Scientific Research Publishing

International Journal of Geosciences, 2025, 16(8), 554-569
https://www.scirp.org/journal/ijg
ISSN Online: 2156-8367
ISSN Print: 2156-8359

Economic Significance of Hajigak and Syadara Iron Deposits, Bamyan Province Afghanistan

Mohammad Hussain Gorziwani

Department of Geology, Faculty of Geosciences, Kabul University, Kabul, Afghanistan
Email: hgorziwani7@gmail.com

How to cite this paper: Gorziwani, M.H. (2025) Economic Significance of Hajigak and Syadara Iron Deposits, Bamyan Province Afghanistan. *International Journal of Geosciences*, **16**, 554-569.
https://doi.org/10.4236/ijg.2025.168027

Received: July 17, 2025
Accepted: August 18, 2025
Published: August 21, 2025

Abstract

Afghanistan has three major natural potentials for its development (the potential of goods and energy transit, the potential of controlling the flowing waters in the country, the potential of using mineral resources). The Hajigak and adjacent Syadara iron deposits in Bamyan Province, central Afghanistan, represent some of the largest and highest-grade iron reserves in Asia. The large Iron deposit of Hajigak is located in the heights of Baba mountains, 100 km northwest of Kabul. Some organizations have estimated the value of the country's mineral resources as high as 3000 billion dolars. Most of these resources are located in Bamyan province. The main advantage of Bamyan province is having abundant coal resources and rich iron deposits in the vicinity. Preliminary and semi-detailed studies show that Hajigak reserves are at least more than two billion tons of iron ore. According to the studies conducted by the Ministry of Mines and Petroleum, the minimum amount of iron ore reserves in Syadara deposit is estimated to be more than 500 million tons. Mineral resources, including Hajigak and Syadara iron deposits in Bamyan Province, are the engine of all-round development of the industry in Afghanistan. The Hajigak iron deposit was formed as a result of contact metasomatism as a result of granite uplift in the Oligocene. This paper examines their geological setting, resource potential, economic viability, infrastructure requirements, and strategic importance, aiming to provide a comprehensive overview suitable for publication in international scientific journals.

Keywords

Hajigak, Syadara, Iron Ore, Afghanistan, Economic Geology, Mineral Resources

1. Introduction

Afghanistan possesses substantial iron ore reserves, primarily in the Central Af-

ghan Iron Belt (CAIB), with Hajigak recognized as the largest. Syadara, located nearby, shares similar geological characteristics. Together, these deposits offer exceptional potential for regional industrial development (Figure 1).

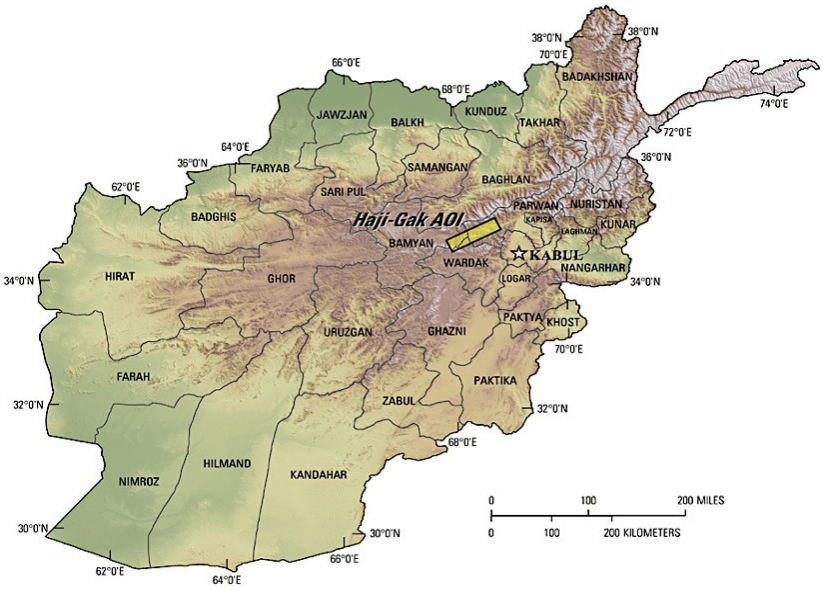

Figure 1. The Haji-Gak Iron ore deposit is located about 100 kilometers west of Kabul in Bamyan, Wardak, and Parwan Provinces.

Afghanistan is one of the countries that is rich in natural resources, based on these natural resources and its sustainable extraction, this country can be economically self-sufficient. Afghanistan has vast natural resources, including huge deposits of gold, silver, iron, copper, coal, and other natural resources. These resources have remained untouched in the country and have not developed much. Long-term instability has made mining not to take place on a large scale. Deposits, especially metal deposits, are always one of the main foundations of the economic and industrial growth of countries. Among these resources, iron, as one of the most consumed and strategic metals, plays an essential role in the development of infrastructure, manufacturing industries, and economic growth.

With abundant mineral resources, especially the huge Hajigak iron deposit, Afghanistan has the potential capacity to become one of the important players in the global mineral market. Hajigak iron deposit, located in Bamyan province, with estimated reserves of more than 2 billion tons, is considered one of the largest and richest iron deposits in the region [1] [2]. Geological investigations show that this deposit was formed as a result of complex metallurgical formation in different geological eras, especially in the tectonic zone of the central Hindu Kush. The presence of various iron minerals, including magnetite and hematite, along with the unique geological structure of the region, has given this reserve a special scientific and economic importance. The way of formation and economic importance of Hajigak and Syadara iron deposits is the purpose of the research. The importance of research is that research in the field of Hajigak iron deposits helps to discover efficient extrac-

tion methods, reduce costs and increase productivity. Also, by examining the security, economic and environmental challenges, solutions for sustainable development and investment attraction can be provided. With the correct management of Hajigek and Siahdara iron resources, it is possible to increase the national income and create job opportunities and industrial growth.

2. Methodology

2.1. Previous Work

The Haji-Gak iron deposit was discovered in 1900 AD and is located in Hajigak Pass area in Baba Mountain, where the English scientist named Hyden conducted her studies for the first time about Hajigak mineral deposit in 1911 AD. During this expedition, a stratigraphic sequence for the area was constructed, and three formations were identified, along with their ages; the formations were Kalu (Awband Formation) of Early Devonian age, Haji-Gak of Devonian age, and Helmand of Carbonaceous age. Hden has observed the hematite layers in the Hajigek iron deposit studies, and in the same way, after Hyden, other scientists have also studied this area.

In the years 1963-1964 AD, geological research and mapping on this deposit was formed by a survey team of Afghan and Soviet experts, and their maps were prepared on a scale of 1:500,000, and the map of the deposit area itself was prepared on a scale of 1:10,000. It should be added that sampling has been done in different areas and at different heights, and in the western parts of the mine, in Awband and Kalu areas, a lot of exploration work has been done, where drilling, trenching and water reserves are well observed [3].

2.2. Fieldwork Methodology

Geological structure of Hajigak Iron ore deposit from several works and sources in relation to the Farah block, especially Kalo formation, its formation conditions, mineral composition of host rocks, their physical-mechanical and petrographic characteristics, stability, color, etc., have been thoroughly and comprehensively analyzed and evaluated.

The ores of Hajigak Deposit were first visited. In these areas, the geological characteristics of the area, the sizes of the ores, their seam characteristics, have been studied. Also sampling was done from Hajigak deposit and the samples were transferred to the thin Section laboratory of the Department of Geology, Faculty of Geoscience, Kabul University after scoring, height and coordinates.

2.3. Laboratory Analysis

we prepared thin Sections from the samples in the laboratory. After preparing the thin Sections, they were transferred to the microscopy laboratory of the Department of Geology, Faculty of Geoscience, Kabul University for comprehensive study.

3. Potential for the Development of Afghanistan

Afghanistan has three major natural potentials for its development, which are as

follows:

The potential of goods and energy transit, the potential of controlling the flowing waters in the country, the potential of using mineral resources.

3.1. The Transit Potential of Goods and Energy

Afghanistan, being located on the border between Central Asia with 300 million population and South Asia with one billion population, has a suitable potential for the transit of goods and energy between these two populations (Figure 2).

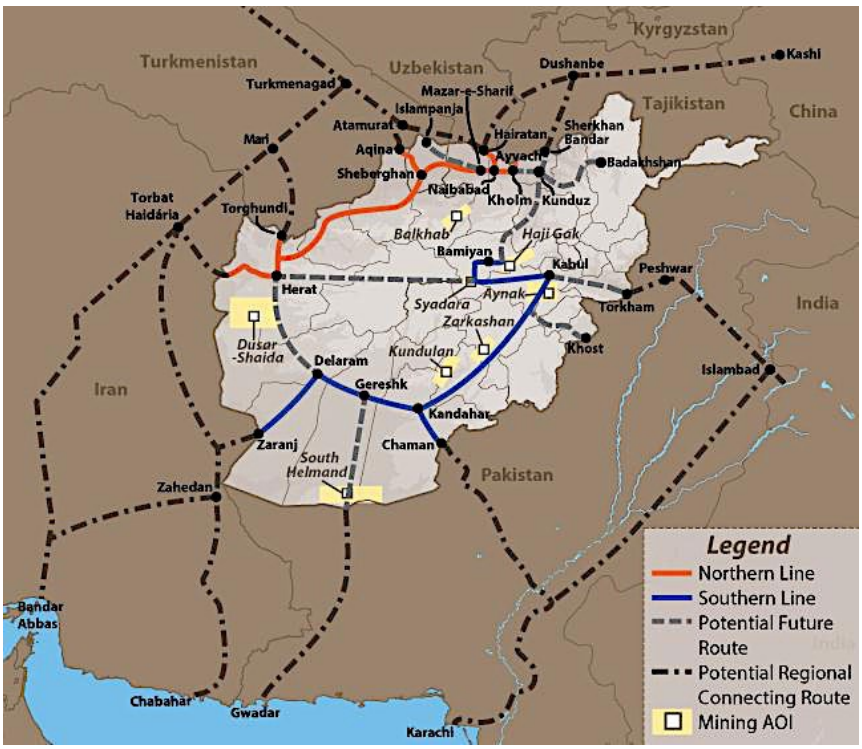

Figure 2. Afghanistan national railway plan.

The comprehensive development of railways plays a key role in this direction. In addition to meeting domestic needs, the development of the country's roads has an undeniable transit role in this regard. Central Asia with huge reserves of oil and gas and hydropower resources on the one hand and South Asia with a growing economy and demand for energy on the other hand have once again placed Afghanistan in the center of energy transit. Many existing projects of energy transmission lines and TAPI gas pipelines are being implemented for this purpose, which both raise domestic needs and help connect the consumption and production markets (Figure 3).

3.2. The Potential of Using Mineral Resources

Some organizations have estimated the value of the country's mineral resources as high as 3000 billion dolars. Most of these resources are located in Bamyan province. The main advantage of Bamyan province is having abundant coal resources

and rich iron deposits in the vicinity.

3.3. Potential for Harnessing Afghanistan's Running Waters

The hydroelectric power generation capacity in Afghanistan is estimated at around 23,000 MW. Currently, around 1000 MW is in operation. The development and expansion of this sector, in addition to producing energy and meeting the needs of industry, will also lead to an increase in hundreds of thousands of hectares of agricultural land, which will play a major role in Afghanistan's development prospects. Figure 4 shows the major rivers of Afghanistan.

Figure 3. Map of TAPI gas pipe.

Figure 4. Afghanistan River map.

4. Hajigak Iron Ore Deposit

The large Hajigak iron ore deposit is located in the heights of Baba mountains, 100 km northwest of Kabul and east of Bamyan (Figure 5). It is considered the largest iron deposit in Afghanistan and in the region. Hajigek iron deposit is located in layered and lenticular form inside proterozoic rocks and is mainly composed of hematite and magnetite. This deposit was identified in 1911 and has been studied by various geologists. Hajigek iron deposit is 12 kilometers long, 550 meters deep and 600 square kilometers in area [4].

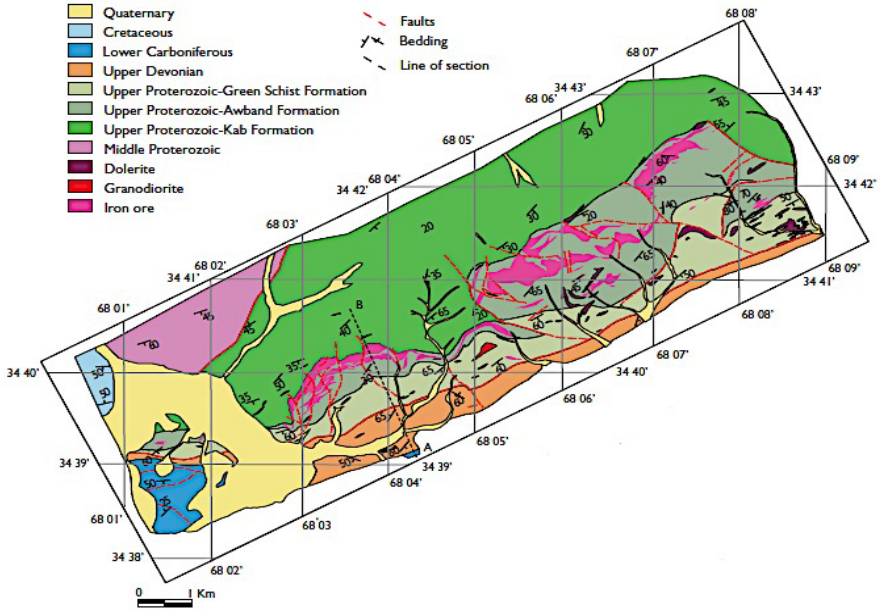

Figure 5. Simplified geological map of the Hajigak area.

Exploratory research of this field has been done by foreign experts. The British, Germans, French and finally the Russians have studied and evaluated this area. The most important researches were carried out by the Russians in the 1970s and 1989s, when they completed the exploration stages and designed the extraction plans.

In the area of the deposit, Proterozoic schist effusive rocks and Devonian-Lower Carboniferous carbonate rocks are located. Here, 16 mineral bodies and 4 parts where mineral fabrics were seen have been separated. The shapes of the mineral bodies are layer-like, rarely lens-like and vein-like [5].

4.1. Geographical Location of Hajigak Iron Deposit

In terms of geographical location, Hajigak iron deposit is located 45 km east of the historical and ancient city of Bamyan province and 100 km northwest of Kabul, at 34 degrees and 40 minutes of north latitude and 68 degrees and 14 minutes of east longitude, and it is located at an altitude of 3250 meters to 3800 meters above sea level. One of the advantages of Haji Gek iron deposit is its deposit, which matures at about 2 billion tons. Also, the location of the iron ore in this deposit is such that its exploitation in the open space is possible. In addition, this deposit is very rich in

terms of the quality and content of the deposit. This area is generally mountainous and has a high altitude, which consists of different valleys and mountains, and has many low lands and heights. But the slope of the northwestern area is smooth and gentle, and also the area of Hajigek iron deposit has a very steep slope, and in the upper parts of it, you can see the effects of glaciers, which ate and removed large pieces of stone from the original position of the stone, *i.e.*, the peaks, and carried them to the lower areas, and this area also has monsoon floods [6] [7].

4.2. Climatic Conditions

In terms of climatic characteristics, Afghanistan is located in the sub-tropical point, and the most important issue in Afghanistan is the existence of the Hindu Kush mountain range, Baba Mountain, Pamir Mountain, Syah Mountain, and Sefid Mountain. The formation of these mountains is generally caused by the movement of the Indian and Asian plates. This chain of mountains has high altitudes and is permanently covered with snow, each of which has different characteristics and features and has a lot of low and high altitudes that affect the climate of the region. Baba mountain is one of the central mountains of Afghanistan, where the Hajigak iron deposit is almost located. The climate of Hajigek iron deposit area is almost dry, which is cold and humid in winter and hot and dry in summer. Its average temperature reaches minus 15 - 20 degrees Celsius in winter and plus 15 - 20 degrees Celsius in summer. In general, annual rainfall in this area is in the form of snow, rain and dew, which occurs in winter and early spring. During the winter, the public road of Bamiyan Kabul is blocked in this direction and the thickness of the snow reaches approximately 50 - 150 cm [8] [9].

4.3. Geological Setting

Hajigak comprises 16 ore zones spanning ~32 km, each up to 5 km long, ~380 m wide, and 550 m deep. Ore consists of massive, semi-banded magnetite-chalcopyrite-pyrite (~80%) and oxidized hematite-martite-goethite (~20%) varieties [10].

The oldest part of the succession crops out north-west of the Hajigak deposits (**Figure 5**). It consists of grey silicified limestones and dolomites interbedded with dark grey crystalline schists and light coloured quartzites that display evidence of amphibolite grade metamorphism. They are mapped as the Jawkol Formation, and interpreted as Middle Proterozoic in age. The Hajigak iron deposit is hosted by the Upper Proterozoic Awband Formation that, together with the underlying Kab Formation, constitutes the Qala Series, a sequence of metavolcanic and metasedimentary rocks up to 4500 m thick [11].

The Kab Formation consists of dark grey sandy sericitic schists, interpreted as metamorphosed terrigenous rocks, acid volcanic rocks and minor beds of marble and phyllite. The Awband Formation is made up of schists (quartz-sericite, quartz-chlorite-sericite, quartz-sericite-chlorite and carbonaceous sericite) that are metamorphosed acid and basic tuffites and argillaceous rocks. The Green Schist Formation, a distinctive unit overlying the Awband Formation, consists dominantly of green chlorite schists, and quartz-sericitic schists locally intruded by granodiorites.

Some reports consider it to be a member of the Awband Formation [12] [13].

Upper Devonian rocks of the Hajigak formation are faulted against the Green Schist formation. The predominant strike of the Proterozoic and Paleozoic rocks is NE with a regional dip of approximately 50 degrees towards the SE [14].

4.4. Regional Tectonics

The deposits are hosted within Proterozoic metavolcanic and metasedimentary rocks of the Awband-Kab (Qala) Formation in central Afghanistan and align with the Herat Fault Zone, arising from Indo-Eurasian tectonic interactions [15].

Three tectonic stages have been reported in Hajigek region (**Figure 6**).

The first stage: the tectonic movements of folding and warping and breaking of Proterozoic and Lower Paleozoic rocks include the folding and warping in the northeast side and in some areas it is opposite to the horizontal axis [16].

The second stage: the folding of the Lower Carboniferous red strata, which was unconformably located at the top of the Paleozoic, and this folding has a normal state.

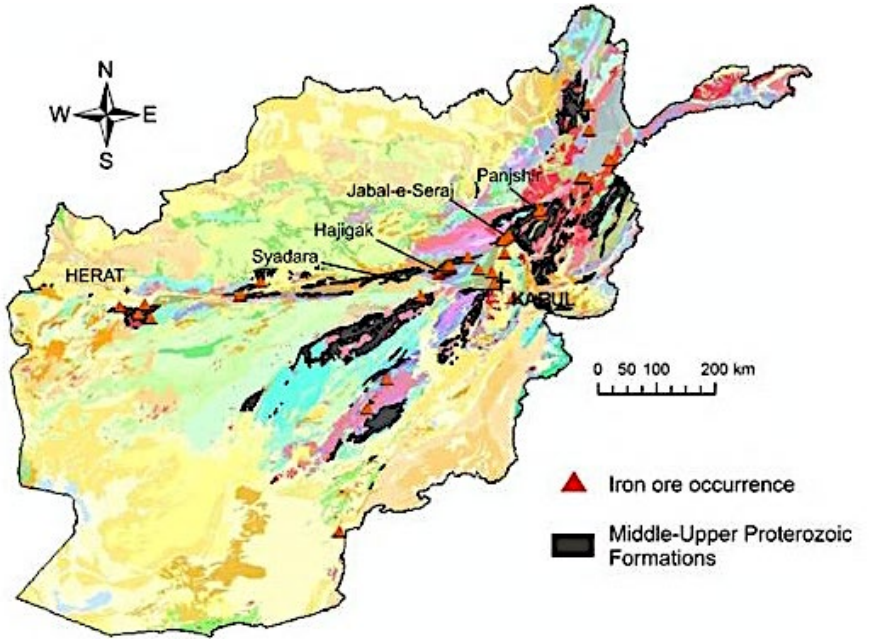

Figure 6. Geological map of Afghanistan showing location of stratiform iron ore occurrences and Middle to Upper Proterozoic formations.

The third stage: tectonic movements have affected young rocks. The failures are of the vertical displacement type, and the floors have slipped horizontally. The vertical displacement is estimated to be 500 meters, which had a direct impact on the formation of the Hajigak iron deposit. But the biggest displacement in the Hajigek Kharzar fault zone is with a dip of 60 - 80 degrees to the southeast, almost parallel to the strata, which continues up to 30 kilometers. It turns out that the failure of Hajigek Kharzar is internal. Because the upper Devniane Hajigak series is in contact with the green schist in most places along the fault in the contact zone, which in some areas forms the lower Paleozoic Awbend series and the lower

Carboniferous Kharzar series on the side of the fault.

4.5. Mineralisation

The Hajigak deposit trends NE-SW for about 9 km and is made up of 16 separate ore bodies, each up to 3 km in length. The deposit can be divided up into three geographical parts, the western, central and eastern parts. In addition to the large ore bodies there is a substantial area of thin fragmental ore deposits in the form of four surficial deposits. The main hematitic ore is medium- to fine-grained and displays a variety of massive, banded and porous textures. It occurs in lenses and sheets, within the Awband Formation. The thickness of the lenses indicated by drilling to be up to 100 m, while the depth of mineralisation is untested 180 m below surface [17] [18].

There are two main ore groups: unoxidised primary ores and semi-oxidised ores.

Unoxidised primary ores occur below 100 m and consist of magnetite and pyrite, with up to 5% chalcopyrite and pyrrhotite. Semi-oxidised ores extend down to 130 m below ground surface, consist mainly of magnetite, martite and hydrogoethite [19]-[21]. There are two other oxidised ore types in the deposit: Hydrogoethite/hematite/semi-martite and carbonate/ semi-martite, occur sporadically in small amounts (**Figures 7-9**).

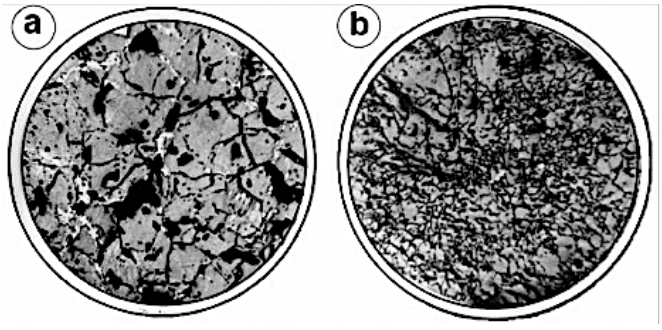

Figure 7. Thin sections of hydrogoethite-semimartite ore. a—Hydrogoethite-semimartite ore with massive hypidioblastic texture. Magnetite (dark grey) underwent martitization (light-grey) and developed pores (black); b—Hydrogoethite-semimartite ore that has been recrystallized. Magnetite (grey) includes quartz (dark grey).

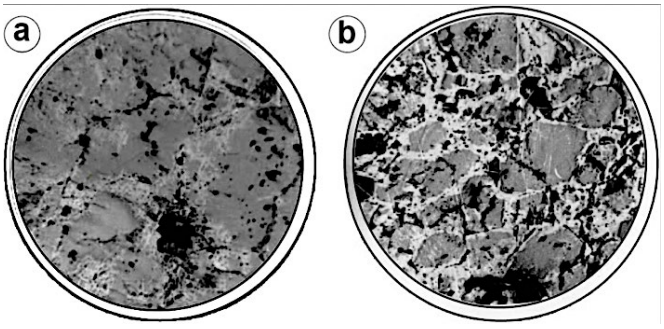

Figure 8. Photographs of martite-bearing ores from Thin sections: a—Martite (light grey)replaces magnetite (dark grey), creating a web or spongy texture. Dark-grey loops are iron oxide minerals, and areas in black are the pores and quartz. b—martite (white) replacing magnetite (grey), creating a mesh texture. Black is pores, and dark grey is the iron oxide minerals.

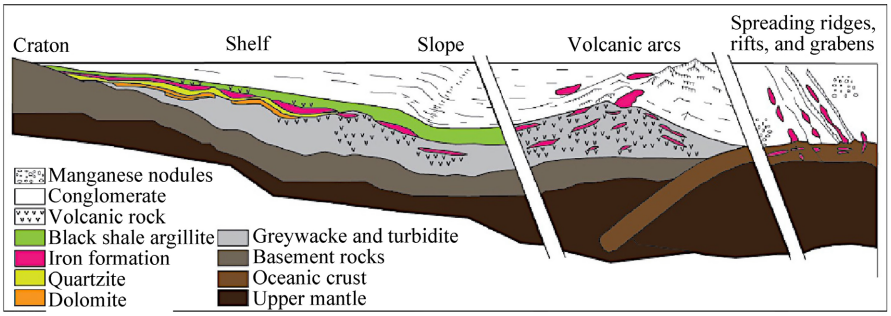

Figure 9. Diagram of the environment most likely for the formation of sedimentary and volcanogenic iron deposits. The diagram shows the formation of Algoma iron type deposits near the Volcanic arc and Lake Superior type deposits near the upper shelf. Rocks of each type of deposit are represented. The Haji-Gak iron deposit contains rocks more closely related to volcanoclastic settings [30].

4.6. Metallogenesis

Various models have been suggested for the formation of Hajigak deposit, including metosomatic skarn, banded iron formation and also submarine-exhalative [22]-[24]. It is believed that as the Upper Proterozoic basin evolved there was an increase in the volcanic input to the sediments. Synchronous with this volcanism Fe-bearing hydrothermal fluids were introduced which led to precipitation of iron oxides and sulphides in the form of large sheets and lenses in oxidising shallow water marine conditions [25] [26]. These fluids would have been circulating sea water or magmatic, or a combination of both. Diagenesis and metamorphism converted the iron oxides to the magnetite that is found in the primary ore. Later supergene and/or hydrothermal processes oxidised the ore into hematite and goethite. This model for the Hajigak iron deposits resembles the Algoma iron type deposit (**Figure 10**), which is hosted by volcanogenic iron-bearing sequences mostly of Archean or Proterozoic age, similar to the Awband Formation at Hajigak. The Algoma iron type deposits from microbanded to mesobanded lenticular shapes that are less than 50 metres thick [27] and occasionally extend for more than 10 kilometers along strike, similar to the Hajigak iron deposit. Rock types usually associated with Algoma iron type deposits are mafic to felsic submarine volcanic rocks and deep-water clastic and volcanoclastic sediments [28] [29].

4.7. Resource Estimates & Ore Grades

Total inferred and measured resources: ~1.8 billion tonnes ~62% Fe. C2 + P2 resources: ~1.66 billion tonnes (~94% of resource base). Magnetite-rich primary ore and oxidized secondary ore types are both present. Regarding the grade of Hajigak iron ore, the following conclusions have been made [31] [32].

1) The probable reserve is 1.8 billion tons and the percentage of iron is 62%.
2) The average grade in the main area of the deposit is 62 - 83% Fe.
3) The grade of the enriched area is 68 - 89% Fe.
4) The proved reserves of the main area is 110.9 million metric tons.
5) The total reserves of the main area is 2070 million metric tons.

In addition to iron, the amounts of elements such as barium (Ba), magnesium (Mn), nickel (Ni), cobalt (Co)and silver (Ag) are also significant in this deposit as co products. The percentage of other elements in this deposit is as follows [33] [34]:

1) Sulfur in sulfates S = 0.04%.

2) Sulfur in sulfides S = 69.4%.

3) Phosphorus P = 0.05%.

According to experts, several coal mines located near the Hajigak iron deposit and in the north of Bamyan can be used for the construction of iron smelting factories, such as Dere Suf and Yakavalang coal mines. Quality coal pieces are available in Sighan and Kohmard districts of Bamyan province in an area of about 80 to 100 km [35].

5. Syadara Iron Ore Deposit

Iron ore mineralization at Syadara [66.89710˚ E 34.61906˚ N] is hosted by a sequence of Proterozoic rocks comparable to those 110 km along strike to East at Hajigak (**Figure 10**). Recent geological mapping by the Afghanistan Geological Survey [36] shows that the mineralization is strata bound, massive magnetite, hosted by chlorite-sericite schist, metadolomite and quartz-sericite phyllite. The mineralization trends NE-SW and more than 10 km along strike length, but individual bodies are discontinuous with an average thickness of 15 - 30 m and steeply dipping 70 - 80˚ to the SE. The thickest body is 50 - 70 m wide and dips 45˚ NW over a strike distance of 500 m. Based on the highest and lowest outcrop elevations, a 400 m depth of the mineralization can be ascertained [37].

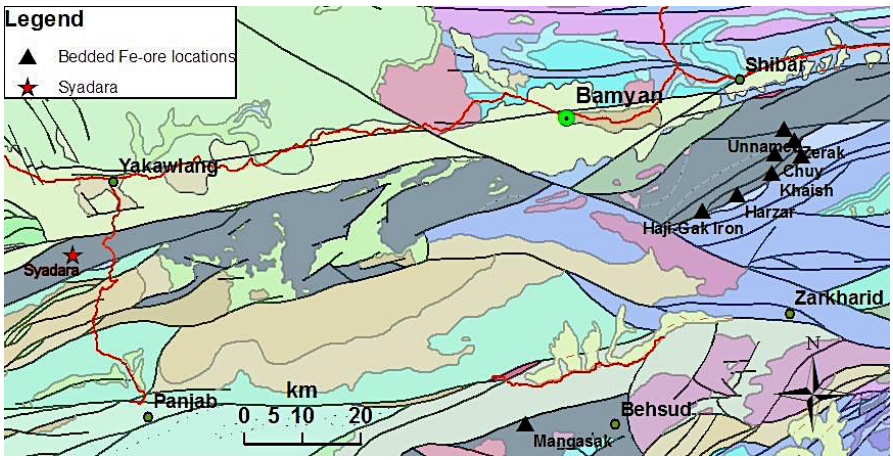

Figure 10. Geological sketch map showing the location of Syadara and Hajigak. Proterozoic rocks shown in dark grey, and roads in red.

The Syadara iron ore body is characterized by massive magnetite with weak hematite-pyrite and trace chalcopyrite mineralization. Intense surficial oxidation represented by goethite, martite and hematite is well developed in places with trace malachite, azurite and neotocite [38].

Ground magnetic and self-potential surveys were completed over an area of 4 km × 1 km with a line spacing of 100 m. The magnetic data correlated well with the mapped massive magnetite body and indicated possible extensions below surface. Furthermore, major lineaments with apparent sense of movement and displacement were detected by the ground magnetic survey.

Composite grab samples were collected from the different magnetite bodies and showed a range of values between 60.8% - 67.7% Fe with 0.23% - 1.55% S and 0.03% - 0.34% P. Using the above data and assumptions about continuity of the bedded ore bodies a hypothetical resource of about 400 Mt at 65% Fe can be estimated.

6. The Value of Hajigak and Syadara Iron Deposits

In order to clarify the value of iron reserves in Bamyan province, we will do some preliminary and simple calculations. We consider the total volume of Hajigak and Syadara iron reserves to be 2.5 billion tons:

Currently, each ton of iron ore is 50 dollars in the world market, so we have:

$$50 \times 2.5 = 125 \text{ billion dollars}$$

More than 60% of each ton of iron ore is converted into pure iron. Therefore, after the construction of the iron smelter, the potential value of iron can be calculated as follows: Also, the value of each ton of the iron smelter's product in the market is around 600 dollars, so we have:

$$2.5 \times 6.0 \times 600 = 900 \text{ billion dollars}$$

Therefore, with the construction of the iron smelting plant, the potential value of the iron deposit will reach 900 billion dollars. After the construction of the iron smelting plant, the development of the metallurgical industry will be provided. In the metallurgical industry, other metals such as chromium, nickel, tin, zinc, lead, carbon, etc. are used to improve the properties of iron and produce various alloys needed by the industry. At this stage, the value added to the primary iron is very high. Just for comparison, pay attention to the difference in the price of a cast or nickel tube with the same weight of simple iron. In the next phase, we can mention the construction of rolling and component manufacturing industries, which directly provide the parts needed by the industries. At this stage, we will see a huge increase in the added value of metallurgical industry products [39].

7. Major Prerequisites of the Iron Industry

The main prerequisites of the iron industry are as follows:

Water: Bamyan has enough of this blessing and has the headwaters of two rivers, Bamyan and Helmand.

Road and rail transportation system: Currently there is a road but the rail system has not yet been established.

Coal: Coal is used in the iron industry as heat for melting and coke for purification. As mentioned in Bella, there are plenty of iron deposits nearby.

Cheap energy: This industry is highly dependent on cheap energy, and as mentioned, there is potential in the Bamiyan coal belt.

8. Contract of Foreign Companies on Hajigek Iron Deposit

In 2010, Afghanistan published the tender notice of Hajigak iron deposit in the international journal. Based on these announcements, 23 international companies expressed their interest in participating in the tender, and as a result, six companies 2005 were recognized as eligible for the contract.

Hajigek iron deposit is divided into four blocks (Figure 11).

Block A has been assigned to the Canadian Kilogold Mine Company, Block B, C and D to the Indian Seal Consortium. In this way, two companies from Canada and India have been preferred to extract the Hajigak iron deposit.

The Indian government is going to invest 14 billion dollars on Hajigak iron deposit, Indian companies will undertake the construction of the railway from Hajigak iron deposit to Chabahar port in Iran. Hajigak iron deposit has three large deposits, two of which are contracted by the Indian group and the last one by a Canadian company with the Afghan government for extraction.

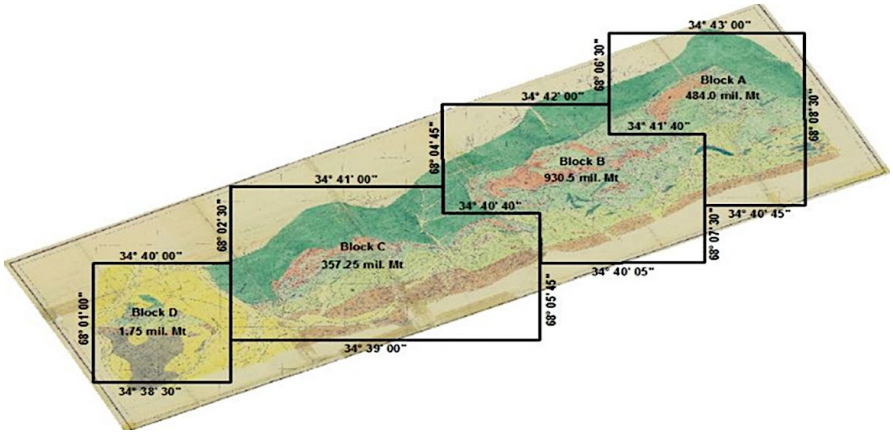

Figure 11. First four blocks A, B, C and D in Hajigak Iron ore deposit.

9. Hajigak Field is the Foundation of Deep Changes in Afghanistan's Economy

The extraction of iron from this deposit is of special importance in various sectors and can bring great changes in Afghanistan in various fields. At the time of concluding the Hajigak iron ore extraction contract with the Indian company, the Afghan government stated that, along with its extraction, the Indian company is obliged to build a steel production plant and build a power plant with a capacity of producing 800 megawatts of electricity per hour.

The amount of money that was supposed to be invested in this company was 10 billion and 800 million dollars, and the Indian company considered itself in need of investing 75 million dollars in the first days of its extraction, and for this reason, it requested the cooperation of the New Delhi government.

10. Strategic Economic Significance

1) High-Grade Ore

The ~62% Fe grade places these deposits among the most valuable globally.

2) Steel Value Chain

Presence of nearby coking coal supports establishment of integrated steel plants.

3) Job Creation &Gross Domestic Product (GDP) Gains

Development projects forecast 6000+ direct jobs and multi-percent GDP growth potential.

4) Infrastructure Development

Key infrastructure includes rail links, roads, and electrification corridors.

5) Foreign Direct Investment (FDI) & Governance

International funding, transparency, and governance reform are critical to success.

11. Development Challenges

Security concerns, difficult terrain, and technical gaps hinder rapid development. Transparent governance and community involvement are required for success.

12. Future Outlook & Recommendations

Recommendations include updated drilling, petrological studies, infrastructure expansion, and institutional reforms.

13. Result and Discussion

Total inferred and measured resources: ~1.8 billion tonnes ~62% Fe. C2 + P2 resources: ~1.66 billion tonnes (~94% of resource base). The total reserves of the main area is 2070 million metric tons Magnetite-rich primary ore and oxidized secondary ore types are both present.

14. Conclusions

The Hajigak and Siyadara deposits represent world-class, high-grade iron resources with potential to catalyze Afghanistan's industrial transformation.

The Hajigak iron-ore deposit is a world class-sized deposit, more than 32 km long and potentially contains 16 separate zones, some of which are up to 15 km long, 380 m wide, and extend 550 m down dip. Seven of these zones have been studied in detail. Previous Russian resource estimates for the entire deposit are 1800 Mt, within which fully explored resources (A + B + C1) amount to 110 Mt. The Kharzar, Khaish, Chuy, Khakriz, and Zerak bedded iron-ore deposits to the east of Hajigak are highly prospective.

A similar prospect, Syadara, has been recently discovered 100 km west of Hajigak and further potential exists to the east at Jabal-e-Seraj and the Panjsher Valley. The Upper Proterozoic rocks of central Afghanistan are highly prospective for discovering more stratabound iron deposits.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

[1] Abdullah, S.H., Chmyriov, V.M. and Dronov, V. I. (2008) Geology and Mineral Resources of Afghanistan (Book 1 Geology). Report Series Published by BGS.

[2] Peters, S.G., Renaud, K.M., Tucker, R.D., *et al.* (2011) A Reevaluation of the Mineral Resources of the Haji-Gak Iron Deposit. USGS Open-File Report 2011-1204.

[3] Tazri, S. (2010) Ahmiyat eqtesadi ma'adan Afghanistan [Economic Importance of Afghanistan's Mines]. Maahnameh Eqtesadi, Ejtemai va Farhangi, Ghaznfar Bank, vol. 2, pp. 3-5. [in Persian]

[4] Sahak, N. (2010) The Science of Ore Deposits (Metallic Ore Deposits). Printing Press of the Higher Education Publication.

[5] Abdullah, S.H. Chmyriov, V.M. and Dronov V.I. (2019) Geology and Mineral Resources of Afghanistan (Book 2). (Sahak, Naqibullah, Trans.), Azem Publication.

[6] Abdullah, S.H., Chmyriov, V.M. and Dronov, V. I. (2008) Geology and Mineral Resources of Afghanistan (Book 2 Mineral Resources of Afghanistan). Report Series Published by BGS.

[7] Abdullah, S.H. Chmyriov, V.M. and Dronov, V.I. (2020) Geology and Mineral Resources of Afghanistan (Book 1) (Sahak, Naqibullah, Trans.), CoAR Publication.

[8] Abdullah, S.H., Chmyriov, V.M., Stazhilo-Alekseev, K.F., *et al.* (1980) Geology and Mineral Resources of Afghanistan (2nd ed.). Kabul, Afghanistan, Republic of Afghanistan Geological and Mineral Survey.

[9] Gorziwani, M.H. (2018) Metallic Deposit. Said Publication.

[10] Ahmadi, H. and Uygucgil, H. (2021) Targeting Iron Prospective within the Kabul Block (SE Afghanistan) via Hydrothermal Alteration Mapping Using Remote Sensing Techniques. *Arabian Journal of Geosciences*, **14**, Article No. 183. https://doi.org/10.1007/s12517-020-06430-3

[11] Afghanistan Geological Survey (2011) Minerals in Afghanistan: Syadara Iron Ore Deposit. AGS Investor Data Package No.2, 6 p.

[12] Afghanistan Geological Survey (2007) Minerals in Afghanistan: The Hajigak Iron Deposit, Afghanistan. Geological Survey.

[13] Afghanistan Geological Survey (AGS) (2014): Minerals in Afghanistan. AGS Investor Data Package No.2, 7.

[14] Naqibullah, S. (2010) Elm-e Maadan (Maadan-haye Felezi) [Mining Science (Metallic Mines)]. Ministry of Higher Education of Afghanistan Press.

[15] Steinmüller, K., Coats, J.S., Braeutigam, B. and Garry, J. (2010) The Metalliferous mineral Potential of Afghanistan. BGS.

[16] Bouladon, J., and de Lapparent, A.F. (1975) The Iron minerals of Hajigak Pass, Afghanistan; Stratigraphic Position, Geological Evolution and Type of Deposit. *Mineralium Deposita*, **10**, 13-25. https://doi.org/10.1007/BF00207457

[17] Sadat, S.A. (2019) Afghanistan: Sarmay-e Zakhayer-e Naft, Gaz wa Maadan-e Arzeshmand-e Jamed [Afghanistan: Land of Valuable Oil, Gas and Solid Mineral Resources]. Kanda Gol Printing and Advertising Company.

[18] Keselove, N.Y. and Peredovfske, A.A. (2019) Mabhni geokimia [Fundamentals of Geochemistry]. Mostaqbel Press, Kabul Afghaistan.

[19] Malistani, H. (2011) Express Report on Hajigak Iron Ore Deposit Bamyan, Central Afghanistan. ResearchGate.

[20] Malistani, H. (2020) Iron Ore and Iron Ore Deposits of Afghanistan. *International Journal of Research and Analytical Reviews*, **7**, 131-146.

[21] Malistani, H. (2016) Geology and Genesis of Hajigak Iron Ore Deposit, Bamyan Central Afghanistan. Bonn University.

[22] Peter, J.M. (2010) Hydrothermal Influences on Iron Formation Genesis. In Geology, Mineralogy, and Genesis of Precambrian Iron formations, Duluth, October 10-16 2010: Precambrian Research Center, University of Minnesota Duluth, Presentation, 36 p.

[23] Treloar, P.J. (2015) Stratigraphic and Tectonic Evolution of the Northwestern Indian Plate and Kabul Block. Lyell.

[24] Pohl, W.L. (2020) Economic Geology Principles and Practice: Metals, Minerals, Coal and Hydrocarbons—Introduction to Formation and Sustainable Exploitation of Mineral Deposits. Blackwell Publishing Ltd.

[25] King, T.V.V., Kokaly, R.F., Hoefen, T. *et al.* (2011) Surface Materials Map of Afghanistan—Iron-Bearing Minerals and Other Materials. U.S. Geological Survey Scientific Investigations Map 3152-B. https://doi.org/10.3133/sim3152B

[26] Kotchetkov, A.Ya. (1976) Some Features of Metallogeny of Central and Western Afghanistan. *Izvestia Vysshik Uchebnykh Zavedeniy*, **4**, 75-77.

[27] Mosier, D.L. and Singer, D.A. (1986) Grade and Tonnage Model of Superior Fe and Algoma Fe Deposits, In: Cox, D.P. and Singer, D.A., Eds., *Mineral Deposit Models*, U.S. Geological Survey Bulletin 1693, 228-230.

[28] Stazhilo-Alekseev, K.F. (2020) Magmatism va metallogeny Afghanistan [Magmatism and Endogenic Metallogeny of Afghanistan]. Azem Press, Kabul.

[29] Orris, G.J. and Bliss, J.D. (2002) Mines and Mineral Occurrences of Afghanistan. U.S. Geological Survey Report 02-110, 95 p. https://doi.org/10.3133/ofr02110

[30] Peters, S.G. (2007) Chemical Sedimentary Deposits in Afghanistan. U.S. Geological Survey Open—File Report.

[31] Gorziwani, M.H. (2015) Economic Geology. Qertaba Publication.

[32] Gorziwani, M.H. (2021) Mineral Exploration. Mader Publication.

[33] Chmyriov, V.M., Stazhilo-Alekseyev, K.F., Mirzad, S.H., *et al.* (1973) Mineral Resources of Afghanistan. *Geology and Mineral Resources of Afghanistan*, 1st Edition, Afghanistan Geological and Mineral Survey, 44-86.

[34] Chmyriov, V.M., Stazhilo-Alekseev, K.F., Azimi, N. and Giroval, T. (1976) Metallogenic Zoning of Afghanistan. Theses of Reports. In: *Bulletin of the IVth Scientific Conference Held in KU and KPI*. Kabul, Afghanistan, pp. 57-58.

[35] Sihun, S. (1390) The Possibilities of Exploiting Afghanistan's Mineral Resources, Challenges and Consequences. *Economic*, *Social and Cultural Monthly of Ghazanfar Bank*, No. 26 and No. 27, 16-19.

[36] Doebrich, J.L. and Wahl, R.R. (2006) Geologic and Mineral Resource Map of Afghanistan. USGS/AGS File Report 2006-1038.

[37] Wikipedia (2025) Mining in Afghanistan.

[38] Zaki, M.A. (2015). Maadan-e Afghanistan, Qarardadha wa Chalesha [Mines of Afghanistan, Contracts and Challenges]. Vajeh Publishing, Kabul, Afghanistan.

[39] Yazdi, R. and Jan, A. (2008), Afghanistan and Poverty Alleviation with Management Development, Mashoor Publishing House and Ganj Marafet Press, 80-90.