

ARCHAEOLOGICAL STUDY OF MINES AND METAL SMELTING FURNACES IN THE CENTRAL DISTRICT OF SARBISHEH COUNTY - SOUTH KHORASAN, IRAN

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Received: 09 April 2022

Accepted: 10 June 2022

Available online: 20 June 2022

Abstract: The eastern and southeastern regions of Iran have long been of great importance due to the existence of metal mines. Although new research has been conducted in recent years on geology and mining, little research has been done on the site's ancient mines. In 2013, an archaeological survey in Sarbisheh County identified a number of mines and metal smelting furnaces. These historic sites are located in the central district of Sarbisheh County in the southern part of the county and in places called Koohakrud, Mesgaran, and Kasrab. In all, nine mines and three metal smelting furnaces were discovered, the largest of which is located in the Koohakrud area, 25 km south of Sarbisheh. The purpose of this research is to introduce the mines and study sites in the central district of Sarbisheh County, how to extract ores, and how to melt metals. In this regard, questions have been raised about the period of mines and metal extraction furnaces. What metal is the most extracted metal and how was the metal extraction method done? Mineral fragments from all these mines and a large amount of slag from the furnaces, and in some of these mines, clay finds have been obtained. The dating of identified mines is very difficult due to the lack of data. However, according to the cultural materials obtained from around these mines and furnaces, the Middle Ages to the late Islamic Middle Ages can be considered for these sites. According to the evidence of metal smelting, the most common mineral used in smelted rocks is copper, and the method of extracting metal mines has been surface and underground mining. The research method in this research was descriptive-analytical, and data collection has been done in a field and library method.

Keywords: Sarbisheh County, Ancient Mines, Metal Smelting Furnaces, Copper, Pottery.

چکیده: مناطق شرقی و جنوب شرقی ایران به دلیل داشتن معادن فلزی از گذشته تاکنون از اهمیت زیادی برخوردار بوده است. هر چند در سالهای گذشته تحقیقات جدیدی در زمینه زمین شناسی و معادن انجام شده است، با این وجود در رابطه با معادن باستانی این منطقه تحقیقات اندکی صورت گرفته است. در بررسی باستان شناسی شهرستان سریشه در سال ۱۳۹۲ تعدادی معدن و کوره ذوب فلز شناسایی شد، این آثار در بخش مرکزی شهرستان سریشه در منطقه جنوبی شهرستان و در مکان هایی به نام کوهک رود، مسگران و کسراب واقع شده اند. در مجموع، از این بررسی ها، نه معدن و سه کوره ذوب فلز کشف گردید که بزرگترین این کوره ها و معادن در منطقه کوهک رود در ۲۵ کیلومتری جنوب سریشه واقع شده است. هدف از انجام این تحقیق معرفی معادن و محوطه های مورد مطالعه در بخش مرکزی شهرستان سریشه، نحوه برداشت و استخراج کانسار و شیوه ذوب فلزات است. در این راستا پرسش هایی مطرح شده اینکه معادن و کوره استخراج فلزات مربوط به چه دوره ای است؟ و فلز مورد استخراج بیشتر چه فلزی بوده و شیوه استخراج فلزات به چه شکل انجام می شده است؟ از تمامی این معادن، قطعات سنگ های معدنی و از کوره ها، حجم بسیار زیاد سرباره و در تعدادی از این معادن یافته های سفالی نیز به دست آمده است. تاریخ گذاری معادن شناسایی شده به دلیل کمی داده ها بسیار مشکل است. ولی با توجه به مواد فرهنگی به دست آمده از اطراف این معادن و کوره ها، می توان قرون میانی تا متأخر اسلامی را برای استخراج و ذوب فلز در این محوطه ها در نظر گرفت و با توجه به شواهد ذوب فلزات بیشترین کانی مورد استفاده در سنگ های ذوب شده فلز مس است. نحوه استخراج معادن فلزات به صورت معدن روباز و زیرزمینی بوده است. روش تحقیق در این پژوهش، از نوع توصیفی-تحلیلی و جمع آوری اطلاعات به شیوه میدانی و کتابخانه ای انجام شده است.

کلمات کلیدی: شهرستان سریشه، معادن باستانی، کوره های ذوب فلز، مس، سفال.

I. Introduction

The antiquity of civilization in Iran and its richness in terms of mineral reserves are the main reasons for the growth of mining and metal smelting in this part of the world (Momenzadeh, 2005). The first metals used by humans were not obtained by mining or smelting ore but existed in pure form in nature and formed pure metals by hot and cold hammering techniques (Vatandoust, 2000: 2). The first known metals in nature were gold, copper, silver, and iron. The small amount of metal that was naturally available to humans and the intensification of the need for metal products caused a great change in the art and industry of metalworking, and this revolution occurred in the smelting of mineral

copper ore in Iran in the late fifth millennium BC (Talaei, 2002: 548; Vatandoust, 2000: 2; Oudbashi et.al: 2012: 157; Nezafati, et.al, 2008: 3). Copper is one of the most useful and probably the first metal used to make various tools and objects. The first use of this metal in the Middle East and the plateau of Iran dates back more than ten thousand years ago (Oudbashi et.al: 2012: 157). The first use of copper to make tools in Iran is from a Neolithic site in southwestern Iran and the Dehloran plain called Ali-Kosh, for which the date of the late eighth and the early seventh millennium is considered (Oudbashi et al., 2012: 157). From the surviving artifacts, it is inferred that miners in ancient Iran

crushed and then melted pure natural copper (hammer copper) and oxidized copper, which were mostly found on the surface of the earth. They did not know how to melt sulfur ores, so in dealing with such mines, they would abandon their extraction. These show that the regions of northern Azerbaijan, Shiraz, Baluchistan and southern Khorasan, Mashhad, Sabzevar, Kerman, Anarak region, the Karkas mountains of Kashan, and Alborz have been the oldest sources of copper (Faizi, 2003: 26). In ancient times, in the early stages, oxide, and carbonate minerals were first used and exploited, and early miners used ores that were close to the ground (Hojabari Nobari and Mazaheri, 2005: 7). Geologists believe that most of the ores that are known today and the mines that are known as active mines today have the type of minerals known and used in the ancient world (Vatandoust, 2000: 2; Momenzadeh, 2003: 1). In fact, they have been identified by tracing mining artifacts and smelting ancient metals. This is especially true in countries such as Iran (Momenzadeh, 2002: 7; Momenzadeh, 2003: 5). The existence of natural copper deposits in a very high amount in different parts of the country has led to the development and advancement of metallurgy in different periods. One of these important sources of copper in the southern region of Khorasan is the Ghale Zari¹ copper deposit, which has also been used as an ancient mine (Vatandoust, 2000: 2). Based on the evidence obtained, smelting of copper ores to obtain copper was first performed in 3500 BC in Ilam and northeast of the Euphrates Valley (Faizi, 2003: 26). Among the ancient mineral resources used by ancient metalworkers, the two most important mines are Ghale Zari in South Khorasan and Vashnove between Qom and Kashan, 45 km from Tepe Sialk (Chegini *et al.*, 2000: 281).

Not much research has been done so far on the study of mineral extraction from ancient mines and the smelting of these minerals in the eastern regions. Although new research has been done in the field of geology and mining in recent years, little research has been done on the site's ancient mines. The Sarbisheh County archaeological survey, which was conducted for two months in June and July 2013, aimed to study the pattern of dispersal and spatial distribution of human settlements in the Sarbisheh site. The purpose of this research was to study the pattern of dispersal and spatial distribution of human settlements in the Sarbisheh region, and many ancient mines and smelting furnaces (Shaddadi) were discovered. Most of these furnaces and metal mines have been identified 25 km south of Sarbisheh. Among the nearly 250 results identified, three metal smelting furnaces and nine copper mines have been identified. According to the sampling done

by the Industry, Mining, and Trade Organization of the province in the mines of this place, the mines of this region have a very high percentage of purity (grade). In addition to this county, this mineral vein extends to Tabas, Nehbandan, and Khouf counties, which is connected to the mineral masses in the Nayband region (Se Changi - Dayhuk section of Tabas county) and Ghale Zari (Khouf). In addition to this county, this mineral vein extends to Tabas, Nehbandan, and Khouf counties, which is connected to the mineral masses in the Nayband region (Se Changi - Dayhuk section of Tabas county) and Ghale Zari (Khouf). In this research, the history of ancient mining activities in the southern region of Khorasan, the introduction of the most important mines and smelting furnaces in Sarbisheh County, as well as methods of metal extraction in the past have been discussed. Sarbisheh County is an unknown site for mining archeology despite its high potential compared to other parts of Iran. For this reason, the identification of these sites is important from the economic, technical, and technological points of view used and the sustainability of the ecosystem. Archaeological studies at ancient mining and smelting sites also increase our knowledge of the process of mineral ores extraction and smelting.

II. Research Methods

Data collection in this research has been done in the form of library studies and archaeological field studies. Historical and geological books and reports of archaeological studies of the region have been used in library studies. Field studies and surveys include mapping, photography, identification of sites and mines and determining the site and type of mines, identification of smelting furnaces, and finally simple random sampling of the studied data such as pottery documents and slag.

III. Research background and mining activities in South Khorasan

Ancient Iranian copper mines exist in the layers of the Tertiary geological period and Ahar, Tarom, Hashtajin, Central Iran, Kerman, and the regions of Eastern Iran. The accumulation of copper, tin, tungsten, and gold in pre-Cretaceous metamorphic Pluto sites, although not known to modern miners, has been widespread since ancient times. Chah Kelap and Chah Chahar Nafari in the triangular site of Mokhtaran, Sahlabad, and Basiran in the south of Birjand (eastern Iran) are two examples of the accumulation of copper, tin, tungsten, and gold, which were also known in ancient times. Ancient mining activities focused on the contrast of the metamorphic Paleozoic schist and

¹ Ghale Zari means castle attributed to gold (Momenzadeh, 2006: 17).

topographic and geomorphological features that surround this county. The county has a geographical area of 8,252 square kilometers, which includes not very wide plains and impassable heights.

The oldest geological formation in Sarbisheh County consists of a thick flysch zone consisting of clay-silica sediments and fine-grained sediments in which small and insignificant volumes of limestone are also seen (Fig 2). In some places, diabase stones and tuff are also associated. These flyschs are strongly folded and, in some cases, slightly altered, and the ophiolites of the melanges of eastern Iran have penetrated inside them. Calorites and melanges are severely disorganized and come in small and sometimes large as kilometers. Gradual changes are seen between these melanges and flysch associated with volcanic rocks (Stocklin *et al.*, 1973). These flyschs are more widespread in Maud and Mo'menabad villages. Volcanic and Middle Eocene

materials have spread in the southwest of Naharjan village, which is known the Karaj Formation. This formation is composed of submarine pyroclastic materials in almost its entire volume, which is accompanied by volcanic and intrusive materials such as lava, dykes, floods, alomera, etc., and sedimentary materials such as shale and lime. What is most important in this formation is the green tuffs that are formed as a result of the alignment of volcanic eruption materials near sea level (Vatan and Yasini, 1969). Paleogene flysch is also more widespread in the east and southeast of the Sarbisheh County, located on the border, and Eocene-Oligocene sandstones are exposed in the same area in the north of the Lanu district. Neogene Arari rocks and Pliocene folded conglomerates are other Cenozoic formations that are more widespread in the south and southwest of the county.

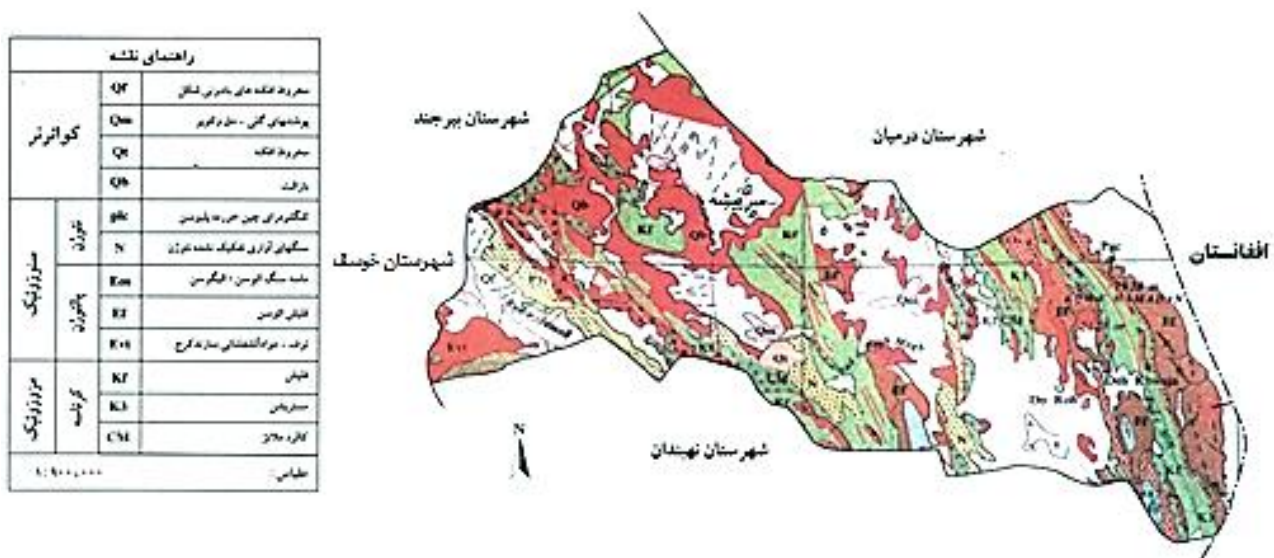


Figure 2. Geology of Sarbisheh County (Geographical Organization of the Armed Forces, 2009).

V. Introduction of Sarbisheh mines

The Sarbisheh County survey identified three smelting furnaces and more than nine metal mining mines, which with the exception of one mine, are located in the southern and southeastern mountains of Sarbisheh. These mines are located in a geological vein of the eastern block of Iran, which can be traced in today's Ghale Zari mines, 80 km south of Birjand. The identified mines are mostly surface mines and only three underground mines have been identified that have been extracted by digging tunnels and underground tunnels. Unfortunately, due to high human traffic, in the study of these mines, no findings were found that are involved in smelting and metal extraction. The largest mines in the region are the Cheng-e Sorkh and Mesgaran mines, the first of which is surface and the second of which are surface and underground. The largest metal smelting furnace was also identified in the Koohakrud area next

to the Koohakrud caravanserai, which could also have been used to house people who worked in these smelting furnaces during the Safavid period. The mines of Sarbisheh area are as follows:

V.1. Mesgaran Naystan Mine

Nayestan mine is located at longitude 772597, latitude 3573168, and altitude 1851 meters above sea level, 10 km south of Mesgaran village and 30 km south of Sarbisheh (Fig. 3). This mine is located in the south of Mesgaran, east of Birjand-Zahedan communication road in the northeastern heights of Sahlabad, and north of Shirshotor village. The Nayestan is the most important mine in the region for copper mining, according to locals. Of course, other large mines such as Shirshotor and Chah Anjir mines are located in the Nehbandan region in the southeast of this place. The wells of the Nayestan mine are located entirely on the slopes or top of a mountain known as Nayestan. The

holes and tunnels in this mine indicate surface and underground excavations. It is possible that due to the existence of many underground tunnels in this mountain range, some of these tunnels have been connected to each other. Most of these holes and underground tunnels for copper ore extraction have been destroyed in recent years due to road construction and mining activities, and some due to scouring of the northern slopes of the mountain and higher parts, and its deposition in these holes is filled. At the foot of the mountain and in several places, there are slag traces and in several other places, there are traces of residential constructions to accommodate the miners. It seems that in this area all mining activities were done to some extent. After extracting the ore at the foot of the mountain, it carried out the purification and separation of some of the impurities from the ore and later transferred the mineral to a more advanced furnace, which was probably the Koohakrud smelting furnace.



Figure 3. Nayestan Mesgaran Mining Pits (by Authors, 2013).

V.2. Mines of Koohakrud

These mines are located in a metamorphic geological structure of melange, metadiabia, and serpentinite from the Upper Cretaceous and include the five mines of Cheng Sorkh, Johar Cheshmeh, Sarab Koohakrud, Posht Koohakrud Bala and Masir Kasrab mine. The largest of these mines are the Cheng-e Sorkh and Joharcheshmeh mines, the former being mined surface and the latter underground. Their location is from northeast to southwest. In continuation of this mineral vein, other mines such as Tag Mir Alam Kasrab mine, Fooladabad Arabkhaneh, and also the famous Ghale Zari mine such as Shadadi Roghani, Shadadi Trangabin, etc. are located.

V.2.a. Johar Cheshmeh Mine

Johar Cheshmeh mine is located three kilometers southwest of Koohakrud Bala village and three kilometers east of Akhund shafi village and east of Birjand - Zahedan transit road. The mine is an underground mine with a length of 30 meters in the east-west direction (762852) and a latitude of 1724 meters above sea level, which forms the main structure of the mine (Fig. 4). The entrance of the mine, which is

created in the highest part of the mountain facing east, is oval and about 150 cm in diameter, which is first dug vertically into the ground and then at a depth of about two meters, a horizontal tunnel about one meter wide extending to the west. The continuation of this tunnel can be seen in the western part and the end of the mineral vein in the west of the mountain. The western portal is much narrower than the eastern portal of the tunnel and is about 75 cm high, which is not possible to enter due to sedimentation and soil deposition. There is no sign of digging in the tunnel walls of this ancient mine. At various intervals along the tunnel, wells have been dug by the Ministry of Industry, Mines, and Trade to test the purity of the mine, which has destroyed parts of the tunnel. Around this mine, discarded mineral masses can be seen in the form of ridges. The Johar Cheshmeh mine is located next to a spring of the same name belonging to the Zabuli - Kurdish family, who have now left the area due to successive droughts and a lack of water resources. After the Mesgaran mine and the Cheng-e Sorkh surface mine, the largest mine in the region appears to have been the Johar Cheshmeh mine.



Figure 4. Johar Cheshmeh Underground Mine Tunnel Entrance (by Authors, 2013).

V.2.b. Cheng-e Sorkh Mine:

This mine is located on the access road to the village of Koohakrud Bala, 1500 meters west of the village, three kilometers north of the Johar Cheshmeh mine, and one kilometer from the Koohakrud copper smelter. The longitude of this mine is 3580036 its latitude is 770550 and its height above sea level is 1711 meters (Fig. 5). Cheng-e Sorkh is a surface mine with abundant pits and a very wide range (Fig. 6). This mine is known as Cheng-e Sorkh because it is located in the east of the same name mountain.

In addition, in the area of the mine, two pieces of pottery of local species with colored and handmade brick paste belonging to the late Islamic centuries (12th and 13th centuries AH) have been obtained, which shows that the later periods the extraction of the mine has taken place (Fig. 6).



Figure 5. Cheng-e Sorkh Mining Pits (by Authors, 2013).

The presence of rock masses in the area of the extraction holes indicates the existence of rooms and architectural spaces for miners to live in. In the scattered rocks of this mine, blue azure traces and veins can be seen along with malachite green veins (Farjami, 2013).

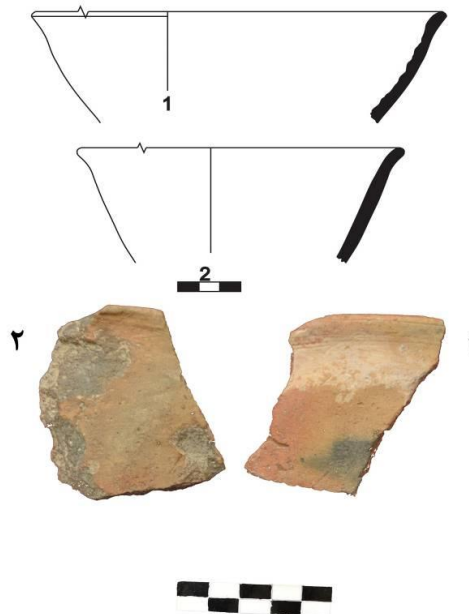
V.2.c. Posht-e-Koohakrud Bala mine

This mine is located in the north of Koohakrud Bala

village at longitude 772510, latitude 3578961, and a height of 1736 meters above sea level. Some of it is a surface mine, and a tunnel has been created in the middle of the mine hole in the east-west direction in the center of the mineral vein. The tunnel portal is currently closed by the Department of Industry, Mines, and Trade, and purity and grade testing wells have been drilled around the mine. Minerals were extracted from this relatively small mine in both surface and underground forms (Farjami, 2013).

V.2.d. Koohakrud Bala Mine

This mine is located at 770973 longitudes, 3579214 latitudes, and 1708 meters above sea level. The mine is located to the west of the Koohakrud Bala smelters and on the slopes of a hill overlooking the surrounding land. This mine is of surface type from which a copper mineral vein has been extracted. The Sarab Koohakrud's mine is a relatively small mine with only two wells. In addition, this mine is the closest mine to Bala Koohakrud's smelting furnaces (Farjami, 2013).



No.	Site name	Site code	Temper	Made	Period	cooking	Fabric	Inner Slip	Outter Slip	Granulation Type	height cm	Rim D. cm	Sherd Type
1	Cheng-e Sorkh		Mineral	wheel made	12 - 13 century	✓	red	red	buff		6.5	26	rim
2	Cheng-e Sorkh		Mineral	wheel made	13 - 13 century	×	grey	red	grey		6.5	18	rim

Figure 6. Cheng-e Sorkh mine Pottery (by Authors).

V.2.e. Masir Kasrab mine

This mine is located at 772176 longitudes, 3580153 latitudes, and 1715 meters above sea level. In the northernmost part of the Koohakrud Bala plain, along with the villages of Gazdez and Kasrab, there is a mine that, according to mining engineers, contains the purest type of copper ore. This mine is of surface type and it is a very small mine that has only two very small extraction holes. In this mine, like other mines in the region, mine test trenches and test wells have been created by the Mining Industry and Trade Department to check the

purity and capacity of the mine. The mine is located north of the current Posht-e- Koohakrud mine. The reason for the small extraction of copper from this mineral vein, despite its richness and high grade, may have been its non-surface Vein in this part of the plain.

V.2.f. Nerro Mine

This mine is located at 767441 longitudes, 3577469 latitudes, and 1615 meters above sea level. Nerro mine is located 500 meters east of Birjand - Zahedan transit road and 500 meters southwest of Koohakrud Payeen village. This mine is a collection of small and large

tunnels and mining pits that can be considered part of the mineral vein of the Koohakrud Bala region and the mines of this region. In the northern part of the extraction holes, it can be seen the remains of the settlements of miners who have been engaged in extraction in this area.

V.2.g. Tag Mir Alam Kasrab Mine (Ghare ezhdeha)

This mine is located at 219885 longitudes and 3586261 latitude zone 41 and 1760 meters above sea level. Tag Mir Alam mine is one of the most important mines in the southern region of Khorasan. This mine can be extracted both underground and surface (groove). Mir Alam mine has three extraction tunnels in the main location and extraction holes in its mineral vein in other parts of (ag) Mir Alam valley on the surface (Fig. 7). Due to the unknown nature of these mines, local people know the tunnels of this mine as natural caves and call them Ghare Ezhdeha. The diameter of the main entrance of the underground mine is 170 cm to the south. The material extracted from this mine was most likely transported to the Koohakrud area, ten kilometers away from the mine, as no signs of metal melting were detected in the vicinity of Kasrab village.



Figure 7. Entrance to the underground mine tunnel of Tag Mir Alam Kasrab (by Authors, 2013).

V.2.h. Payvand-e-bala Copper Mine

This mine is located at 742766 longitude and 3616854 latitude and 1963 meters above sea level. Payvand-e-bala Copper Mine is located 30 km west of Sarbisheh and 2 km north of Payvand-e-bala village of Mood District of Sarbisheh County. The veins of this mine are located in the middle of the green layers of Serpentine and the northern hills of Payvand-e-bala village and overlook this village. The mine has two large mineral extraction pits for extraction, and smaller mining pits are formed around the large pits (Fig. 8). Scattered around the mine are rocks scattered on the surface with blue veins (azurite) along with green veins (malachite). At the highest point of the excavated area, spaces for workers and miners seem to have been built. Payvand-e-bala copper mine is located among the

serpentine veins and is a surface mine. The copper of this mine was probably transferred to Koohakrud smelting furnaces 60 km away or Keydasht smelting furnaces in its southeast.



Figure 8. Payvand-e-bala Mining Pits (Authors, 2013)

VI. Metal extraction methods

The extraction of old mines such as new mines has been based on two main types of underground and open space operations. The underground method was to dig a pit vertically in the soil and then move in horizontal corridors until they reached the mineral veins. The technique of digging vertical pits and horizontal tunnels was a familiar technique in the Islamic world that was used to build aqueducts. Indeed, most miners preferred to dig horizontal corridors and follow the veins instead of digging vertical pits on the slopes of a mountain. This method could only be used when the land was suitable, but it was easier and less expensive for the miners who worked privately. Remarkably, reports of mines with vertical pits have often been used for state-owned mines (Hill, 2002: 19). The Abul fada provided a clear description of private silver mining activities in the Panjshir Valley. "The people of Panjshir pierce the earth like a sieve, and the veins that are likely to lead to silver, they dig enough to reach silver ... Sometimes a man found a vein, and another from another position finds the same vein, and both of them dig. In such cases, it is supposed that whoever gets the silver sooner, belongs to him. The people of Panjshir should commit deeds in this contest that do not even reach the mind of the devil, and when one of them reaches silver, the one who is left is miserable and his capital is wasted. If they both come together, they will share and dig in the tunnel until the light is on, and when the lights go out they will stop, so whoever goes beyond this position will die in a few moments ..." (Abul Fada, 1970: 539).

In surface mines, minerals are known on the surface and there is no need for tunneling or tracing of mineral veins in the form of horizontal and vertical wells. In surface mining, due to the large volume of minerals, these mines are extracted in the form of holes on the surface. This type of mineral extraction does not require much effort and time, and usually, a slope level to the

mineral extraction site is added by deepening the extraction hole, to transfer, separate the mineral (ore formation), and transfer it to smelting furnaces. In the mineralization stage, impure materials such as rocks and insignificant minerals were separated so that the metal ore could be fired with more purity. At this stage, the ore was crushed and separated. Crushing of stones in the past was done with a heavy metal mallet. Air conditioning was one of the major issues in underground mining. In private mines, they stopped working as soon as the lights went out. However, in state-owned mines, equipment was usually found to ventilate the mines, and especially in mercury-deep mines, proper ventilation was mandatory. Ventilation was a major problem, especially in very deep mines. According to the conventional method, either a well was drilled in a suitable place for ventilation of deep tunnels or, as is common in the method of digging aqueducts in Iran, they used several rods that also provided fresh air to the horizontal tunnel. This method of ventilation had ancient roots that date back to pre-Islamic times (Yousef Hassan and Hill, 1996: 318).

The main tool of the miners was a kind of double-edged pickaxe, which in Arabic was called “Menghar”. It had a sharp end for splitting rocks and a flat end for pounding or sinking. In other words, on one side it had a long, sharp blade that was used for digging, and on the other side, it had a kind of hammer-like piece that was used to pound the edges. They also had other tools such as hammers, styluses, pounders, crowbars, hoes, dustpans, and so on. Well, wheels were used to extract minerals and other materials from the depths of the rods. One of the simplest and most effective types of good cycles is the one that is still used in Iran for digging aqueducts or in construction workshops (Yousef Hassan and Hill, 1996: 314; Hill, 2002: 19). Tallow burning lamps were used to illuminate the underground mineral space. These lights, when turned off, indicate a lack of oxygen in the miners' workspace. In order to place lamps and tallow burning lamps inside the mine, the miners created small ledges in the mine wall so that they would not be hindered in their work.

Drilling systems in the past consisted of tunnels and shafts that were always dug in the heart of the mountain either parallel to or perpendicular to the spread of the mineral. Vertical trenches in this area sometimes extend to great depths. One of the effects of mining activities in those tunnels is the presence of polished walls due to the blows of stony and primary hammers. Some parts of the mine were mined by heat due to their high hardness (Emami, 2003: 268). The process is such that first the work front is heated and then cold water is sprayed on the walls, causing the walls to crack or break, and then the mineral is collected. Most of the mining activities took place in the areas where people live or close to residential centers. This is exactly what

happened in the Kasrab and Koohakrud areas, where minerals were transferred from the Kasrab and Koohakrud mines to the Koohakrud smelters. Mining of mineral veins was done in one area and horizontally in a tunnel, but in other parts, mining activity inside the veins was done superficially.

VII. Metal smelting furnaces

Unlike mines, which are located in some places as complexes, smelting furnaces are located separately at a distance from each other. The largest of these furnaces is the Koohakrud smelting complex, located south of the Koohakrud mineral vein and southwest of the current village of Koohakrud. No structural or architectural effects were observed in these furnaces, and only metal slag determined the location of these furnaces. All three furnaces identified are located in three important ancient, and habitat areas related to the Islamic era. These situations show the importance of these areas and the importance of metal in the daily lives of the people of that time.

VII.1. Koohakrud Bala Melting Furnaces

This furnace complex can be considered the largest furnace identified so far in eastern Iran. This furnace is located south of Koohakrud Bala Caravanserai and 300 meters west of Koohakrud Bala Village. Furnace slag is widely dispersed around (Fig. 9).

The copper ore required for these furnaces, as mentioned earlier, was extracted and supplied from six mines in the Koohakrud region and the Mesgaran copper mine or the Payvand-e-bala copper mine. There is no trace of architecture in the area of the furnaces, and only holes that may have been the site of metal smelting can be found everywhere in the Koohakrud area.



Figure 9. Slag accumulation in Koohakrud Bala melting furnace (by Authors, 2013).

There is only one caravanserai (latitude 771429/3578915) belonging to the Safavid period in the eastern part of the furnace, which is likely to have been used by Safavid metalworkers as their residence (Fig. 10). The sahn of the caravanserai, which has a very simple space and is far from decorative components,

includes other spaces and houses. This caravanserai, which is made of materials such as stone, mud, clay, and plaster, has appropriate and harmonious spaces. The rooms are located on either side of the central courtyard or sahn. Among the interesting components in the rooms are very simple and practical niches that do not even have a special geometric order and are created in the form of indentations and different ways. In addition, the presence of wall heaters shows that this caravanserai was also the residence of miners in the cold season. The ceilings of the rooms were generally in the dome form made of clay and stone, and the capacity of each room was for three or four people.

The interesting and important thing about Koohakrud furnaces is that the water spring that flows next to the caravanserai is unusable due to its water passing through the copper mineral veins and is very poisonous and deadly. Melting metals has always been the main step in exploiting the early stages of extraction. In this area, smelting activities have been carried out

along the existing mining area and trenches. The presence of smelting furnaces, smelting workshops, and most importantly smelting slag at very short distances adjacent to each other indicates this. The slag in this area is all dark or light brown (Fig. 11). Metal smelting furnaces are usually located in areas close to mines or are located in areas where suitable and sufficient fuels are available to metalworkers. It seems that the Koohakrud region, in the periods when these furnaces were active, had suitable vegetation of trees and shrubs suitable for fueling the furnace, or that this fuel was supplied from areas in Sarbisheh or Doroh area because these areas have been a good place to grow *Haloxylon* and *Pistacia Atlantica* shrubs. Charcoal from pistachio trees is an excellent reducing agent for metallurgy, and the dry wood of *Haloxylon* trees produces high heat and leaves little ash (Junidi, 1974: 147). The pottery obtained from around the upper Koohakrud site belongs to the Middle Ages to the late Islamic Middle Ages and is divided into two groups unglazed and glazed pottery (Fig. 12).



Figure 10. West side of Koohakrud Caravanserai (by Authors, 2019).

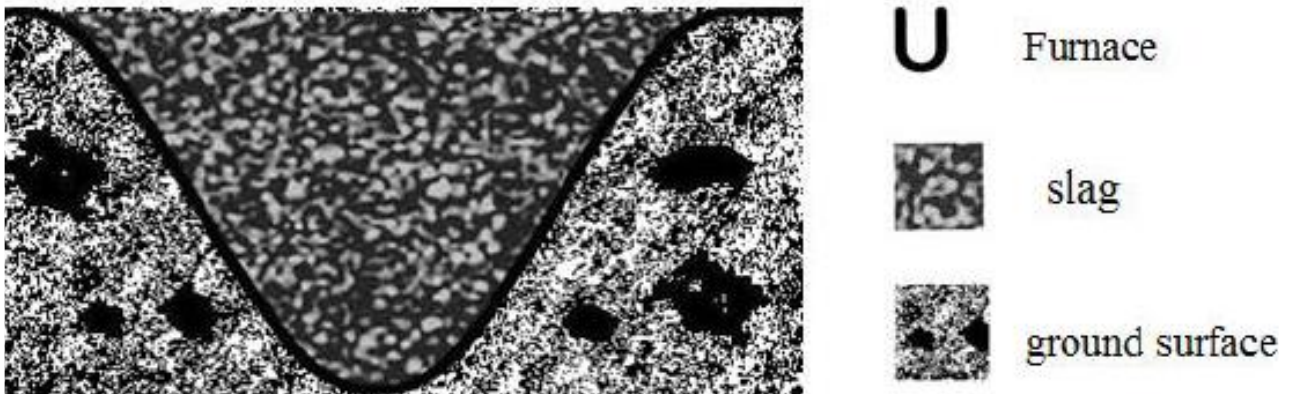


Figure 11. Melting hole in the Koohakrud Bala area (Hashemi Zarjabad *et al.*, 2015).



Figure 12. Pottery from around Koohakrud Bala Furnace (by Authors, 2013).

VII.2. Keydasht smelter

This work is located in the west of Keydasht village and one kilometer west of the village and overlooking it. There are no architectural works left from this furnace and only the slag of the furnace can be seen on the surface to a large extent. This furnace is part of a set of furnaces located in the southern part of Sarbisheh County and its minerals were supplied from the mineral veins of Koohakrud or west of Sahlabad. The southern region of Sarbisheh County has many mines and furnaces due to its natural richness and copper veins. The village of Keydasht has many ancient monuments, the oldest of which is the site of the Ghale kohneh related to the late historical period and early Islam. There is also a patriarchal castle in the village that was used until the Pahlavi period. These artifacts indicate that Keydasht residents may have used the furnace in historical and Islamic times. It should be noted that the distance from Koohakrud to Keydasht smelter is about 20 km southeast of a straight line.

VII.3. Shirkohak Melting Furnace

Shirkohak Furnace is a place located in the middle of the plain (Tag) Doroh and fifteen kilometers south of the county in a relatively wide plain covered with Haloxylon and Tamarisk bushes (Fig. 13). This smelting furnace is completely destroyed and the only signs of its existence are slag. At present, there is no water source near this monument, but in the past, the Shirkohak aqueduct flowed in the south of this place, which dried up due to drought and was later completely destroyed by seasonal floods in Doroh Plain. Copper mines are likely to exist in the mountains around Doroh, as only this furnace has been identified in the area of Doroh and no traces of ancient mines have been found. Shirkoohak furnace can be related to the Middle Islamic (Seljuk-Ismaili) period according to the archeological monuments in the region and the sayings of the inhabitants of Doroh. As is mentioned in historical

books, Doroh (valley) region was one of the important centers of the gathering of human groups in the Islamic Middle Ages, especially in the Seljuk era (Jovaini, 2012; Fazlullah Hamedani, 2008: 107). Ismaili metalworkers, just as they used the mines of the Ghale Zari region to their advantage to make weapons and other livelihoods, also took advantage of these furnaces at that time.



Figure 13. Slag Dispersion and Shirkoohak Melting Furnace Position (Authors, 2013)

VIII. Conclusion

Sarbisheh County, due to its location in the Iranian copper belt and its special geological structure, has many mineral veins that have turned this county into a miners' paradise. In the past, these mineral veins were considered by ancient metalworkers, especially in the Islamic period. They have extracted minerals from both surface and underground mines, of which nine mines have been identified, of which three mines are underground and the rest are surface mining. Most of these mines are located in the southern Sarbisheh mining area, which extends to the southwest and the Ghale Zari mines.

It seems that all metal smelting activities in this area were carried out in the Koohakrud area and minerals were transferred to these furnaces from different areas. Of course, the two furnaces that have been built in the Keydasht and Doroh area also have performed some of

the metal smelting activities, which due to the relatively long distance (especially the Doroh smelter), other mines should be located near these melting furnaces. In general, the southern Sarbisheh region is one of the most important economic regions in the historical and Islamic periods due to the number of mines, extraction volume, and the number of smelting furnaces in the Koohakrud region and has played an important role in economic exchanges and social issues in the region. One of the problems in studying mines in the region is the

lack of data that can date these furnaces and mines. Only two pottery pieces from the late Islamic centuries were identified from the Cheng-e Sorkh mine. Also, mining activities on the remains of ancient mines in recent decades have caused many of these mines to be destroyed. Further studies in this mineral vein, which are located in the county of Khouf and Nehbandan, will lead to the discovery of new furnaces and mines and will show the capabilities of the people of this region in different periods in the field of smelting different metals.

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