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The Study of Mining and Metallurgy in the Central Part of Bam County Based on Archaeological Surveys and Historical Sources

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Abstract

The Kerman region stands out as one of the most significant mining areas globally, owing to its extensive and abundant mineral resources. Bam County, situated in the southeastern part of Kerman, has historically served as a crucial hub connecting the southeast of Iran with Sistan and Afghanistan, attributed to its distinctive geological and geomorphological characteristics. Enjoying considerable commercial and military importance since the Sassanid era, Bam County has garnered attention in archaeological research as a strategically vital region. The exploration of Bam's archaeological sites becomes imperative for historical governments, highlighting the need to investigate and comprehend ancient centers engaged in metal smelting and mining activities. Consequently, an archaeological survey of the central part of Bam County was initiated in 2018-2019 with the specific objective of identifying metal smelting workshops and ancient mines. This article presents the outcomes of a field survey conducted in the central part of Bam County, shedding light on evidence of metal smelting centers, furnaces, and historical mining activities. The primary research inquiries center around the chronology of mining evidence in the central part of Bam County, the types of metals extracted, and the processes involved in metal mining and metallurgy within this region. Employing field and documentary methods, the research adopts a descriptive-analytical approach. The study identified and examined eight sites showcasing evidence of smelting and slag, one ancient mine, and two active mines. These sites have been associated with the extraction and processing of metals and elements such as tin, zinc, lead, silver, iron, and, to a lesser extent, gold. Notably, the substantial volume of zinc and zinc oxide processing in seven sites holds significance. Although cultural materials for chronological dating were absent in the investigated sites, historical sources indicate that the extraction and smelting of these metals in the region date back to at least the 3rd century AH (9th century AD) and persisted until the Qajar period.

Keywords: Southeast Iran, Metallurgy, Central Bam County, Smelting, Ancient Mines.

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1. Introduction

The identification of metalworking sites, workshops, and the exploration of the origins of metals, as well as the methods employed in metalworking and metallurgical activities, constitutes a critical facet of archaeological studies. These investigations play a pivotal role in elucidating cultural evolutions, subsistence patterns, economic and political relations, and the dynamic interplay between humans and their environment within distinct regions. Furthermore, the imperative of introducing and documenting evidence and activities related to ancient mining and metallurgy is underscored by geological transformations, natural factors, threats, and contemporary human interventions, particularly in the context of current mineral economy plans.

The mineral-rich region of Kerman, encompassing approximately 50,000 km^2, spans the western, southern, and southeastern regions of Kerman province. This area, renowned for hosting the richest mineral deposits in Iran, has long been a focus of archaeological attention. Noteworthy sites such as Tal-i Iblis, Tepe Yahya, Sheikh Ali, and Khabis (Shahdad) have been documented, along with numerous smaller and larger mining centers, metal smelting locations, and accommodations for metalworkers, totaling over one hundred sites. Significant ancient mining activities are evident in locations such as Gol Gohar iron, Midok copper, Sarcheshmeh copper, lead and zinc deposits in Qanat Marwan, among others (Momenzadeh, 2009: 255). Excavations and surveys, such as those at Tel-i Iblis in Bardsir Plain, have yielded valuable evidence of ancient metalworking (Caldwell, 1967). Tepe Yahya and the adjacent ancient mine of Sheikh Aali (Emami & Parvaresh, 2016) exemplify extensive metalworking activities from prehistoric times to the Islamic era (Thornton and Karlowsky, 2001). Notable metal finds in Shahdad on the western edge of Lut Desert (Eskandari & Emami, 2022) and Darestan Bam on the eastern edge of Lut Desert underscore the historical use of metal and prosperity of metalworking in the area during prehistoric times (Garajian, 2008).

Despite these significant findings, the extent and quality of studies on mining and metallurgy in this region have not adequately matched its cultural-historical importance. The strategic location of the southeast of Iran as a passage and communication bridge between Central Iran, the Sistan area, Oman coasts, and the Indian peninsula heightens the importance of understanding ancient mining and metalworking activities in the Bam region. This led the authors to conduct a comprehensive survey in the central part of Bam County, with a particular emphasis on rural settlements as integral components of sustainable living in the region. The emphasis on villages in this research stems from their ancient and native names, often reflecting connections to metalworking activities. This comprehensive survey aims to elucidate the chronology of mining evidence in the central part of Bam County, identify the types of metals extracted, and comprehend the cycle of metal mining and metallurgy in this region.

Recognizing the economic significance of mining and its role in shaping settlements, the research endeavors to unravel the archaeological evidence of the production cycle. By understanding the potential of metalworking in this region and the residents' adept utilization of ecological facilities, such as water resources, vegetation, and mineral deposits, it becomes possible to gain insights into the historical exploitation of natural resources and the development of local communities.

2. Methodology

In order to collect the findings, first a comprehensive survey was conducted with an emphasis on rural settlements as an ancient part of sustainable living in the Bam region.

Based on this, the distribution of archaeological data and mining features in each site was separately investigated step by step. Then, some of the findings (such as slag and other metallurgical remains) were transferred to the Department of Geology and Mineral Exploration for laboratory studies, in order to have a better look to the chemistry and mineralogy of the objects studied in this research. Furthermore, part of the information was collected from documentary sources. Finally, after classifying and describing the results, all investigations have been done on the selected samples.

3. The Background of Archaeological Research

Among the initial field surveys conducted in the Bam region, Ali Akbar Sarfaraz's brief visit to Tel-i Atashi in 1966 marked an early exploration. Subsequent to Sarfaraz, Ahmad Mostowfi, affiliated with the Department of Geography at the University of Tehran, directed attention to Bam County in 1973. In his study on the Lut Desert, Mostowfi published concise yet valuable reports encompassing natural geography, historical geography, and archaeological evidence specific to Bam County. Following the destructive earthquake in January 2002, comprehensive archaeological research in Bam and its vicinity commenced under the guidance of the late Shahriar Adl, the cultural representative of UNESCO. The inaugural survey season of Bam County transpired under the supervision of Mohammad Taghi Atai in 2013. Subsequent visits to the Lut Desert and the Daristan Bam region, supervised by Omran Garajian in 2007, contributed to the understanding of the area. A subsequent survey season in Bam County, overseen by Shahram Zare in 2008, encompassed the wider territorial limits, including Narmashir, Farhaj, and Regan. Shahriar Adl subsequently identified Tel-i Atashi as the prehistoric cultural landscape of Bam County during the pre-pottery era, culminating in excavations in 2008 under the leadership of Omran Garajian's Daristan Prehistoric Archaeology Research Team.

In 2012, Asadollah Jodaki identified evidence of three ancient mines near the village of Karak on the Bam-Nartij road, leading to the analysis of mineral samples from this site. The subsequent surveys included the collection and analysis of rock samples from the Bam citadel and the natural rock beneath it (Atai and Zare, 2016). The research trajectory continued with magnetometric surveys by Mohammadkhani and Garajian in the Daristan region in 2011, followed by Garajian and Moten's successive seasons of surveys and excavations from 2016 to 2018. In the summer of 2008, Shahram Zare excavated Afraz/Gosal, Darzin, Bidaran, and Bam sites. Additionally, Zare conducted the third-season survey of Bam County in 2012. The exploration of the cultural landscape of Bam persisted through Shahriar Adl and Leila Fazel's collaborative efforts from 2012 to 2015, encompassing the four counties of Bam, Narmashir, Fahraj, and Regan. In 2012, Asadollah Jodaki identified evidence of three ancient mines around the village of Karak on the Bam-Nartij road, and two samples of minerals from this site were analyzed. In subsequent surveys, samples of the rocks from the Bam citadel and the natural rock below it were collected and analyzed (Atai and Zare, 2016).

Figure 1. Two samples of metal artifacts discovered from site B.5 of Daristan, Bam County (Daristan Archaeology Board, 2008)

4. Geographical and Geological Location of the Study Area

The city of Bam (58˚20′E, 29˚6′N, 1060 masl) is located about 190 km southeast of Kerman City (Fig. 2). The natural boundary of Bam County is limited from the north to the Kaboudi Mountains and Lut Desert, from the east to Lut Zangi Ahmad and the Nayband fault (Afraz, 4 Km east of Bam City), from the south to the Bam Plain and the Pishkohs, and from the west to the Darzin Plain and the Darzin fault (Nabawi, 1976: 61).

The political boundaries of Bam County are limited from the north to Kerman County, from the east to Narmashir and Regan counties, from the south to Regan and Anbarabad counties, and from the west to Jiroft County. Between the two provinces of Kerman and Sistan-Baluchistan and besides their only communication route, Bam is the only city that has maintained its social and political centrality from the past to the present day. The location of Bam is very important because it is located on the four major communication routes between Hormuz (present-day Minab) and Bandar Tays (near Chabahar), Sistan, and Gwashir (present-day city of Kerman). Bam connected the Oman Sea and the coasts of India and the caravans that were passing through thousands of kilometers of desert roads to the northern cities such as Kerman, Yazd, Tabas, "Nishapur", and Rayy. In fact, it connected the spice and pepper routes to the Silk Route (Bastani Parizi, 1992). In the past, Bam was called Dar al-Arba’ah (the place of Arba’ah) and the reason for that was the presence of four prestigious cities in a limited area that was under the supervision of a governing area. In some historical sources, these four cities are mentioned as “Bam, Narmashir, Nessa and Regan” and in others as “Bam, Narmashir, Nessa and Ghazan Khasat”. Nowadays, Bam is known as the gateway to southeastern Iran because the only communication route to southeastern Iran passes through Bam. This city is the most reliable and valuable historical and ancient city between Kerman and Sistan and has maintained its economic and administrative centrality from the past to the present (Vaziri, 1983).

The volcanic-sedimentary belt of Dehj-Sardoueyeh, with a length of about 955 km and a width of about 45 km, is completely located within Kerman province. This belt starts from Anar and Dehj regions in the northwest-southeast direction and ends at Jebel Barez of Jiroft. The activity of this belt started intensively from the Eocene era and continued until the Quaternary. The Eocene formations occupy the most important and extensive geological units of this zone (Aghanabati, 2004).

Figure 2. Location of Bam County, Kerman province (Statistical Center of Iran, 2014)

5. Ancient Mines and Metalworking Sites

Archaeological surveys were conducted in the central part of Bam County, which includes the two regions of Abareq and Deh Bakri, with the aim of introducing metal smelting and mining centers (Fig. 3).

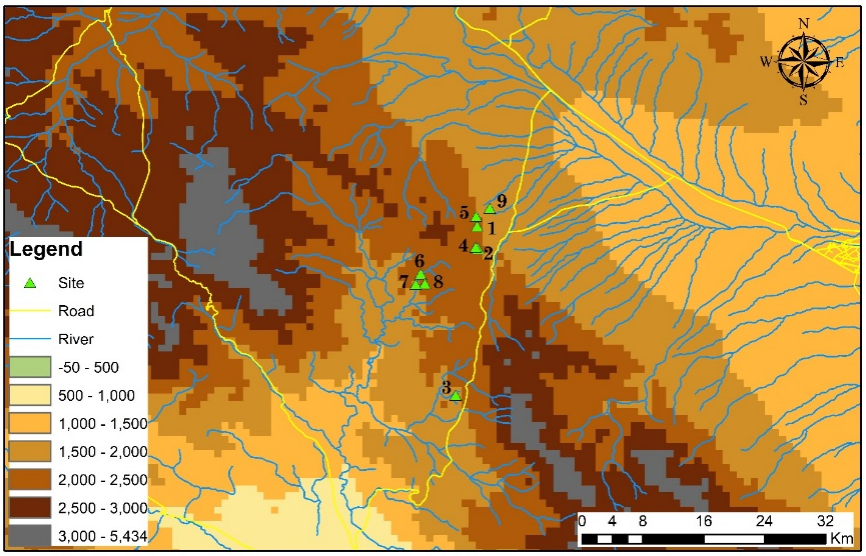

Figure 3. Location of surveyed sites in the Marqak and Dehbakari areas: 1-Kooh Chāh, 2-Marqak, 3-Kahno, 4-Se Darān, 5-Bāgh Gooni, 6- Pāy Chenārha, 7-Zeryā, 8-Asiyākadeh, 9-Khlthā

5-1. Abareq/Awaraq area(1)[1]

Awaraq, Abareq, or Abarik, located 50 km northwest of Bam County, which some also call Awaraq, is an old village in the Bam region. This village is limited to Mount Kol-e Gavi from the north, Mount Deh Bakri from the south, Mount Red from the west, and Mount Kabudi or black gold from the east. The seasonal river Tahroud flows in the southwest of the village. Mount Shah Chehel Tan is located in the northwest and Mount Red is located in the west of the village. The hot water that originates from Mount Shah Chehel Tan flows in the west of the village (Assaadpour Behzadi, 2002: 54).Stone Castle or Zangi Castle of Abareq[2] (2) is located about 46 km northwest of Bam County and about 500 m east of the Posht Qale village of Abareq. The bed of the Tahroud seasonal river is located in the west and southwest of it, and the Kerman-Bam road passes 2 km east and northeast of the castle. The castle is built on top of a rocky ridge about 30 m high and its plan is similar to the English letter L. The castle facilities start from the slope of the rocky ridge and continue to its top. Parts of the walls and several towers of this castle with a height of 3 to 4 m remain. The walls around the castle are 2 m thick. There was a well on top of the ridge in the heart of the rock, which is closed today (Zare, 2015).The active zinc, lead, and silver mine of Khan Khatun is situated 30 km from Abareq. Another active mine in this area is the Sarvestan Bam marble mine, which is located on the Bam-Jiroft side road (Fig. 4 & Fig. 5).

Figure 4. Abareq Castle, view from the south and north (Khojasteh Behzadi, 2019)

1. In his travelogue, General Sykes mentioned various samples of lead and zinc in the northwestern mountains of this region (Sykes, 1984: 251). Firouz Mirza Farmanfarma (1963: 6) in his travelogue of Kerman and Baluchistan mentioned the hot spring of this region, and Professor Haynes Gobeh (1991: 367) also mentioned this settlement.

2. In the south of Abareq, you can find ruins and an old castle. “When we go from Tahroud Valley towards Sarvestan, it is visible a large castle and a ruined building on a high hill overlooking the riverbed. A huge fence made of thick Sasanian mud and clay is the exterior of the castle” (Mostowfi, 2005).

Figure 5. General view of the distribution of slags and clay cylinders (Khojasteh Behzadi, 2019)

5-1-1. Abareq-Keshit Road

One of the surveyed places in the Abareq district is the Abareq side road towards the Keshit village (a part of Kuhbanan, Kerman). In this area, between many mounds and vegetation, a 200-meter-wide surface is covered with many traces of clay cylinders, coal, and furnace slag. On the way back from the mentioned road, on the south side, there is a structure made of clay, mud, and bricks, which the local guide referred to as a furnace (Fig. 6). In general, the Abareq region and the mountains around it (Nero, Kaput, and Siyahkuh) all have traces and metal deposits, including zinc, copper, and iron.

Figure 6. Pottery found from the Abareq site (Khojasteh Behzadi, 2019)

5-1-2. Marqak and Deh Bakri

Marqak and Deh Bakri are mountainous areas of the western region of Bam Plain. Firouz Mirza Farmanfarma (1963:80) mentioned this village as the “Eighteenth Station” in his travelogue of Kerman and Baluchistan. Syeks also mentioned this region in his travelogue. 54 km west of Bam and 4 km west of the Jiroft-Darzin asphalt road, the Marqak River, which originates from the Jamali and Bakhtiari mountains, flows in the south of the village. Mount Ab Cheko is located in the north and northeast of the village. Among the villages related to this large village are Dahaneh Marqak, Gol Malek, Deh Redin (Darreh Din), Shirkash, Se Darān, Bidkhon, Ab Shuro, Tafiat, Do Jangan, Deh Nou, Zaria, Kohanu, Kohan Ab, Gbaro, Gezma, Gol Abad, Gol Andaz, and Do Gol. The Deh Bakri River, which originates from Degu and Barez mountains, flows in the east of the village. Mount Shir is in the east and Mount Red is in the west of the village. This river has divided Deh Bakri into two eastern and western parts. Deh Bakri is a region with an area of about 70 km^2 (Assadpour Behzadi, 2002: 65, 69).The Kerman

mountains with high and snow-capped summits such as Mount Hazar (4500 masl), Mount Chihltan, and Mount Lalehzar as well as rivers such as Halilroud, Tahroud, Chari, Bampur, and Lalehzar have provided favorable conditions for the establishment of human societies since the Epipalaeolithic era. As a corridor between two dry deserts, they have linked ancient civilizations together. Tepe Sialk Kashan is located near the end of the northern part of the Kerman mountain chain, Tel Iblis is located in its central part, and Bampur Valley is located near its southern end (Abbas-Nejad, 1994).The slopes of Jebal Barez are the most suitable part of the region in terms of pastures. The vegetation of the slopes includes mesquite (a shrub with leaves similar to Konar and covered with sharp thorns), Konar (cedar tree), and Astabraq, which is from the family of Arab-Indian plants. In Jebal Barez, there are also plants such as Gavan (Astrog jluss), Artemisijberby (Artemisijberby), and pistachio (Pistaeiazeera). In the past, Baneh (Pistacia Atlantica) forests covered vast mountainous areas, but today it is being destroyed.The remains of Deh Bakri Castle are located about 30 km southwest of Darzin and about 50 km southwest of Bam on a mountain overlooking Deh Bakri Pass. The castle was built on the west side of Deh Bakri Pass on the right side of the Deh Bakri-Jiroft asphalt road and above the tunnel. The Deh Bakri area is one of the strategic communication points on the road from Bam to Jiroft, and the location of the castle is important from this point of view. The castle is built on a flat surface on top of one of the ridges of the pass, which is about a 20 × 50 m area. On this flat surface, a lot of building materials such as rubble and bricks are scattered. The vegetation of the mountain is Pistacia Atlantica, thorny shrubs, artichoke bushes, and wild plants, which partially cover the surface and surroundings of the castle (Zare, 2015).

5-1-3. Kooh-e Chāh

At the beginning of the Bam-Deh Bakri road, along Jebal Barez, on the left side of the road, there is a village called Gavan Gargi, on its slope and on the way of the river, there is a mountain called Kooh Chāh (2122 meters above sea level). On the outer surface of the mountain slope towards the peak, there is a large scattering of slag and traces of metal melting. Near the peak, a deep and square-shaped well with dimensions of approximately 2 × 2 m shows the effects of mining ore over the years. On the right side of this main tunnel, smaller and interconnected tunnels can also be seen (Fig. 7 & Fig. 8).

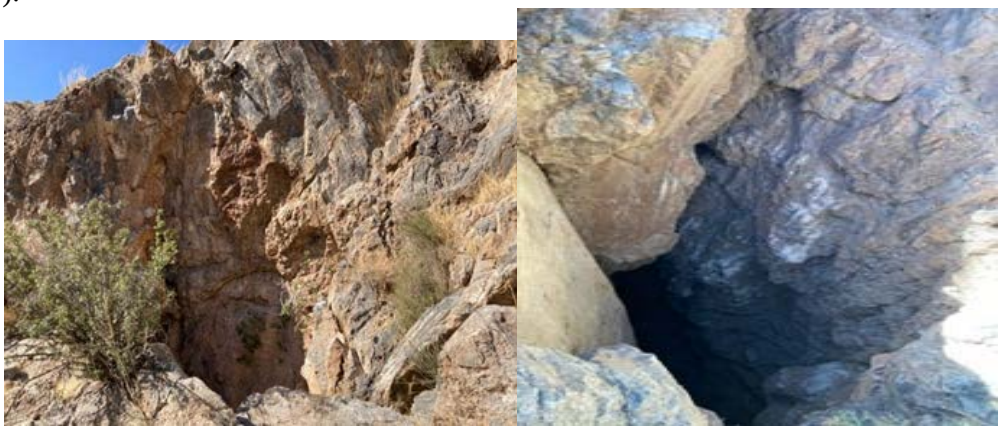

Figure 7. Stone Samples of Kooh Chāh (Khojasteh Behzadi, 2019)

Figure 8. Sub-tunnel (Khojasteh Behzadi, 2019)

5-1-4. Marqak

There is a bathhouse known as the hundred-year-old bathhouse in the Marqak village. In addition, traces of clay cylinders can be found in the gardens and under the roots of the trees that appeared due to the flood (Fig. 9).

Figure 9. Marqak village (Deh Redin) (Khojasteh Behzadi, 2019)

5-1-5. Kahno forest

On the right side of the Deh Bakri- Jiroft road, after the first tunnel, there is a dirt road that passes through a dense forest called Kahno (2123 masl). After traveling for almost 3 km, it reaches a village called Chanar Sokhteh (2141 masl). In the middle of this path and in a large area of this forest, traces of metal melting furnaces with an area of 1×1m can be seen. Iron slag, cylindrical, and conical clay pieces related to the furnace are scattered on the surface of the Kahno forest. A small number of iron ore pieces and brick pieces can also be seen on the site. There is a circular space of stones and mud on the site. A part of the site is slightly hollow, which looks like a furnace. In another part of the site, the remains of the furnace building can be seen. This place is located approximately 200 m from the first point.

In the west of the Kahno village, in the central part of Bam County and Deh Bakri area, and in the northern part of the river bed known as Darbadi Valley, there are traces of furnaces. The effects of the furnace are visible in the form of layers of ash and charcoal. In a large part of the river bank, which fell due to the flood, the traces of furnaces are visible. Among the layers of coal and ash, cylindrical pieces related to the

furnace and metal slag can be seen (fig 10). There are stones with cup patterns in its vicinity.

Figure 10. Scattering of remains of furnace on the Kahno forest site (Khojasteh Behzadi, 2018)

5-1-6. Castles of Se Darān

In the Se Darān village (1993 masl) located in the central part of Bam county, in the upper Marqak area, on the heights known as the Se Darān Castles in the southwest of this village, there are few remains of a historical building. In a place in the middle of the Se Darān village, next to a garden and on the river bank, there are many clay cylinders of the furnace. At the foot of this mountain, the bed of three rivers is visible. Vegetation of the site is Baneh trees, Kahkom (Acer monspessulanum), and at the bottom, fir trees (Fig 11).

Figure 11. Remains of metal smelting furnaces in the Seh Darān village (Khojasteh Behzadi, 2018)

5-1-7. Bāgh Gooni

The Bāgh Gooni site (1359 masl) is located in the west of the Hassan Abad village, in the middle of mountains. On the surface of this site, fine cone-shaped works (clay cylinders), slags, iron ore, copper ore, and parts of the furnace building are scattered. Surrounding the site is a dense forest of Baneh trees (Fig. 12).

Figure 12. Remains of furnace in the Hassan Abad village (Khojasteh Behzadi, 2018)

5-1-8. Pāy Chenārha

In the Deh Bakri area, located in the central part of Bam county, in the north of the Anaran village and among the pomegranate orchards known as Bagh Zir Mazar, on the hillside, a square-shaped structure made of rubble with lengths of 1.5 m. A large rock forms part of this wall. The space has no roof and entrance on the north side. In the middle of the space is a natural rock with an irregular geometric shape and no pattern, which is called the Ghadamgah stone. The lands around the shrine of Imam Reza (a.s.) are called Pāy Chenārha (or Pāy Chenālha) lands. On the surface of the land around this shrine, there is a significant amount of clay pieces related to the furnace in cylindrical and conical shapes. In this site, a millstone with a diameter of one meter is located among a pile of rubble (Fig 13).

Figure 13. Remains of mill and smelting furnace in the Anaran village (Khojasteh Behzadi, 2018)

5-1-9. Zeryā village and Asiyākadeh

In more than 25 hectares of agricultural lands of the Zeryā village and its surroundings (2074 masl), cylindrical pieces of clay and metal slag are scattered. In addition, in the west of the Zeryā village, there are traces of furnaces and metal smelters on a site called Asiyākadeh (1870 masl). This site is surrounded by mountains and the Anaran River flows from its edge. In a major part of the site, spaces have been built with stone rubble. The remains of the furnace can be seen on the surface of these spaces, and cylindrical and conical pieces and metal slag are scattered around them to a considerable extent. Besides, there are small pieces of copper ore on the surface of the site. Natural factors such as river flooding have destroyed parts of the site. The Anaran River, Pelengo Qanat, and the springs of Kalil and Pelengo are located in the southwest of the site, and the spring of Imam Hosseini is in the south of it (Fig. 14 & Fig. 15).

Figure 14. Remains of Furnace on the Asiyākadeh site (Khojasteh Behzadi, 2018)

Figure 15. Remains of Furnace in the Zeryā village (Khojasteh Behzadi, 2018)

5-1-10. Khlthā

59 km northwest of Bam and north of the Hashr Abad village, there is a small site with dimensions of approximately 10 × 10 m, covered with metal stones and slag, which the nomads call Khlthā (1804 masl). Green and red stones can be seen on the surface of this site. The water sources of the Hashr Abad village are qanāts and seasonal rivers (Fig. 16).

Figure 16. Artifacts found from the Khlthā site (Khojasteh Behzadi, 2018)

6. Discussion

A noteworthy discovery in the surveyed vicinity within the central part of Bam County pertains to the identification of clay cylinders present in multiple sites, with the notable

exception of the Kohan Kooh Chāh mine. These clay cylinders are presumed to be associated with the extraction process of zinc and zinc oxide (ZnO), commonly known as Tūtiyā. While the isolation of pure zinc metal was credited to Baraslus in the 17th century AD, research by Loufer suggests that zinc oxide and lead monoxide (PbO), resultant from zinc and lead smelting furnaces, were exported from Iran during the Sassanid era, predating the discovery of the elemental form of zinc by at least a millennium. Consequently, zinc was utilized in its impure state since at least the Sassanid period. The challenge in obtaining zinc in its elemental form lies in the necessity to regenerate zinc oxide at temperatures ranging from 1200°C to 1400°C in proximity to coal, within closed containers. It should be noted that zinc metal evaporates at 906°C, and beyond this temperature, it is available in vapor form, requiring careful cooling without exposure to air (Craddock, 2018). However, historical constraints, where the entire process occurred in open-air conditions, resulted in the production of zinc oxide as the final product. Remnants of ancient furnaces utilized for zinc oxide production, still discernible today, are typically situated in valleys near water sources but have suffered significant deterioration over time due to erosive factors (Ghorbani, 2000).

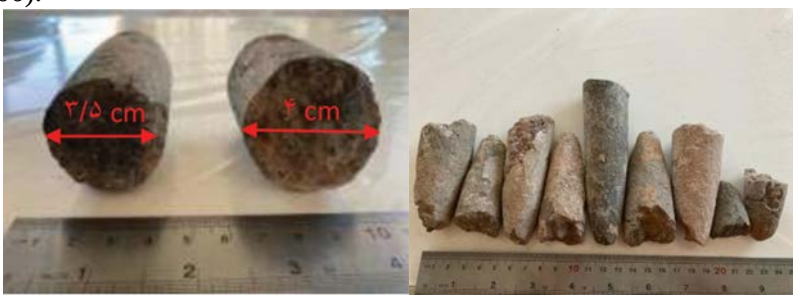

Figure 17. Broken clay cylinders in different sizes (Khojasteh Behzadi, 2019)

Regarding the method of extracting zinc oxide from ore, historical sources offer valuable insights, with Aghili Khorasani's account being particularly comprehensive and accurate. He delineates two types of two-story furnaces employed in zinc oxide production: (1) the long type furnace and (2) the short and narrow head type furnace, both featuring an oven-like space or fireplace in the lower part (Aghili Khorasani, 2003). The short version of these furnaces can be observed in Kuhbanan of Kerman. Al-Taha reported the presence of clay pens or nails around old zinc oxide mining mountains, ranging from 10 to 30 cm in length and 3.52 cm in diameter (Al-Taha, 1996: 56). Additionally, he elaborates on the method of extracting zinc oxide, involving the creation of pens and long ingots from sticky soil, colloquially known as rust soil in Iraq. These objects, with slightly narrowed ends, are dried, salted, and subsequently placed in furnace floors in various orientations. The coagulation of lead smoke during melting ensures the preservation of the smoke, preventing its dissipation. Once a significant amount of coagulated smoke is observed, the pens are broken, and the solidified smoke is separated from them (Al-Taha, 1996).

Clay cylinders resembling the pens described by Aghili Khorasani are abundantly found around zinc oxide production furnaces. Crafted in varying sizes, these cylinders measure between 10 and 30 cm in length and 2 to 3.5 cm in diameter, with their dimensions seemingly not affecting their functionality (Al-Taha, 1996). While Hamdollah Mostowfi mentions the length of these rods as one yard (Mostowfi, 2002), no rods of this length have been reported thus far. It is apparent that the clay cylinders

identified in Bam metallurgical sites likely served a similar purpose to these rods in the extraction of zinc oxide. The mineralization observed indicates the presence of baked clay, corroborating Aghili Khorasani's account. For the separation of zinc oxide, the rods were halved, and in the studied sites, all the nails are broken, with no complete samples found among them. The furnaces associated with zinc oxide extraction in different regions of Iran, as revealed through archaeological excavations, exhibit a wide, two-story structure. The lower floor takes the form of a vault, functioning as the heating space for zinc oxide production. The furnaces' fuel played a critical role in achieving the requisite temperature (960°C). Zinc oxide, produced in the form of steam, was conveyed through openings between the two floors to the upper part, where clay cylinders were positioned on the floor. Due to the lower temperature in this upper section compared to the zinc evaporation temperature, the vapor sublimated and solidified, covering the cylinders. The furnace was subsequently extinguished, and the clay cylinders, now coated with solid zinc oxide, were removed. The solid zinc oxide adhering to the head of the cylinders was deemed lighter and of superior quality. Zinc oxide obtained through this method likely retained its cylindrical shape (Ghorbani, 2000). Consequently, it appears that zinc oxide extraction was more prevalent than the extraction of other metals in the surveyed sites. Given that zinc is commonly found in association with lead and silver in minerals, the extraction of these metals was widespread in the region from Bam to Jiroft.

While this study did not yield indicative artifacts for determining the chronology and interrelationships between sites, historical sources play a crucial role in establishing the relative chronology of the examined metallurgical sites. Notably, Istakhri's descriptions from the 3rd century AH about Jiroft to Bam mines hold significant importance. In his work "Masalek and Mamalek," Istakhri notes the presence of numerous mines in the cities of Kerman, specifying iron mines in the Jebal Barez mountains. Silver mines were reported in the mountains stretching from Jiroft to Darbai branches, emphasizing the abundance of silver mines in Darbai's blessed valley (Istakhri, 1968). Consequently, it is evident that metals, particularly zinc or Tutia (zinc oxide), were extracted in the region since at least the 3rd century AH. In the 4th century AH, the author of "Hodud Al-Alam" references lead mines in the Bam and Jiroft areas (Hodud Al-Alam, 1961), indicating the simultaneous extraction of zinc alongside lead in the region during the 4th century AH. Maqdasi openly speaks about the extraction of zinc oxide from the Jebal Barez mines in the 4th century AH, underscoring the wealth and prosperity of the region (Maqdasi, 1983). The exploitation of mines and metallurgical activities persisted in the following centuries, with Abdulqasem Kashani referencing Tutia (zinc oxide) near Kerman in the 8th century AH (Kashani, 1966). Additionally, Abulqasem Kashani provides insights into the extraction process, mentioning the construction of a furnace with terracotta nails in its wall and the use of Tutia stone in conjunction with a strong fire for extraction (Kashani, 1966). The mining of lead, zinc, and silver continued in the region until the Qajar period, as indicated by Abdul Hossein Mirza Farmanfarma's account of the Abareq lead mines in Bam (Farmanfarma, 1981).

In summary, the Kerman area, particularly around Bam County, has served as a significant hub for ancient mining and metallurgical activities since at least the 3rd century AH. Beyond lead, zinc, and silver mines, the extraction and processing of various metals, non-metallic materials, and precious stones have been widespread in this region, contributing to metalworking activities. The iron mines in Jebal Barez have

attracted attention since the 3rd and 4th centuries AH (Istakhri, 1968; Ibn Hoqal, 1987). The book "Javahernameh Soltani" notes the exploitation of impure gold and jade mines in some southern mountains of Kerman. Even in the 8th century AH, jade extraction continued in these areas, as documented in the books "Geography of Minerals" and "Arais Al-Javahir," as well as "Lajevardi Kermani" (Mostowfi, 2002).

7. Conclusion

The central part of Bam County, particularly in the Sarvestan and Abareq regions, boasts substantial mineral potential. Presently, active marble mines operate in these areas, contributing to extraction and export activities. The Abareq area, characterized by surrounding mountains with abundant vegetation, water resources, and operational zinc and copper mines, presents favorable environmental conditions conducive to metallurgical pursuits. Geologically, the region is endowed with abundant mineral deposits within its encompassing highlands. The presence of metal smelting furnaces is indicative of extensive mining and metalworking activities, traceable at least from the Sassanid period to the Islamic era. Additionally, it holds strategic importance, situated along historical communication routes, enabling the facilitation of extra-regional product distribution through the Center-Southeast Iran communication highway. Beyond Sarvestan and Abareq, the Deh Bakri area serves as a connecting point between the cities of Bam and Jiroft. The area's extensive vegetation and seasonal rivers have historically rendered it a suitable locale for human habitation and industrial endeavors.

All the sites scrutinized in this research exhibit remnants of smelting furnaces and metal extraction activities. The prevalence of evidence such as slag, underground mining, and numerous tunnels surrounding the area attests to the extensive and sustained use of metals in this region. Remarkably, artifacts like clay cylinders, enduring environmental changes and river flooding, provide tangible indicators of copper, lead, and zinc metal extraction. Despite the absence of definitive cultural materials to establish the chronology and interrelationships among the sites, historical sources prove instrumental in constructing the relative chronology of the studied metallurgical sites. According to historical, geographical sources, and travelogues, the extraction and utilization of metals—lead, zinc, silver, iron, and to a lesser extent, gold—have been ongoing activities in these regions since at least the 3rd century AH. Consequently, considering the geological context of the region, archaeological evidence, and historical documentation, it becomes evident that the indigenous populations of this area extensively and consistently exploited the natural resources and mineral deposits in their vicinity. The substantial underground mining at Kooh Chāh, located at the inception of the Deh Bakri section and approximately at the center of the surveyed area, strengthens the likelihood that this locale served as a central supply hub for the neighboring sites.

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مطالعه معدن کاری و متالورژی در بخش مرکزی بم ، با تمرکز بر بررسی‌های باستان شناسی و منابع تاریخی

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چکیده

جنوب‌شرق ایران در دوره پیش از تاریخ یکی از منشأهای فلزگری جهان شناخته شده است، امروزه نیز منطقه کرمان با دارا بودن منابع عظیم و غنی معدنی یکی از استان‌های مهم معدنی به شمار می‌آید. در این میان شهر بم در جنوب‌شرق کرمان به دلیل شرایط خاص زمین‌شناسی و زمین‌ریخت‌شناسی از دیرباز به‌عنوان مرکزی برای پیوند مسیر جنوب خاوری ایران با سیستان ، افغانستان و بلوچستان بوده است و بر اساس مطالعات انجام‌شده این شهر از دوره ساسانیان اهمیت بازرگانی و نظامی زیادی داشته است. با توجه به این مهم، بررسی باستان‌شناختی بخش مرکزی شهرستان بم ، با هدف شناسایی مراکز ذوب فلز و معادن کهن در طول سال‌های ۹۷-۹۸ آغاز شد. در این مقاله، ۸ محوطه با آثار ذوب و سرباره ، یک معدن کهن و دو معدن فعال که مورد بازدید قرار گرفت ، معرفی می‌گردد تا با استناد به نتایج بررسی پیمایشی در بخش مرکزی بم ، به شواهد و نشانه‌های یافت شده از مراکز ذوب فلز ، کوره‌ها و معدن‌کاوی کهن بپردازد. شواهد و مدارک حاصل از یافته‌های به‌دست‌آمده از فلزگری باستانی و معرفی مراکز ذوب فلز در این ناحیه از شرق کرمان موجب معرفی و نشان دادن چشم‌انداز جدیدی از فعالیت‌های فلزگری باستانی در منطقه است .گرچه جهت تاریخ‌گذاری شواهد سطحی چندانی به دست نیامده ، اما با توجه به منابع مکتوب تاریخی میدانیم که منطقه بم در ادوار تاریخی و اسلامی به شکوفایی صنعتی رسیده است.

واژه‌های کلیدی: جنوب‌شرق ایران ، متالورژی، بخش مرکزی بم، بررسی باستان‌شناختی، فلزگری باستانی، معادن کهن.