zarandiyeh-SadrAbad-Gazanak	04	99-SF-15
Iron Oxide - Copper Minerals (Covllite and Diogenite)	Olivine-Pyroxene, Primary mineralization and quartz with Spanifax texture	Zarandiyeh-SadrAbad-Gazanak	05	99-SF-17

section petrography are:The southern region with Bampur as the center.

1. Nature and properties of non-plastic components (mineral composition and relative percentage, size, shape, distribution and orientation of different particles).
2. Optical properties and texture of metal matrix (such as refraction of light and color).
3. Shape, amount and orientation of cavities.
4. Relationship between canister body materials and melting catalysts.

By interpreting the above characteristics, important information on various aspects of the structure of slag, such as the characteristics of the mineralogical composition and filler used in metals, the method used by the metalworker to prepare and extract the metal deposit, and the melting temperature to create a more stable product is provided. By examining the similarities and differences between textures, in addition to establishing connections between different minerals and identifying the characteristics related to determining their origin, technological processes used in construction (selection and processing of metal ores, technique Melts, extraction methods and thermal characteristics) is analyzed. Understanding the nature of these processes plays an important role in our knowledge and understanding of the past, especially in relation to raw materials, distribution and dispersal of traded goods, expertise

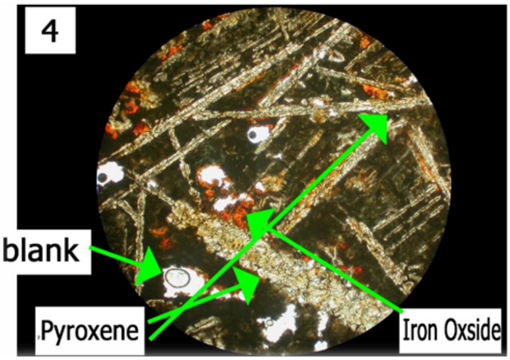
Table 2. Proposed Chronology of Copper Extraction And Smelting Time

Susiana	Godin	Sialk	Copper Smelting	Period
Old Uruk 3500-3750 BCE	Godin V New Chalcolithic 2	Sialk III 6-7	_	3500-3750 BCE
Terminal Susiana A	Godin VI Middle Chalcolithic	Sialk III 4-5	_	New village
Susa A	_	Sialk III 1-3	_	Middle village
Susiana d (Choghamish phase)	_	_	_	4200-4400 BCE
Susiana C	Godin VII Old Chalcolithic	_	Copper extraction and smelting (Gazanak of Sadrabad Site)	4600-4800 BCE
Susiana A (Jafarabad phase) Susiana B	_	Sialk II B	Copper extraction and smelting (Gazanak of Sadrabad Site)	5000-4800 BCE
Ancient III	Godin IX (segabi)	Sialk II A	Copper hammering (Coldhamering)	5000-5200 BCE
Ancient II	_	Sialk I B	Copper hammering (Coldhamering)	Initial village
Ancient I	_	Sialk I A	_	6300-6000 BCE
Before pottery	_	_	_	7500-6300 BCE

in manufacturing and technological development. In the case of metal slag in the Gazanak Tepe and the final metal extracted for daily use, which in all samples, clearly and definitely refers to copper extraction and due to the lack of Chalcolithic period in Gazanak, as well as slag found in places The core of plum ware and Sialk II ware resulted in the hypothesis that the extraction and use of copper by humans dates back to later than the date that Ghirshman and Majidzadeh believed was in the Middle Chalcolithic (3000-3700 BCE) (Ghirshman, 1938: 123; Majidzadeh, 1998: 152; Majidzadeh 1996: 71) and thus needs to be reconsidered.

This hypothesis is strengthened when we collected and recoded this slag in the industrial context of Gazanak in the layers of the transitional period (Sialk II). In this regard, and with the results obtained in the five slag samples, we can take a look at the change in the date of copper smelting and extraction in the central Iranian plateau and according to the dating of Cheshmeh Ali A ware, it can be 800 years older. It should be from the current date (at least in the Gazanak area).

Of course, in traditional methods of using copper, this date is divided into older periods and Sialk I, which according to Ghirshman, "the oldest copper object of



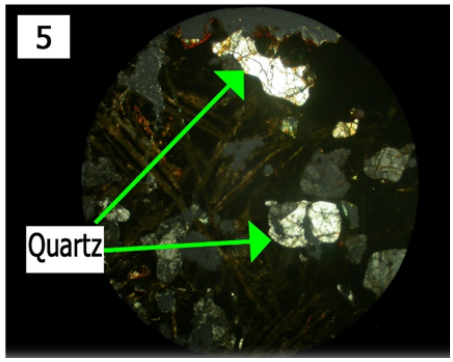
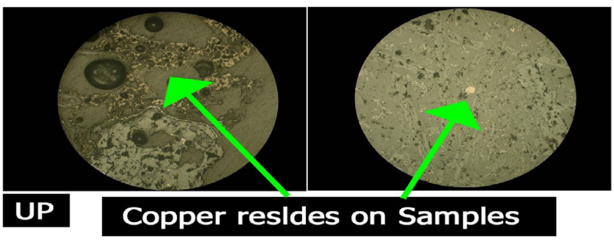


Fig. 4. Photomicrograph, Sample 09, PPL Light, Field of View Length 2.7 mm, Spinifex Texture, Olivine Miner al Which is Seen as a Blade and in the Middle of Them there is Green Pyroxene Mineral. Iron Oxide is also Seen in Red.

Fig. 5. Photomicrograph, Sample 09, XPL light, 2.7 mm Field of View, Quartz Mineral Residue in the Slag Field, Most Likely used as a Melting Aid.



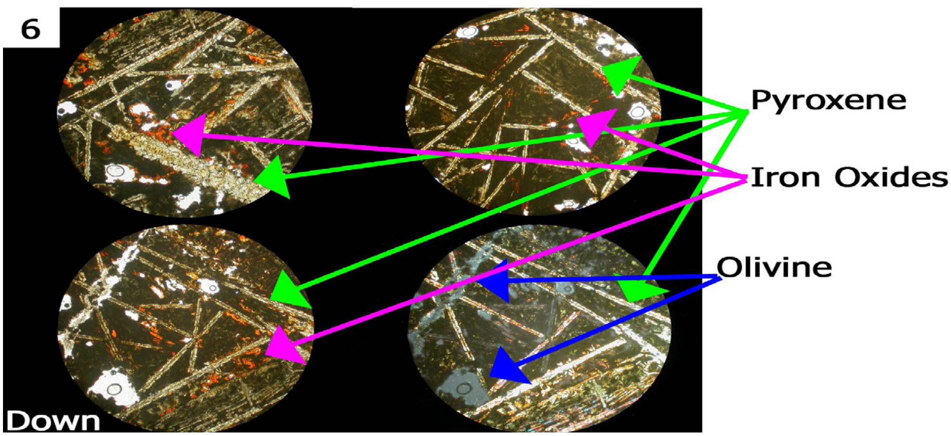
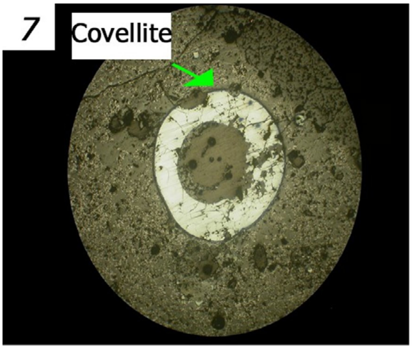


Fig. 6. Photomicrograph, Sample 09, PPL light, 2.7 mm field of view, spinifex tissue, olivine mineral, which is seen as a blade and in the middle of them there is a green Pyroxene mineral. Iron oxide is also seen in red.

the first period, which is a hammered flag with a round cross section, from layer number 3 (meaning Sialk I-3) was obtained. From the same layer of other similar tools, which probably had handles, two marbles with a diameter of 5 mm were obtained. In layer 4, a pin with a bevel on both sides and a hunting hook were found, which was made using the hammering method. No trace of metal was found in the first two settlements, although this does not necessarily indicate



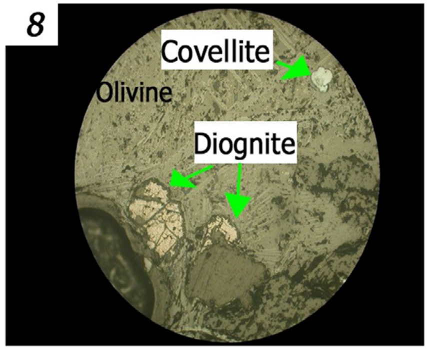


Fig. 7. Photomicrograph, sample 16, reflective light, 2.7 mm field of view, copper mineral vesicle in the center of the figure.

Fig. 8. Photomicrograph, sample 15, reflective light, field of view length 2.7 mm, debris of Covllite and Diogenite (copper minerals) in the center of the figure.

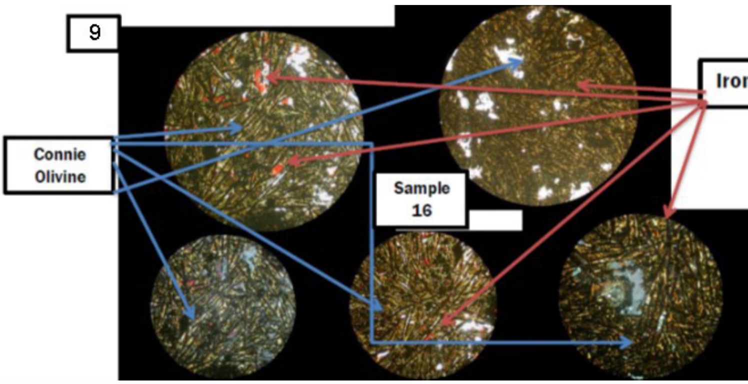


Fig. 9. Photomicrograph, sample 16, PPL light, 2.7 mm field of view, spinifex texture, olivine mineral, which is seen as a blade and in the middle of them there is a green pyroxene mineral. Iron oxide is also seen in red.

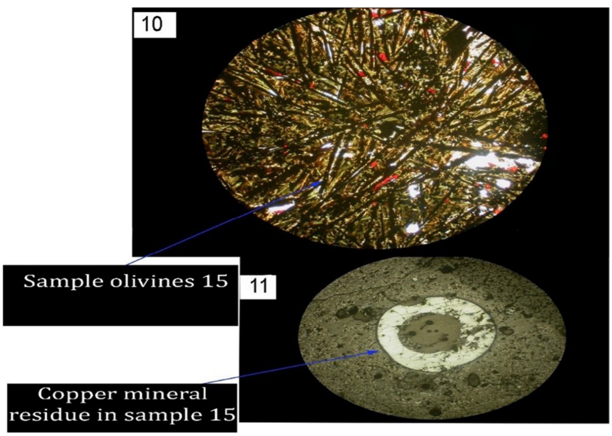


Fig. 10. Photomicrograph, sample 15, PPL light, 2.7 mm field of view, spinifex texture, olivine mineral, which is seen as a blade and in the middle of them there is a green pyroxene mineral. Iron oxide is also seen in red.

Fig. 11. Photomicrograph, sample 15, reflective light, field of view length 2.7 mm, debris of covolite and dignite copper ores) in the center of the figure.

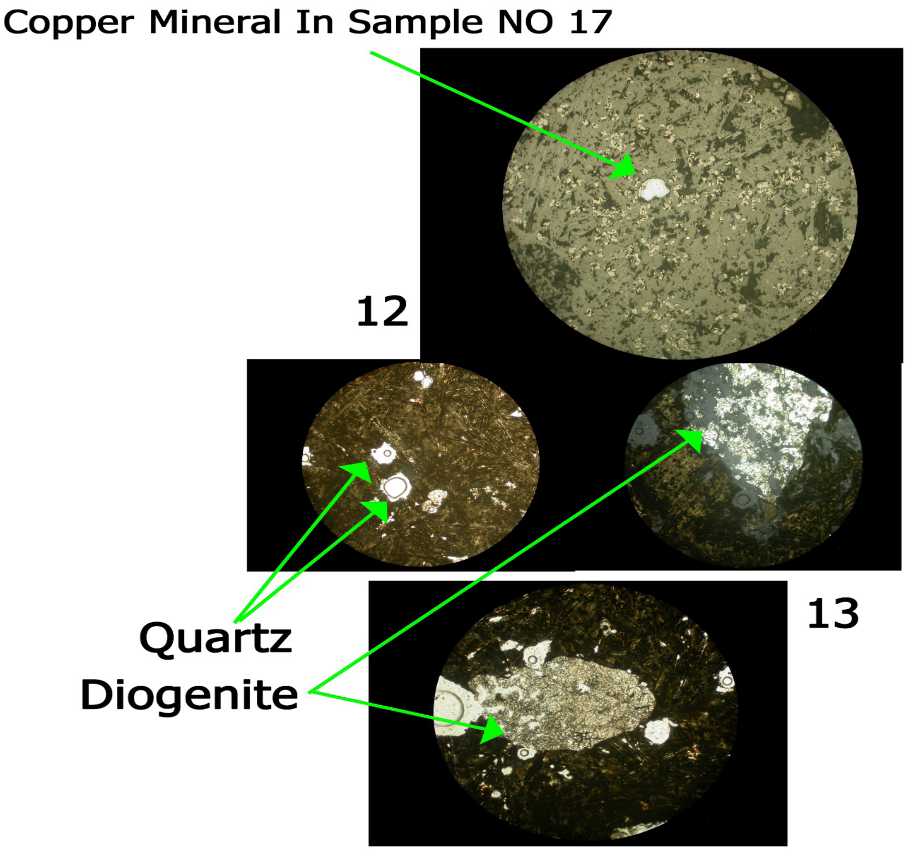


Fig. 12. Photomicrograph, sample 17, PPL light, 2.7 mm field of view, spinifex texture, olivine mineral, which is seen as a blade and in the middle of them there is a green pyroxene mineral.Iron oxide is also seen in red.

Fig. 13. Photomicrograph, sample 17, reflective light, field of view length 2.7 mm, residues of Covolite and Dignite minerals (copper ores) in the figure surface.

that these two layers belong to the Neolithic period. The copper objects collected from the remnants of this first period do not show any signs of melting and are all hammered (Ghirshman, 1938: 29).

Table No. 2 Proposed chronology according to the descriptions and experimental experiments, especially petrography of samples taken from Sadrabad area and Gazanak Tepe for smelting and extraction of copper metal in Susiana, Godin Tepe, Sialk and date for processing copper metal in Sadrabad area of Zarandieh and Gazanak Tepe is designed according to the field work of the 2020 and 2021 seasons. The table below is completely suggested and based on the tested samples, and of course it is not claimed that it is not without flaws (Table 2).

The above table presents a proposed chronology for the period of extraction and smelting of copper, which is the first metal that man became acquainted with. In the following, we will look at the images of microscopic studies of slag, and if there is a need for explanation, we will present them during the images. In these images, photomicrographs have been

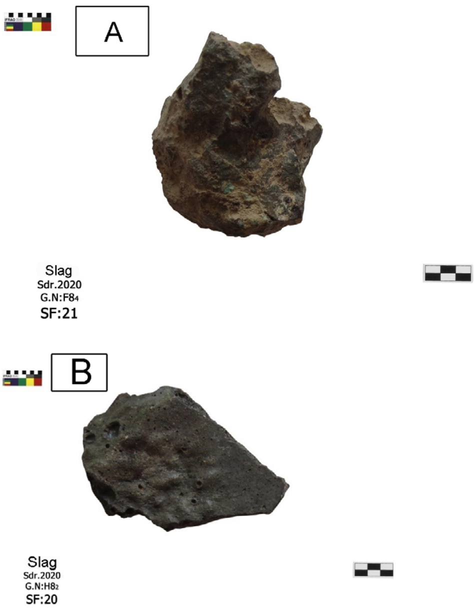


Fig. 14. Samples of Slags

studied in two spectra of transmitted and reflected light, which leaves no doubt that both olivine and pyroxene of the samples are observed, as well as minerals left over from molten metal.

In figure 4, we can see pyroxene in the sample of Experimental Slag 9, which has become a blade due to the high temperature of melting and rapid cooling. Pyroxene is a free silicate that is abundantly found in earth layers and metal deposits. Also, iron oxides that have been oxidized due to age and changed to red color. Iron oxide is usually gray or white in color, but after a long period of time (due to atmospheric factors), it oxidizes and changes to red. In figure 5, we can see the Experimental Sample 9, where quartz is completely used as auxiliary silicate for melting. This mineral is also found abundantly in the layers of the earth and the surface of silicate, it is an aid for adhesion to make copper melt.

In figure 6, we can see the test sample 9, the copper remains left on the slag are clearly visible in the picture. These remaining coppers are crystallized due to the temperature of melting and usually Covllite mineral is formed next to it.

In figure No 7, you can see the Experimental Slag Sample 16, which is a Covllite mineral that is mostly formed around the copper deposit that has been melted and quickly cooled. This mineral always appears together with copper as silicat. Of course, Covllite is also found abundantly in Earth's layers, but its occurrence is mostly next to copper in the from of oxides, sulfides and silicates. The presence of this mineral in the experimental sample as well as the presence of native raw copper is a convincing reason for smelting and extracting copper metal in the area.

In figure 8, we can see the experimental sample of slag 15, which is clearly visible in the polished section of the Diogenite mineral slag, which appeared in all sample along with Olivine and Covllite. Diogenite, along with Olivine and Pyroxene, is one of the components of the planets and one of the primary minerals found in the planets, including Earth. These minerals were present on other planets of the solar system at the beginning of their formation and were caused by meteorite collisions in 4.5 billion years. Diogenite is usually found in-copper deposit and is formed as a free element at high temperature. The color of Diogenite is usually gre en and it is one of the rarer elements than Pyroxene and Olivine.

In ficture 9, we see the experimental sample of slag 16, where Olivine mineral, iron oxide, quartz particles and Pyroxene are clearly visible, Olivine appears different colors.

In figure 10 of test sample 15, Olivine and Pyroxene minerals can be recognized in the form of a blade, which is the result of high melting temperature and rapid cooling.

In figure 11 of the test sample 15, the mineral Covllite can clearly identify next to the remaining copper on the sample.

figures 14-15 are samples of slag harvested for petrographic testing (Fig. 14-15).

Discussion

Regardless of the results of the experiments, this hypothesis must be confirmed in the heart of the earth, and it can be said with certainty when all the relevant findings are repeated in one layer and on one horizon, and it is basically materialistic scientific archeology. In the case of this hypothesis, the opposite has happened. As has always been the case, hypotheses first emerge from field explorations until they are subjected to experiments. But this time, we have the definitive confirmation of experiments, and to a large extent we also have strong field evidence to express this theory, and only the stratigraphy is the last piece of the puzzle. For this reason, we refrain from hastening the archaeological position in this hypothesis in order to find the answer to our questions in the heart of the earth and to witness a change and revision in the chronology of copper smelting and extraction in the central Iranian Plateau.

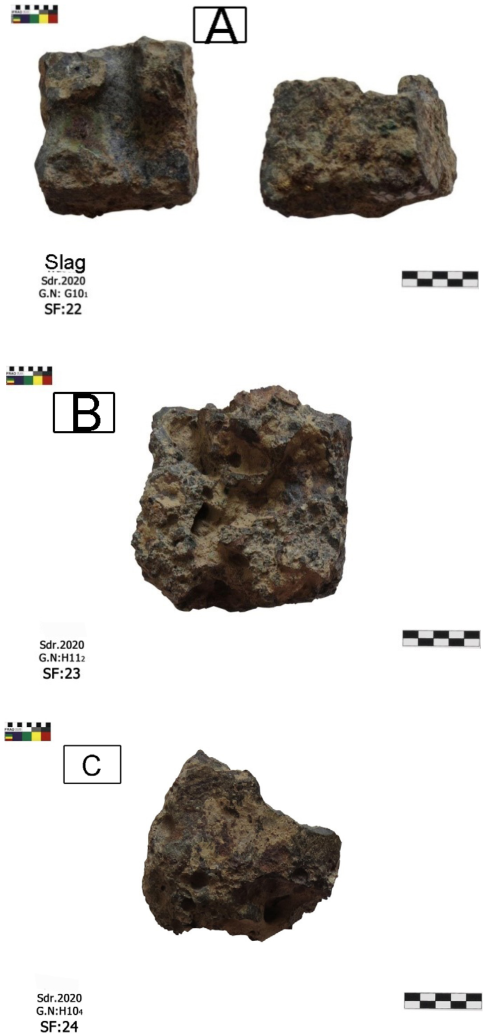


Fig. 15. Samples of Slags

Conclusion

The samples of slag selected for the study are five. In the initial study, the possibility of extracting copper for its preparation was considered, which was achieved in the microscopic study. All samples are similar in texture and composition. In these five samples, the residual copper texture on the slag is quite clear. In these samples, the predominant texture is sphenifex, in which, the skeleton of Olivine mineral is seen as a blade and elongated in the slag field, and in the distance between olivine mineral, pyroxene mineral is formed in the form of broom tail or swallow tail. The formation of proxene in the form of a blade indicates the high melting temperature and rapid cooling of the melt. The melting point was probably as high as about 1000 ° C. In this field, in addition to olivine and pyroxene minerals, remnants of primary minerals and quartz mineral fragments are observed, which most likely used this mineral as a melting aid. Residual metallic mineral residues in the slag field consist of large amounts of iron oxide along with vesicles of copper compounds (Covellite and Diogenite). Available iron oxide minerals: Covllite, hematite and a small amount of magnetite. According to microscopic evidence, these slags are the result of melting the raw material for copper extraction.

The same is true of the present study, and according to the field survey and analysis of the settlement pattern, and with the help of special findings and pottery and theoretical archaeological foundations, we put our knowledge and findings to experiments to help with all this. With Humanities and Experimental Sciences, we come to a hypothesis that unanimously emphasize the history of the extraction and smelting of the first metal (copper) by humans, which archaeologists have hitherto believed to be in the Middle Chalcolithic (Sialk III_{4-5}) in the central Plateau of Iran. This happened and man succeeded in melting and using copper in their daily life. Although this hypothesis will have pros and cons, but according to the petrographic test, we expressed the hypothesis that the date of extraction and smelting of copper by humans dates back to the late Sialk II period between 4300 and 5300 BCE, and this dating is based on experiments and evidence such as the absence of human habitation in the Gazanak Tepe during the Chalcolithic (Sialk III) or even the lack of evidence of this period in this area, this assumption was reinforced on us. Apart from the certainty of the experimental results, the nature of our fieldwork has been investigated and identified, and although the results are still empirically conclusive, in archaeological fieldwork our criterion and the only missing piece of the puzzle is that drilling, stratification and bore. If a Trench does not happen in the field, we think this puzzle has a small piece.

As a result, with the date of extraction and melting of copper that is discussed (Sialk III_{4-5}) (period of 3000 to 3700 BCE) [According to Ghirshman] the use of this metal in the first period of Sialk is hammered and cold. But with the results of petrographic test and elemental analysis of five samples of metal slag from the Gazanak Tepe, and the absence of Chalcolithic or Sialk III period and the frequency in distribution of plum ware and Cheshmeh Ali in this site, a hypothesis can be made. The date of extraction and smelting of copper by humans in the Iranian plateau is in the late Sialk II period and at the same time with the emergence of plum ware in this region and the use of copper widely dates back to the Sialk II_{1-2} phase.

Bibliography

Betancourt, P.P. (1984). "East Cretan White-On-Dark Ware.", *Studies on a Handmade Pottery of the Neolithic*. PP: 33-36.

Baghershahi, M. (2020). *Systematic review of Sadrabad Zarandieh archeological sites*. Tehran. Cultural Heritage Research Institute. PP: 188-204.

Dyson, R.H. (1991). "The Neolithic Period Through the Bronz Age in Northeastern and North-Central Persia, under Ceramic", In Ehsan Yarshater (ed.), *Encycolopedia Iranica*.

Coningham, R.A.E. & Fazeli N, H & Young, R.L & Donahue, R.E. (2003). "Location, Location, Location: A Pilot Survey of the Tehran Plain in 2003", *Journal of the British Institute of Persian Studies.* Volume 42, 2004 - Issue I. PP: 57-59.

Fazeli, N, H & Abbasnegad R. S. (2005b). "Social Transformation and International interaction in the Qazvin Plain during the 5th, 4th and 3th millennia BCE", *AMIT, pp.7-26.*

Fazeli, N. H.; Wong. E; Potts, D.T. (2005a). "The Qazvin Plain revisited: a reappraisal of the Neolithic.", *Ancient Near Eastern Studies*. PP: 2-14

Fazeli, N. H.; Coningham, R.A.E; & Batt, C.M. (2004). "Cheshmeh-Ali revisited: towards an absolute dating of the Late Neolithic and Chalcolithic of Iran's Tehran Plain", *Journal of the British Institute of Persian Studies*. Vol. 42, Issue 1, PP: 222-229.

Ghirshman, R. (1938). *Fouilles de Sialk, pres de Kashan. Tehran Cultural Heritage Organization*.PP:48-51

Majidzadeh, Y. (1976). *The Early Prehistoric Cultures of the Central Plateau of Iran, An Archaeological History of Its Development During the Fifth And Fourth Millennium B.CE.* Ph.D Dissertation, University of Chicago Press. PP: 187-196.

Majidzadeh, Y. (1979). "An Early Prehistoric Coppersmith Workshop at Tepe Ghabristan, Akten des VII.", *internationalen Kongresses fur Iranische Kunst und Archaeologie*, PP: 82-92.

Majidzadeh, Y. (1981). "Sialk III and Potetery Sequence at The Ghabristan; The Cohrrence of The Cultures of The Central Iranian Plateau.", *Iran* 19: 141-144.

Malek Shahmirzadi, S. (1977). *Tepe Zageh A Six Millennium B.C Village in the Qazvin Plain of The Central Iranian Plateau*. Ph.d Dissertation, University of Pennsylvania. PP: 188-196

Matthews, R. Fazeli, H. (2004). "Copper and Complexity: Iran and Mesopotamia in the Fourth Millennium B.C.", *Iran, 42*, pp: 61-75

Myer, G.H; McIntosh, K.G.; & Betancourt, P.P. (1995). "Definition of Pottery Fabrics by Ceramic Petrography," In P.P, Betancourt; C. Davaras; I, Pseira (eds.), The Minoan Buildings on the West Side of Area a *University Museum Monographs 94, Philadelphia,* pp. 143–153.

Peacock, D.P.S. (1971). "Petrography of Certain Coarse Pottery, in Excavations at Fishbourne 1961–1969". *Volume II: The Finds Reports of the Research Committee of the Society of Antiquaries of London 27, B. Cunliffe, ed., Leeds*, pp. 255–259.

Peterson, Sarah, E. (2009). *Thin Section Petrography of Ceramic Materials*, Philadelphia, PennsyIvania Academic Press.

Schmidt, E.F. (1933). "A New Expedition to Persia", *The university Museum Bulletin 4/5*. PP: 140-142.

Schmidt, E.F. (1934a). "The Joint Persian Expedition", *The university Museum Bulletin.* PP: 5/2:40.

Schmid, E.F. (1934a). "The Joint Persian Expedition", *The university Museum Bulletin.* PP: 5/3:86-87.

Schmidt, E.F. (1935a). "Excavetions at Rayy", *The university Museum Bulletin*. PP: 5/4:25-27.

Schmidt, E.F. (1935b). "The Persian Expedition", *The university Museum Bulletin.* PP: 5/5:41-49.

Schmidt, E.F. (1937). *Excavations at Tepe Hissar Damghan 1931-1933*, University of Pennsylvania Press, PP: 123-154.

Schmidt, E.F. (1937). *Excavations at Tepe Hesar Iran*. University of Pennsylvania press, PP: 57-85.