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Ministry of Mines and Petroleum

IRON ORES

MINERAL RESOURCES IN AFGHANISTAN

2021

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Hajikak Mine, Afghanistan
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IRON ORES

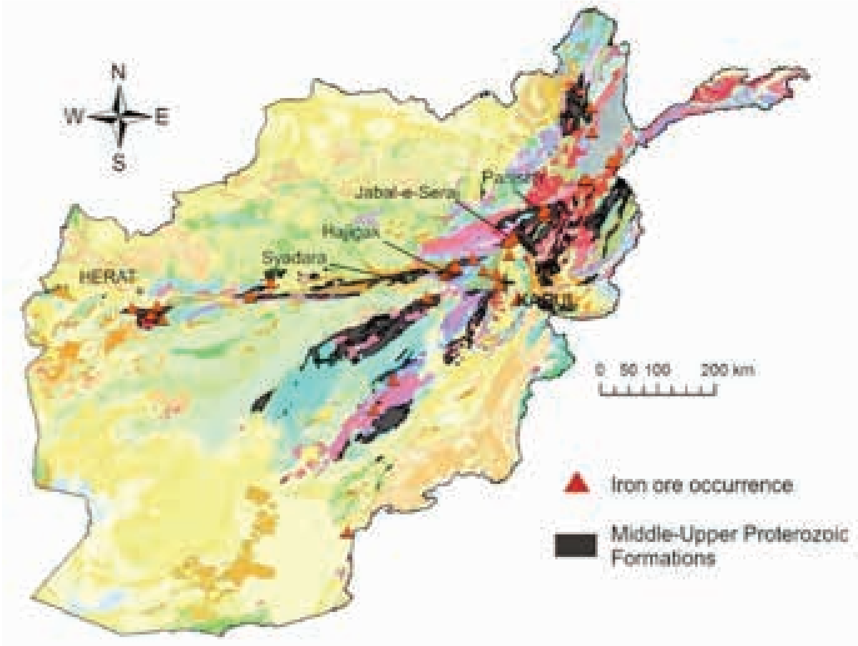


Figure 1. Geological map of Afghanistan showing location of stratabound iron ore occurrences within Middle to Upper Proterozoic formations.

Geologic Outline
The well known iron ore deposits are found from western Afghanistan along the Herat fault system through central Afghanistan and north-ward to the Panjshir valley and possibly into Badakhshan (*Figure 1*). The best-known sedimentary Hajigak and Syadara iron deposits are locating in the same belt, hosted With by Neo-Proterozoic metamorphic rocks that represent the basement rocks of the Gondwanaland continent. At Syadara, the basement rocks are sandwich between Herat and Gagharnaw faults, represent the final closing of the Paleotethys Ocean (*USGS GIS, Peters et al., 2007*).

HAJIGAK

The largest and best known deposit Hajigak is discussed first with brief descriptions of the other occurrences to show the potential for further discoveries. Hajigak has been the subject of numerous studies but the most comprehensive study of the geology and mineralisation is by Kusov et al. and recently reinterpreted by Peters et al. (*2011*), who give a comprehensive list of (*1965*) and recently references.

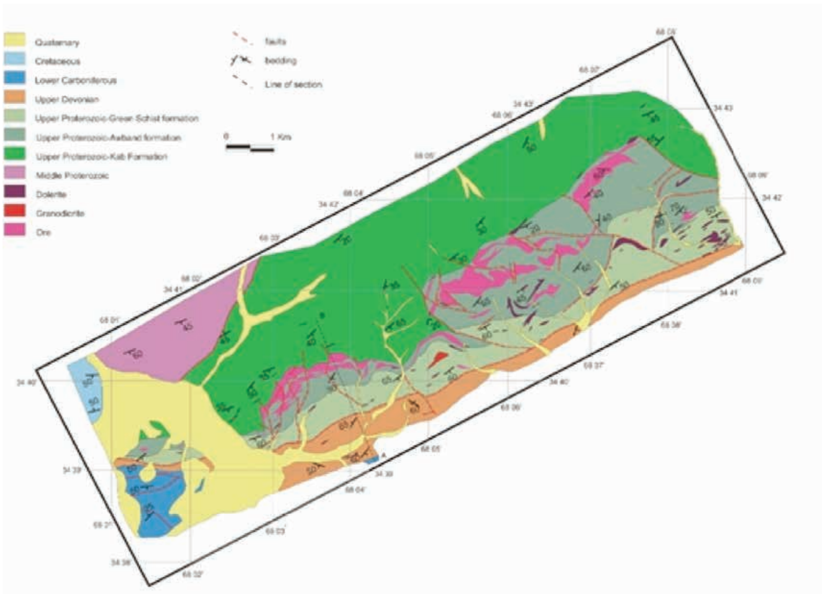


Figure 2. Simplified geological map of the Hajigak area (after Kusov et al., 1965).

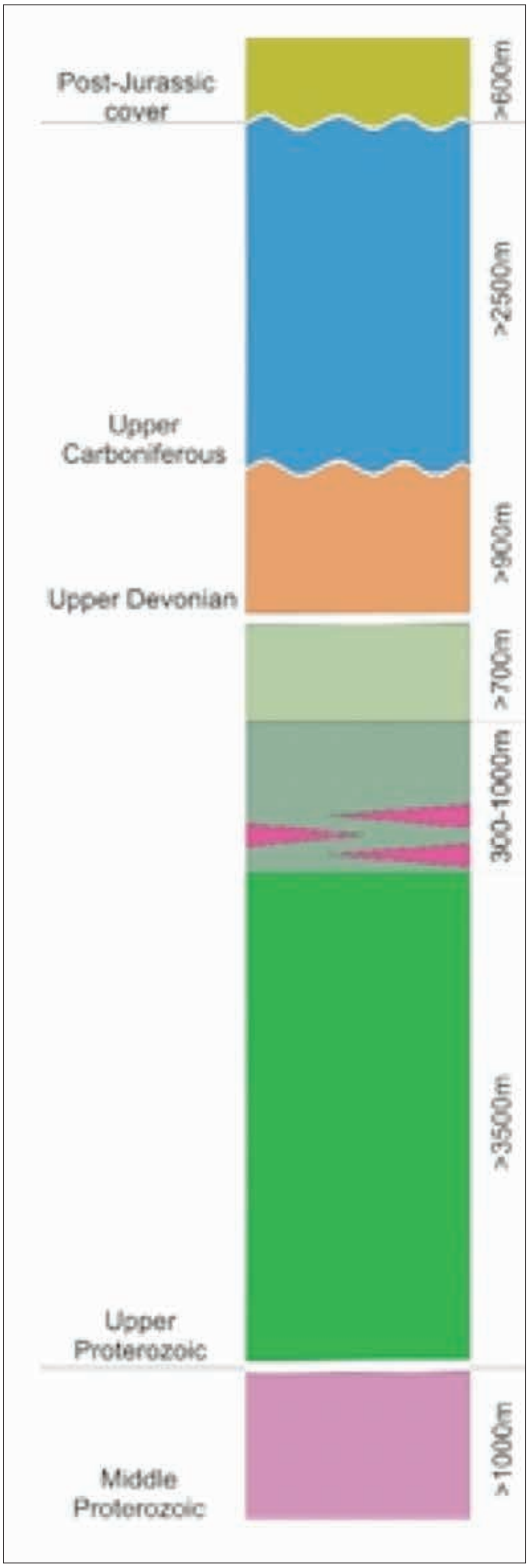


Figure 3. Stratigraphic log of the Hajigak area. (after Kusov et al., 1965).

Geology of Hajigak

The oldest part of the succession crops out north-west of the Hajigak deposits (*Figure 2*). 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 4,500 m thick (*Figure 3*). 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.
Upper Devonian rocks of the Hajigak formation are faulted against the Green Schist formation. The predominant strike of the Proterozoic and Palaeozoic rocks is NE with a regional dip of approximately 50° towards the SE.

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. 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.

There are two other oxidised ore types in the deposit: Hydrogoethite/hematite/semi-martite and carbonate/ semi-martite, occur sporadically in small amounts. Alteration of the host rocks, which may be related to the mineralizing event, includes sericitisation, silicification and carbonisation.

Exploration

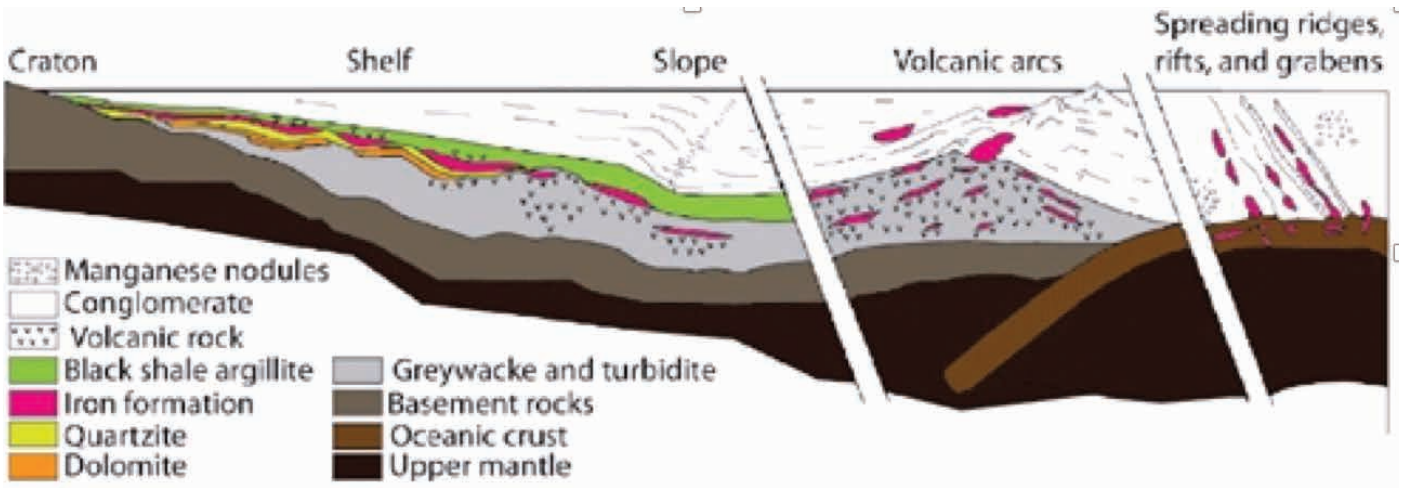
Iron occurrences were observed during initial geological mapping of the area in the mid-thirties but the economic potential was not fully recognized until a joint Afghan-Soviet project, between 1963 and 1965, carried out an extensive study which mapped and described the deposit in some detail (*Figure 2*). The regional geology was mapped at 1:50,000 while the Hajigak deposit was mapped at 1:10,000. Focusing on the western area of the deposit, the study included detailed prospecting, trenching, four deep drill holes, a 200m long horizontal adit and shafts into the fragmental ore. For two of the main ore bodies, I and II, horizontal plans and vertical cross-sections were generated allowing the ore to be resource classified. Although the ore bodies were thought to be of limited depth extension there is no deep drilling to confirm this. The detailed study focused on the western section of the ore body and a detailed resource estimate could only be made for a small portion of the deposit.

Metallogenesis

Various models have been suggested for the formation of Hajigak deposit, including metosomatic skarn, banded iron formation and also submarine-exhalative. 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. 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 4*), 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 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.

Figure 4. 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 Hajigak iron deposit contains rocks more closely related to volcanoclastic settings. (Diagram from Peters et al., 2011).



Soviet category	Equivalent classification	Ore type	Mt Ore	Fe %	S %
A	Measured or proven	Oxidized ore	9.1	62.52	0.14
B	Measured or proven	Oxidized ore	19.2	62.69	0.09
C1	Indicated or probable	Oxidized ore	65.1	62.15	0.13
C1	Indicated or probable	Primary ore	16.2	61.3	4.56
C1	Indicated or probable	Fragmental ore	1.2	60.62	0.08
C2	Inferred or possible	All ore types	314.3		
C2	Inferred or possible	Fragmental ore	8.6		
P2	Hypothetical resources	All ore types	1,333.3		
P2	Hypothetical resources	Fragmental ore	8.6		
		Total	**1,769.9**		

Table 1. Reserves and Resources of the Hajigak deposit (Kusov et al., 1965)

Iron resources of Hajigak
The original resource estimation by the Afghan-Soviet team in 1965 has been re-evaluated by Sutphin, Renaud and Drew (*Chapter 7D in Peters et al., 2011*) and they have estimated that the A+B+C1 resources total 110.8 Mt and the C2+P2 resources are 1659.1 Mt (*Table 1*). The latter category (*prognosis*) resources are based on field mapping data and not drilled or sampled and would have little basis in modern Western resource classifications. Further exploration has the potential to upgrade current C2 and P2 resources to A, B, and C1 resources and enhance the potential for iron mining at Hajigak. Much more exploration, drilling, sampling, and analysis is needed before a full economic evaluation of the deposit can be made.

Iron resources of NE Hajigak
North-east of Hajigak a number of occurrences of bedded iron ore have been identified by Afghan teams and are regarded as an eastward continuation of the Hajigak mineralization along strike for approximately 20 km.

Table 2 provides details of the occurrences and the hypothetical resources, but further exploration is required to assess their true potential. Further details can be found in Abdullah (*2008*) and Peters et al. (*2011*).

Sample	Ore Type	Resource Mt	Fe %
Khaish	Hematite, magnetite	117	55.54
Kharzar	Hematite, magnetite, martite	~10	62.76
Chur	Hematite, magnetite	n/a	56.93
Zerak	Hematite, magnetite	20	56.93
Sausang	Hematite, magnetite	300	n/a

Table 2. Iron occurrences NE of Hajigak (from Peters et al., 2011)

SYADARA IRON ORES

Summary
Large massive magnetite bodies were discovered by the Afghanistan Geological Survey (*AGS*) at Syadara during the 2010 field season (*Figure 2*). Magnetite ore bodies are located approximately 110km west and along strike of the world-class Hajigak iron deposit, within a similar geotectonic setting. The discovery of Syadara confirmed the 200km long Proterozoic metamorphic belt as highly prospective for iron ore, and significantly improves the overall economic outlook of Hajigak. Preliminary mapping, sampling and ground magnetic survey over a portion of the ore body was completed during the 2010 field season by Afghanistan Geological Survey. Geological work to date has indicated strata-bound, magnetite with weak sulphide mineralization hosted within slates, phyllite and schist.

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The ore body is largely discontinuous, steeply dipping, on average 15 to 30m thick and trends NE-SW for more than 10km along strike-length. The thickest observed section is about 50-70m wide x 500m long and dips at 45° to the NW. Elsewhere the body is 30m thick and dips steeply (*80-85 degrees*) to the SE. The change in dip may reflect folding, shallow at the hinge and steepest on the limbs. Dextral-slip faulting is evident but the apparent displacements are less than a few tens of metres.

Based on outcrop dimensions, an inferred resource of >400mt of iron ore is plausible. Assay results (*see Table 3*) from composite grab samples returned grades ranging from 50-67% Fe (mean of 65% Fe) and are consistent with grades at Hajigak.

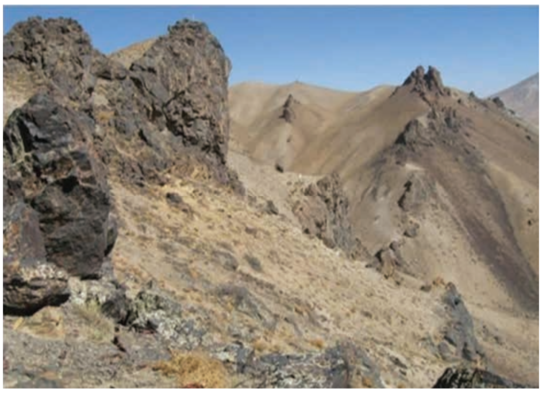


Figure 5. View NE along strike showing an iron ore outcrop of 500m long and 50-70m thick, moderately dipping at 45 degrees to the NW. Elsewhere the body is 30m thick and dips steeply (80-85 degrees) to the SE. (AGS 2010)

Location and Accessibility
Syadara iron ore located in the north-west of Kabul city, Afghanistan. The coordinate's position of the most northern end of magnetite outcrop at Syadara is 66.89710°E and 34.61906°N (*Figure 6*). The area can be reached from Kabul by road distance of approximately 300 km.

Syadara Magnetite Ore Body
Geology
Iron-mineralization is mainly hosted within the green-schist facies, metavolcanics and phyllites. A thin dolomite sequence is in close proximity with the magnetite (*Figure 4*). The rocks are part of the Neo-Proterozoic metamorphics which host the world-class Hajigak iron ore deposit, located some 110km east of Syadara. The geologic map (*Doebrich and Whal, 2006*) shows Neo-Proterozoic meta-sedimentary host rocks, which consist of greenschist facies and phyllite, marble, dolomite and metavolcanic rocks with interlayered sedimentary rocks. Within the deposit area, the beds have been deformed and are steeply dipping. Inter-beds of black carbonaceous slates and screes of chert were also observed near the AGS camp (*see Figure 7*).

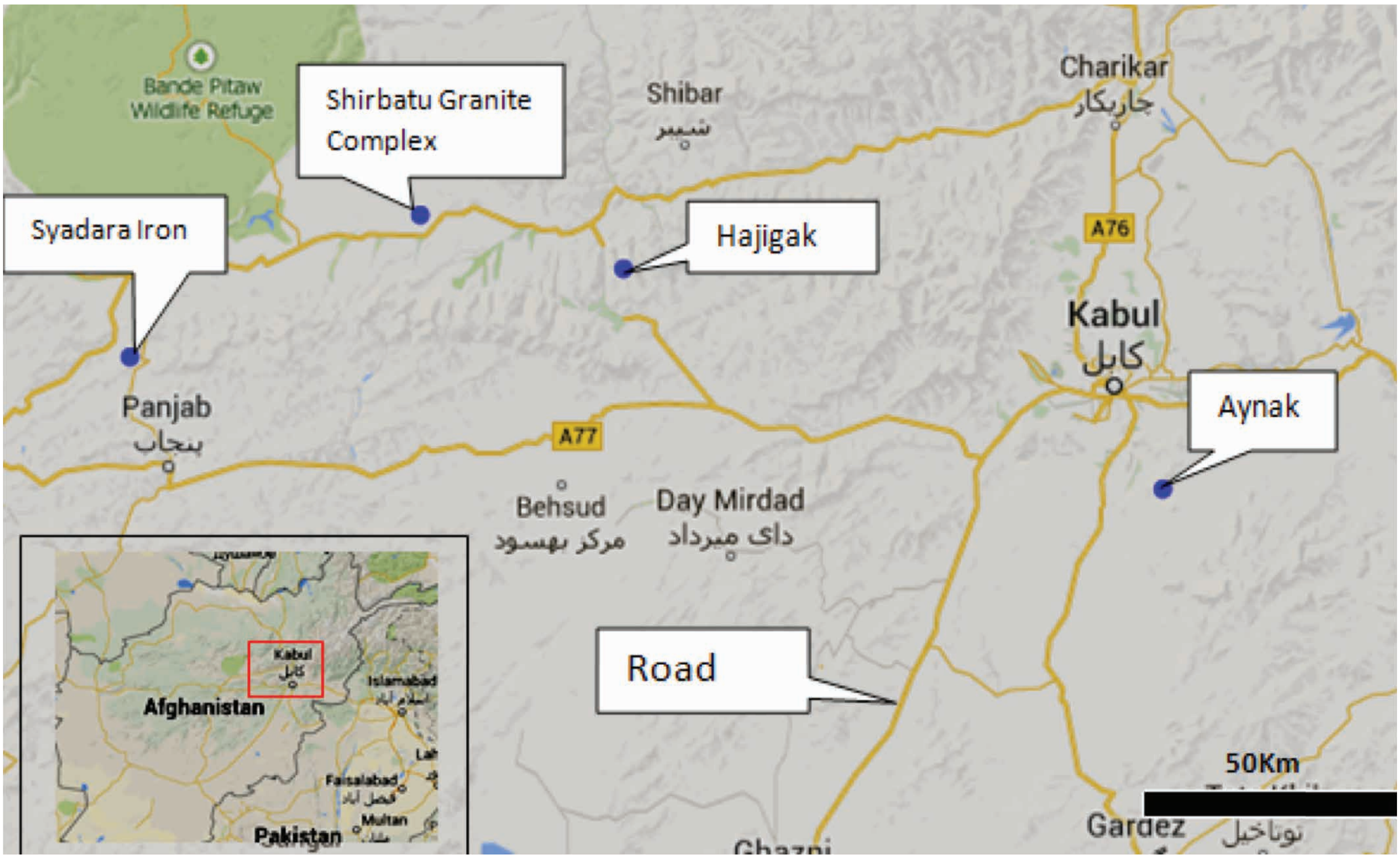


Figure 6. Location map of Syadara and Hajigak iron ores with respect to major deposits and infrastructures. The yellow lines show route of access, the railway line is currently under feasibility studies. Blue dots are major iron and other deposits.

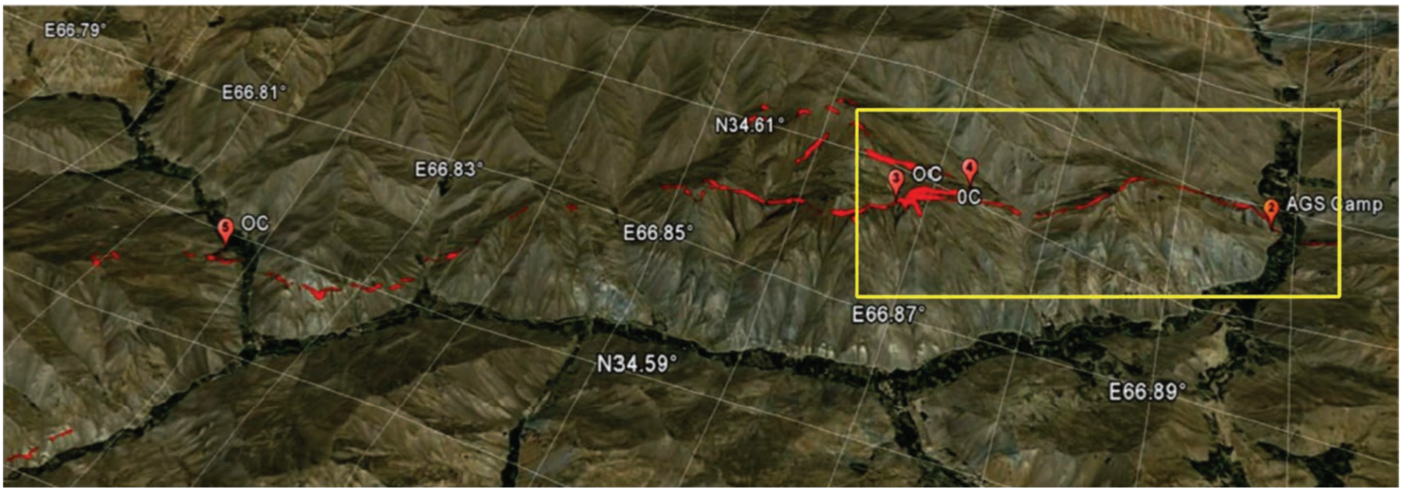


Figure 7. Red polygons show approximate trace of magnetite body. OC3 and OC4 mark the location of the shallow-dipping 50-70m thick magnetite body (see magnetic anomaly map in Figure 8). Elsewhere, the thickness of the ore body is about 15-25m. The yellow frame represents the approximate position for the detailed map in Figure 4. (AGS 2010).

Mineralization

The Syadara iron ore body consists of massive magnetite with weak specular hematite, pyrite and with minor to trace chalcopyrite (*Figure 4*). Intense oxidation represented by limonite (*goethite-hematite*) is well developed in places, with trace malachite-azurite and neotocite (*proven by* H_2SO4 *test*). The ore body extended at both ends NE-SW, for more than 10 km along strike (*Figure 4*). The magnetite body is discontinuous and has variable thickness. The average thickness of the mineralization is between 15-30m and steeply dipping, (*70-80º*) to the SW. The thickest outcropping mineralization was observed between OC3 and OC4. At this locality, the body measures approximately 50 to 70m wide dipping 45º to the NW over a distance of 500m along strike. A depth of approximately 400m to the mineralization could be ascertained, based on the highest and lowest outcrop elevations (*AGS 2010*).

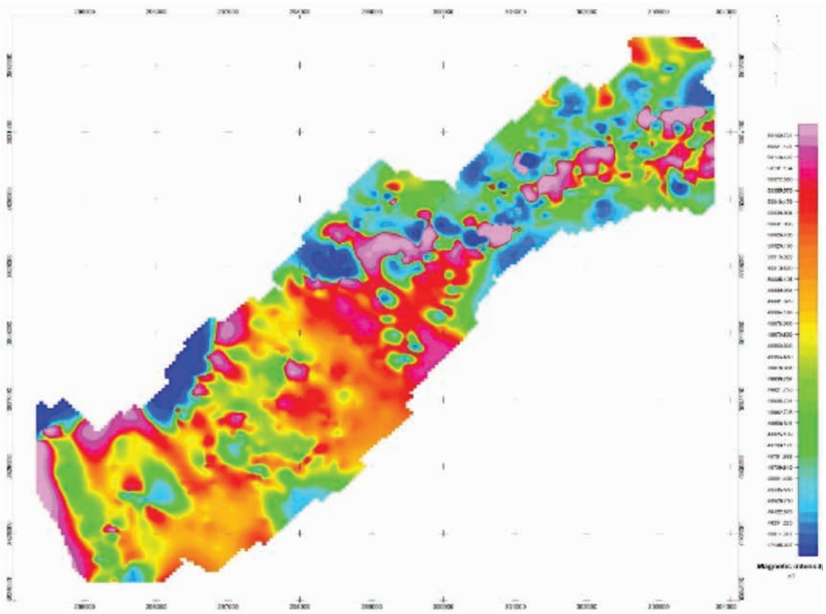


Figure 8. Magnetic anomaly map Syadara area of interest: The pink and red colored areas show the high magnetic intensity zones (magnetic ore bodies) and the green and blue colored areas show the low magnetic intensity zones (host rocks).

Structure

The magnetite body is mostly undeformed, but several shear/fault contacts and dextral slip with the wall rocks have been observed. Several post-mineral NW-SE trending strike-slip faults, cross-cutting the mineralization were inferred from the well-developed galleys, but only limited displacements are apparent (*AGS 2010*).

Geophysics and Remote Sensing

A geophysical survey was carried out by the Afghanistan Geological Survey in Siya Dara area of interest in 2019. This survey was carried out using Magnetic and Gravity methods. This survey covered about 16 km2 area. Base on the survey's results, a heavy magnetic ore belt is located with the length of about 8 km starting from Dan-e Sirdagh village to Shahre Naw village. As per geophysical investigation, the estimated depth of magnetic ore bodies is 2 kilometers *(Figures 8 & 9)*. Recently the AGS remote sensing experts caried out an investigation to identify the iron oxide reflectance using the ASTER and Landsat 8 image and the result of this study shows a close match with the geological mapping and geophysical identified anomalies in the area *(Figure 10)*.

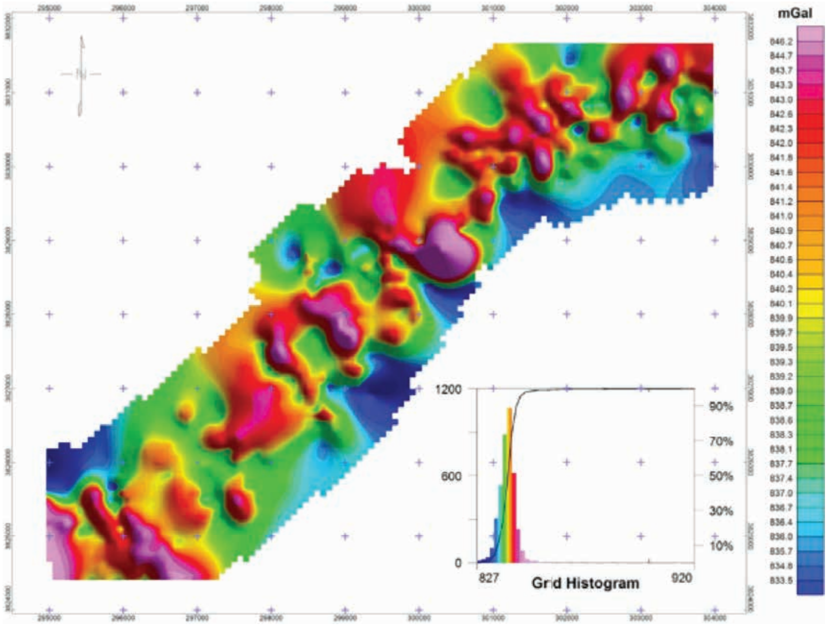
Assay Result

The arithmetic average for assay results from composite grab samples collected from different magnetite ore bodies ranges from 60.81 to 67.87% Fe. Average results, with deleterious elements from some of the identified bodies are shown in the Table below *(AGS 2010)*.

Sample	Fe%	S%	P%
BD1	66.74	0.23	0.05
BD2	60.81	1.55	0.03
BD7	65.33	0.33	0.05
BD8	66.8	0.87	0.18
BD12	67.67	0.51	0.34
BD15	65.67	1.55	0.04
BD6	66.83	0.23	0.05

Table 3. Shows the results of identified samples.

Figure 9. Gravity anomaly map of the Syadara area: Pink and red colored area show the high-density rocks probably magnetic ore bodies and the green and blue colored area show the low-density rocks.



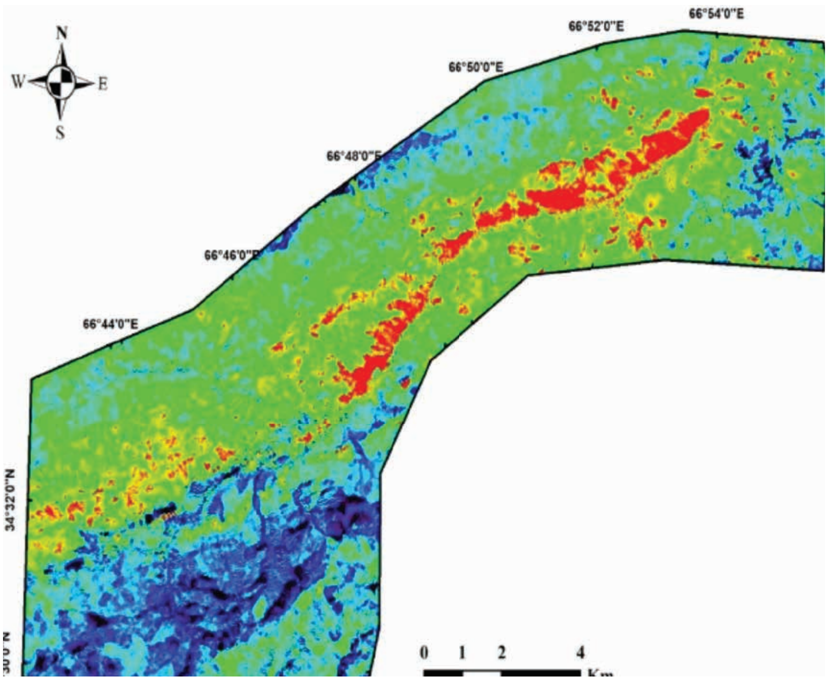


Figure 10. Remote sensing map of Syadara area, Bamyan Province. Red colored area shows the iron oxide spots.

ORE OCCURRENCES

Jabal-e-Seraj
The mineralisation is represented by large hematite lenses and bed-shaped bodies formed of ferruginous marble of Proterozoic age (*Figure 1*), 10 to 30 metres thick and extended over 1 km. Reconnaissance mapping was carried out by AGS in 2008 and the occurrence is not considered to have economic potential because of tectonic disruption of the ore bodies. Speculative iron ore resources determined by earlier Afghan-Soviet teams were 7.2 Mt (*Abdullah et al. 2008*).

Panjshir Valley
Stratabound iron ore has been identified at a number of localities in the Panjshir region (*Abdullah et al., 2008*) (*Figure 1*). Geological mapping by AGS in 2010 identified a strongly folded bed of iron ore in Proterozoic schists and marble. Forty-nine hematite-magnetite bodies were identified and, assuming a nominal depth of 50 m, a speculative resource of 45 Mt at 35-55% Fe (*average 48% Fe*) was calculated. Further details can be provided by AGS (*AGS unpublished data, 2011*).

Other areas
Two occurrences of hematite mineralization have been reported in Proterozoic rocks in Herat Province in the west of Afghanistan (*Figure 1*). At Chashma-i-Reg a zone of hematite mineralization, 300 metres wide and extending for 2 km was recorded in sandstone and limestone of Proterozoic age, and at Bande-i-Sarakh hematite mineralization was observed in a fault zone in shattered limestone of Proterozoic age with an area of 0.3 km2 (*Abdullah et al. 2008*). Abdullah also records an occurrence at Mangasak, Maydan Province (*Figure 7*), where a zone of 50 to 100 m thick and 1,200 m long with lenses and veinlets of magnetite, has been found in carbonates, at the contact between Proterozoic gneiss and schist. In Badakhshan Province in NE Afghanistan, at Zanif, hematite lenses, 2 to 50 m thick and extending for 20 to 250 m, have been found in a fault zone at the contact between marble and schist and gneiss of Proterozoic age. The iron ore grades 30 to 40% Fe. These occurrences extend the area of interest for iron ore in Proterozoic rocks and deserve further exploration as part of a countrywide search for further resources.

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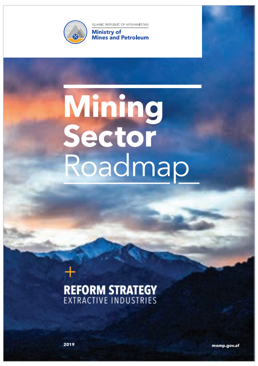

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