HISTORIA I ŚWIAT, no 14 (2025)
ISSN 2299-2464
e-ISSN 2956-6436

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Metallurgy and Ancient Mining in Tujerdi District of Fars Province, Iran

https://doi.org/10.34739/his.2025.14.07

Abstract: *The production of metal artifacts, as one of the earliest forms of industry and craftsmanship, has long attracted scholarly attention. Iran has historically been one of the primary centers for metal production across various periods. The geology of Fars Province reveals rich mineral resources that have supported mining activities since ancient times. This study is based on archaeological surveys conducted in the Tujerdi district of Sarchahan County, located in eastern Fars. During these surveys, one mine and nine slag sites were identified. Further surveys are expected to uncover additional sites related to ancient mining and metallurgical activities. The investigation also contributes to understanding the role of mining in the formation and economy of past societies. Based on the findings, it appears that copper and iron were the main metals extracted in the region. Pottery collected from the surveyed sites suggests chronological spans ranging from the Parthian to the Sasanian and Islamic periods*.

Key words: Fars, Tujerdi, Mining, Smelting Technology, Slag

Introduction

The Iranian highlands, rich in mineral resources, have long been recognized as one of the major centers of early metallurgy in Southwest Asia.[1] The history of metal production in Iran dates back to around 7000 BCE, with substantial evidence for copper smelting emerging by the 5th millennium BCE.[2] Early copper objects from this period often contain notable amounts of arsenic, reflecting early experimentation with alloying.[3] The appearance of bronze artifacts – primarily copper-tin alloys – by the end

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[1] Pigott, 1999; Simpson & Niece, 2010: 95; Mortazavi *et al*., 2011: 49; Hajitabar & Haji, 2022.
[2] Dougherty & Caldwell, 1967; Moorey, 1969; Pigott, 2004; Pernicka, 2004; Thornton *et al*., 2002; Thornton, 2009: 303; Helwing, 2013.
[3] Pigott, 2004, 2011; Thornton, 2009.

of the 4th millennium BCE marks the onset of the Bronze Age in western Iran.[4] Several scholars argue that Iran was an early hub for the production and smelting of copper and bronze.[5]

Recent research in archaeology and archaeometry has increasingly focused on the extraction, production, and circulation of metals in antiquity. However, the rapid expansion of modern industrial mining threatens to destroy many ancient mining sites. Timely documentation and archaeological study of these areas are crucial for preserving this important aspect of Iran's cultural heritage.

In the Fars cultural zone, the earliest evidence of metal use dates back to the Mushki period (late 7th millennium BCE). Excavations at the Mushki site yielded several copper artifacts,[6] with additional evidence of metal objects from Hormangan,[7] Bakun,[8] and Hirbodan.[9] Despite the significance of these finds, mining and smelting activities in the region have received limited archaeological attention. Previous studies have only briefly addressed mining and metallurgical sites in Bavanat.[10]

In 2019, the first systematic archaeological survey was carried out in the Tujerdi District of Sarchahan County.[11] This survey led to the identification of 109 archaeological sites, ranging from the Neolithic to the Late Islamic periods, including one ancient mine and nine slag disposal sites. The present study aims to reconstruct the ancient metallurgical landscape of the region and to shed light on the technological and cultural aspects of mining and metal production. Key research questions include: When did ancient mining and metallurgy begin in this region? What metals were extracted? What processes contributed to the formation of slag sites? The study presents preliminary findings in response to these questions, based on field survey data.

Tujerdi district: Geographical and Geological Setting of Sarchahan County

Sarchahan County is located in the eastern part of Fars cultural zone, encompassing three main districts: Markazi, Bagh Safa, and Tujerdi. The Tujerdi district lies in the southeastern part of the county and serves as a significant area for archaeological and geological research. Sarchahan shares its southern borders with Arsanjan and Bakhtegan counties, its northern boundary with Bavanat County, the western border

[4] Pigott, 2004; Fleming *et al*., 2005; Thornton, 2009.
[5] Muhly, 1985; Pigott, 1999, 2011.
[6] Fukai, Horiuchi & Matsutani, 1973.
[7] Khanipour, Emadi & Akbari, 2018: 19.
[8] Alizadeh, 2006.
[9] Yeganeh, 2023.
[10] Emami & Yaghmaei, 2009; Khanipour, Kavosh & Naseri, 2020.
[11] Khanipour & Molaei Kordshouli, 2023.

with Pasargad and Khorambid counties, and is adjacent to Khatam County in Yazd province to the east.

Topographically, the region is predominantly mountainous, interspersed with seasonal rivers and natural springs, contributing to its ecological and economic significance throughout history. From a geological perspective, Sarchahan is located within the Sanandaj-Sirjan structural zone, a major metallogenic belt in Iran known for its rich mineral resources and tectonic complexity.[12]

Archaeological survey in Tujerdi

Wide parts of southern Iran are archaeologically referred to as the Fars Cultural Zone.[13] In this region, relatively unified cultural developments have been observed since the Neolithic period, and these cultural traits remained stable well into the Islamic period. In the context of modern political geography, this cultural zone is now divided into several provinces, including Fars, where Bavanat and Sarchahan are located.

Over the past century, various archaeological surveys and excavations have been conducted in this zone.[14] While some regions have been extensively studied by archaeologists, others – particularly the eastern and northeastern zones – remain poorly understood due to the limited availability of archaeological research. To better understand the cultural transformations in eastern Fars, the first author initiated archaeological research in the Bavanat county in 2015. At that time, Bavanat consisted of three districts. In the first phase of the project, the Central and Mazayjan districts were surveyed, resulting in the identification of 200 archaeological sites.[15] It was decided that the third district, Sarchahan, would be surveyed in subsequent years. In 2019, the Sarchahan district was administratively separated from Bavanat and elevated to the status of an independent county.

Located near the border between Fars and Yazd provinces, the Khansaar Dam serves as a key infrastructure providing drinking water for the city of Harat and supporting agricultural and industrial water needs in the region. The dam's reservoir is situated in the Tujerdi district of Sarchahan County. Following a request by the Regional Water Company of Yazd Province for historical and cultural assessments in the dam area, the Iranian Center for Archaeological Research (ICAR) was commissioned to conduct an archaeological survey.

[12] Asadi, Moore & Fattahi, 2013: fig. 2.
[13] Khanipour & Azizi Kharanaghi, 2024.
[14] Stein, 1936; Fukai, Horiuchi & Matsutani, 1973; Whitcomb, 1985; Alizadeh, 2006; Amiri, Mousavi Kouhpar & Khademi Nadooshan, 2012; Khanipour, Naseri & Nouruzi, 2017; Moradi & Karimian, 2020; Khanipour, Niknami & Abe, 2021; Yeganeh, 2023; Khanipour, 2023, 2025a.
[15] Khanipour *et al*., 2019; Khanipour, 2024, 2025b.

To complement earlier research in Bavanat, the author carried out a systematic survey of the Tujerdi district in Sarchahan.[16] Initially, a salvage survey was conducted in areas most directly affected by the dam construction, including parts of both Sarchahan County and the adjacent Khatam County[17] in Yazd Province. This effort aimed to identify archaeological sites at risk of destruction. Subsequently, a broader regional survey was carried out across the Tujerdi district with the objective of identifying additional archaeological sites and documenting patterns of cultural change over time. As a result of these surveys, more than 100 archaeological sites were identified in the Tujerdi district, along with 8 sites in the Khatam County area. These findings significantly enhance our understanding of the settlement history and cultural dynamics of eastern Fars and neighboring regions.

Mining and metal extraction in the Tujerdi district

Today, the economy of the Tujerdi District is primarily based on agriculture and animal husbandry. Despite its relatively small population, the region benefits from fertile soils and sufficient water resources. These favorable environmental conditions have contributed to continuous human occupation in the area throughout various historical periods. As a result of the archaeological survey conducted in the district, more than one hundred sites were identified, including settlement sites, cemeteries, qanats, slag sites, and ancient mines. This article focuses specifically on the sites related to metallurgy.

The survey methodology was based on systematic fieldwalking. Initially, aerial photographs of the region were analyzed to identify areas with high archaeological potential. These locations were marked and subsequently visited on foot. The team also sought to cover the district as comprehensively as possible, including agricultural zones, foothills, and mountainous areas, in order to document all visible archaeological remains. The mining and metallurgical sites identified during the survey can be classified into two main types: one mine and nine slag sites [Fig. 1].

[16] Khanipour & Molaei Kordshouli, 2023.
[17] An archaeological survey of Herat County was conducted by Azizi Kharanaghi in 2021; Azizi Kharanaghi, 2024; Salimi & Azizi Kharanaghi, 2025.

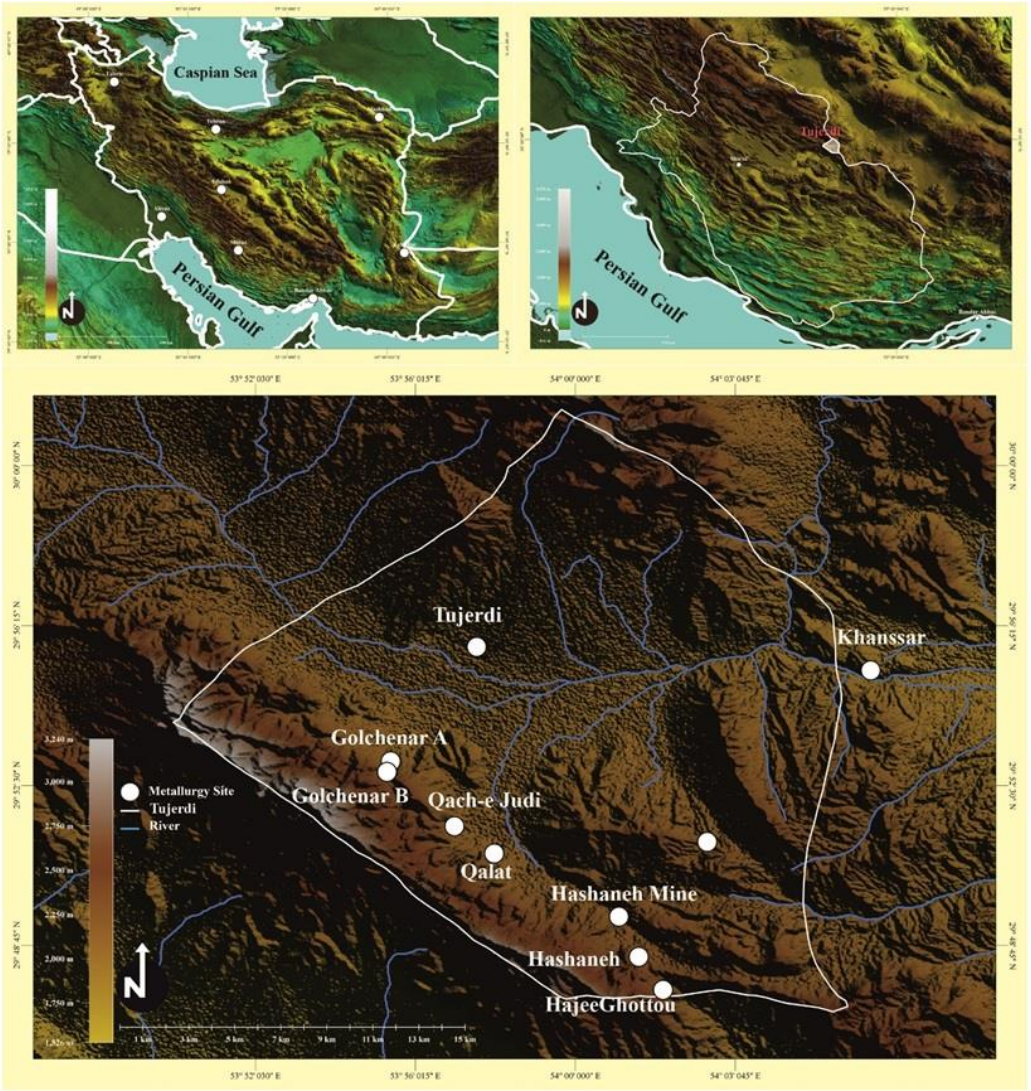

Fig. 1. Distribution map of mine and slag sites in Tujerdi (map by H. Molaie Kordshooli).

Hashaneh Mine

Hashaneh mine is located in the highlands on the southern margin of the Tujerdi plain, 4400 meters southeast of Qalat village. This mine is an open-pit mine and has been used in the past due to metal veins outcropping. here is an iron ore outcrop on the southern slope of the mountain, extending over a length of approximately 120 meters and a width of about 50 meters. The boundaries of the deposit can be distinguished by the color contrast between the surrounding soil and the mountain rocks, as well as by the brown-colored exposures of the iron ore itself. The effects of mining can be seen on the surface of the rocks, and in front of it and on the slope of

the mountain, a large number of large stones can be seen, which seem to have been separated from the rock by the miners, and the parts with a higher amount of metal have been transferred and they left parts of the rock that had a smaller percentage of metal here [Fig. 2]. No pottery or other archaeological materials were found in the mine that could assist in determining its date.

Hashaneh slag site

Hashaneh slag site is located 6100 meters southeast of Qalat village and 1800 meters southeast of Hashaneh mine. The site is located in a mountainous landscape and on the slopes of a small valley. This site is small and flat. Slag distribution can be seen in a range of 80x100 meters, with more distribution in some places [Fig. 3]. The distribution of cultural materials on the site is low and includes slag and pottery. This indicates metal smelting activity in this site. There is a spring 300 meters south of this site. There are three groups of pottery that can be divided into three groups: buff, red and gray. All the pottery has a fine, grit temper, and it has been well-fired. The pottery shows clear signs of having been wheel turned or handmade, and the slip is typically even, although there are often darker patches on some examples. There is a hole in pottery No. 5 [Fig. 4], which indicates that this pottery was probably broken and repaired. The pottery can be dated to the Sasanian period based on its color, fabric, and temper. These ceramics are comparable to the Sasanian-period pottery recovered from Tol-e Gap Kenareh,[18] Hajiabad,[19] Malyan[20] and Qasr-e Au Nasr.[21]

Haji Ghottou slag site

Haji Ghottou slag site is located 7600 meters southeast of Qalat village and 1600 meters southeast of Hashaneh slag site. Slag distribution can be seen in an area of 50x60 meters. The distribution of cultural materials on the site is low and includes slag. This indicates metal smelting activity at this site. There is a spring 80 meters west of this site, and the required water is supplied from this spring. No cultural materials such as pottery, which could help in dating the site, were recovered from this location.

[18] Khanipour, Naseri & Nouruzi, 2017: 102, fig 17; Khanipour *et al*., 2021, figs. 5-6.
[19] Azarnoush, 1994: fig. 188.
[20] Alden & Balcer, 1978: fig. 5, no. 2.
[21] Whitcomb 1985: fig.42.

Fig. 2. Overview of Hashaneh Mine (Photo by M. Khanipour).

Fig. 3. Slag distribution at the Hashaneh slag site (Photo by M. Khanipour).

Fig. 4. Pottery from the Sasanian and Islamic period, Negino (1 and 2), Hashaneh (3-6), Qalat (7-9), Qach-e Judi (10-13), Golchenar slag site A (14-18) (Photo by M. Khanipour).

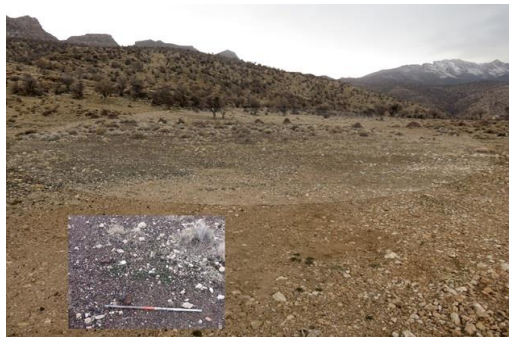

Fig. 5. Slag distribution at the Qalat slag site (Photo by M. Khanipour).

Fig. 6. Slag distribution at the Qach-e Judi slag site (Photo by M. Khanipour).

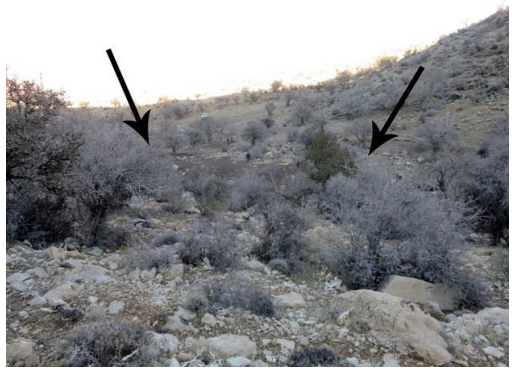

Fig. 7. Overview of Golchenar slag site B (Photo by M. Khanipour).

Qalat slag site

Qalat slag site is located 950 meters northwest of Qalat village. The site is located on the northern slopes of the mountains. Slag distribution can be seen in the range of 70x100 meters [Fig. 5]. This has a high concentration of slag at three points, and the thickness of slag accumulation is about 30 cm. The pottery color of this site is red and the quality of their firing is well Fired [Fig. 4], only the effects of over firing can be seen on the exterior of pottery number 7. According to the color, fabric, and temper, the pottery of this site can be dated to the historical period (Parthian or Sasanian).

Qach-e Judi slag site

Qach-e Judi slag site is located 6100 meters southeast of Qalat village and 1800 meters southeast of Hashane mine. Slag distribution can be seen in an area of 80x100 meters, with more distribution in some places [Fig. 6]. There is a spring 375 meters south of this site from which the required water is supplied. Four pieces of pottery have been collected from this site. Depending on the firing temperature, the fabric can range from red to light brown to brown to orange in colour [Fig. 4]. A handmade or wheel-turned vessel was made using these wares. There was little care taken with the surface finish, and some examples have surface slips. It is common for the exterior and interior of handmade items to have visible finger marks. On the interior of wheel-turned vessels, finger striations are often evident. There is an incised pattern on the exterior of pottery No. 11. The pottery can be dated to the Sasanian period based on its color, fabric, and temper.

Golchenar slag site A

Golchenar slag site A is located 3700 meters west of Saghouye village and 3200 meters southeast of Chenaroye village. The site is located on a low ridge on the eastern slope of the mountain. Slag distribution can be seen in the range of 50x20 meters, with more distribution in the center. There is a spring 220 meters south of this site. This site's pottery is divided into two groups, glazed and unglazed, and each group has a red or buff fabric. Glazed pottery includes two types of glazes, monochrome green-glazed and sprinkled glaze, which can be dated to the early Islamic period [Fig. 4]. Similar pottery with Splashed decoration [Fig. 5, no. 2] has been found at Estakhr,[22] Bishapur,[23] Tol-e Gap Kenareh,[24] Qasre Abu Nasr,[25] Jiroft,[26] all dated to the 9th to 12th centuries CE.

[22] Khanipour & Mahjoor, 2012: fig. 12.
[23] Amiri, Mousavi Kouhpar & Khademi Nadooshan, 2012: 26, fig. 19.

Golchenar slag site B

Golchenar slag site B is located 3800 meters west of Saghouye village and 400 meters south of Golchenar slag site A. Slag distribution can be seen in an area of 100x35 meters. A hole has been dug in the center of the slag, which shows that the slag thickness is about 70 cm. Around this site, stone walls can be seen [Figs. 7-8], probably related to industrial activities on this site. There is a spring 200 meters north of this site from which the required water is supplied. This site is the largest slag site identified in Tujerdi. Five pieces of pottery have been collected from this site. This ware is well-fired, wheel turned and tempered with medium to coarse grit. Surfaces range from fine to medium, some vessels are coated with a light brown or buff slip, and the fabric is typically red, light brown, or brown.

Khanssar slag site

Khanssar slag site is located 440 meters southeast of Khanssar village and on the border of Fars and Yazd provinces [Fig. 1]. The site has 15x20 meters, and many parts have been destroyed due to construction of a road. The destruction shows that the slag deposits measure approximately 40 cm in thickness. The Azam River is located 400 meters south of this site. No pottery or other cultural artifacts suitable for dating the site were recovered.

Negino slag site

The Negino slag site is located 7000 meters southeast of Soltan Abad village and southwest of Negino Spring. Metal slag is distributed 120x100 meters at this site [Fig. 9]. However, in the center there is an accumulation of slag and residues from metal extraction with a thickness of about 150 cm. This is in an area of 30x40 meters. Which shows that metal melting was done on a large scale at this site. Parts of this accumulation have been destroyed over the past few years. The presence of the Negino spring has caused metal extraction at this place. On the site, two pottery pieces were found. One is red-orange in color and has an incised surface [Fig. 4].

[24] Khanipour, Naseri & Nouruzi, 2017: 102, fig 17.
[25] Whitcomb, 1985: 69-71, figs. 24-25.
[26] Choubak, 2012: 107, fig. 32.

Fig. 8. Architecture and slag distribution at the Golchenar slag site B (Photo by M. Khanipour).

Fig. 9. Overview of the Negino slag site (Photo by M. Khanipour).

Fig. 10. Crucibles and slag distribution at the Tujerdi slag site (Photo by M. Khanipour).

Fig. 11. Islamic pottery from Tujerdi site (Photo by M. Khanipour).

Tujerdi slag site

Tujerdi slag site is located 100 meters west of Tujerdi village and 500 meters south of the Tujerdi to Korei road. Although other sites are located on mountain slopes, this site is in the center of the plain. The site is 50x80 meters, and slags and crucibles are distributed [Fig. 10]. The interesting point about this site is the large distribution of crucibles on the surface of this site. Agricultural activities over the past few decades have destroyed a large part of this site. The pottery of this site can be divided into two categories, glazed and unglazed. Unglazed pottery fabric colors include red, buff and gray, some decorated with molded, incised or appliqué. Glazed pottery has red or buff fabric which can be divided into 7 groups: Monochrome green-glazed ware is characterized by a buff or red fabric; a translucent bluish-green glaze; “Splashed” (monochrome and polychrome) and sgraffito glazed wares are usually of a red fabric coated with white slip and a transparent glaze. The glaze is stained with splashes,

stripes, and spots of brown, green, and sometimes yellow. Pottery decorated in black on white slips under a colorless glaze; Glazed relief [Fig. 11]. The ceramics comparison with Estakhr,[27] Bishapur,[28] Tol-e Gap Kenareh,[29] Bavanat,[30] Qasre Abu Nasr,[31] Jiroft,[32] Nishapur[33] and Neyriz,[34] attributes this site to the early Islamic period.

Discussion

The results of the surface surveys conducted in the Tujerdi district reveal a significant concentration of metallurgical activity during several periods, particularly from the Sasanian to the early Islamic centuries. The spatial distribution of sites associated with metal smelting indicates that the choice of these locations was not arbitrary, but rather influenced by specific environmental, geological, and infrastructural factors. The widespread presence of iron and copper deposits across eastern and northeastern Fars – especially in Bavanat and Sarchehan counties – highlights the strong geological potential of the area. This mineral-rich environment appears to have been a major factor in the establishment of numerous metallurgical sites. In contrast to other parts of Iran, where metal production activities are more dispersed and limited in scale, Tujerdi presents evidence of a relatively well-organized and sustained system of metal extraction. It seems that local communities not only had extensive knowledge of their natural environment, but were also able to implement it effectively within a structured metallurgical framework. As a result, the Tujerdi and Bavanat regions contain numerous ancient mines and slag sites that attest to long-standing traditions of ore extraction and metallurgical activities.

Archaeological research on ancient mining across Iran has identified two main types of operations: underground tunneling and open-pit mining that follows surface-level mineral veins.[35] Both approaches are evident in the study area. At the base of the Hashaneh mine, large piles of crushed rock fragments and quarrying waste provide clear evidence of mineral sorting and hand-picking prior to smelting, a critical pre-processing stage in metal extraction. This step requires access to water, and notably, most slag sites in the region are located in proximity to springs. For instance, springs are found near both the Hashaneh and Qalat sites, and the Khansar site is located near to the Azam River. The ore seems to have been transported from

[27] Asadi, 2012: 212, fig. 28; Khanipour & Mahjoor, 2012: fig. 12.
[28] Amiri, Mousavi Kouhpar & Khademi Nadooshan, 2012: 26, fig. 19.
[29] Khanipour, Naseri & Nouruzi, 2017: 102, Fig 17.
[30] Khanipour *et al*., 2021: 18, fig 13.
[31] Whitcomb, 1985: 69-71, figs. 24-25.
[32] Choubak, 2012: 107, fig. 32.
[33] Wilkinson, 1973: pl.4; Elahian, Taghavi & Ataie, 2024: 60, tab. 15.
[34] Moradi & Karimian, 2020: 289, fig. 3, No. 11.
[35] Haji Alilou & Laleh, 2014; Khanipour, Kavosh & Naseri, 2020.

mines to places near these water sources for smelting. In addition to mineral resources, other key factors such as access to water and fuel clearly influenced the siting of metallurgical installations. Many sites are located in vicinity to water sources – river or springs – as well as in regions with shrubland vegetation suitable for charcoal production. These patterns suggest a high level of technical and environmental awareness among past communities. Site choice appears to have been shaped by a complex set of criteria that included technical, ecological, and potentially even social considerations. An important aspect of this study is the variation in scale among the surveyed sites. Major production centers like Golchenar B, with its extensive slag heaps, architectural remains, and prominent industrial features, likely served as primary smelting locations. In contrast, smaller sites such as Hashaneh or Haji Gattu may have had seasonal, auxiliary, or temporary functions. These differences may reflect underlying socio-economic structures, production hierarchies, or chronological shifts in activity intensity.

A significant challenge in analyzing industrial metallurgical sites in Tujerdi is the difficulty of chronological attribution. Many sites lack diagnostic ceramics or other cultural materials that would allow for reliable relative dating. However, some sites – such as Negino, Hashaneh, Qalat, and Qach-e Judi – have yielded pottery that is comparable to ceramics from known historical contexts. Pottery from the Tujerdi site itself [Fig. 11] suggests that industrial-scale metalworking was actively carried out during the early Islamic period, roughly between the 9th and 12th centuries CE. Based on the assumption that some tablets from Persepolis mention mines located in the northeastern region of Fars, Emami and Yaghmaei[36] proposed that two mines in the Bavanat area may date back to the Achaemenid period. However, similar to the findings from Tujerdi, the archaeological survey of Bavanat[37] yielded no Achaemenid-period pottery from the sites associated with metallurgical activities.

Conclusions

The archaeological survey in the Tujerdi district of Sarchahan County, have revealed significant evidence of ancient mining, slag site and metallurgical activities. The survey conducted in 2020 led to the identification of one ancient mine and nine slag sites, shedding new light on the technological and economic importance of this area throughout history. Based on surface pottery, these sites appear to date from the Parthian/Sasanian to the Islamic periods, with a concentration of industrial activity during the early Islamic era.

[36] Emami & Yaghmaei, 2009.
[37] Khanipour, 2025c: 18.

The Hashaneh mine, likely an open-pit type, exploited naturally exposed veins of iron ore The proximity of the slag sites to water sources, such as springs and rivers, suggests that water usability was a crucial factor in the choice of smelting locations. In addition, the presence of vegetation would have supported the production of fuel needed for metal smelting.

The variety in the scale of slag accumulation across different sites, such as the large-scale operations at Golchenar B and the smaller ones at Hashaneh and Haji Gottou, indicates various levels of metallurgical activity. This may reflect differences in resource availability, labor organization, or chronological phases of extraction.

Although the study succeeded in identifying and mapping key industrial sites, challenges remain, particularly in establishing precise chronologies due to the limited quantity of diagnostic archaeological material. Nevertheless, this research highlights the integral role that mining and metallurgy played in the subsistence and economic strategies of past communities in the Tujerdi district. Future research should focus on archaeometallurgical analysis, and regional comparisons to reconstruct the full scope of ancient mining and smelting practices in this part of Iran.

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Disclosure statement
No potential conflict of interest was reported by the author(s).

To cite this article: Khanipour, M., Molaei Kordshouli, H. (2025). Metallurgy and Ancient Mining in Tujerdi District of Fars Province, Iran. *Historia i Świat*, 14, 103–118. https://doi.org/10.34739/his.2025.14.07