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MINERAL RESOURCES IN AFGHANISTAN

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Shah Foladi Geology Park, Bamyan – Photo Credit: Dr. Hassan Malestani

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Compiled by
Hussaindad Shafai
Abdullah Asifi
Qasim Akbar

Designed by
Rohola Rezaei

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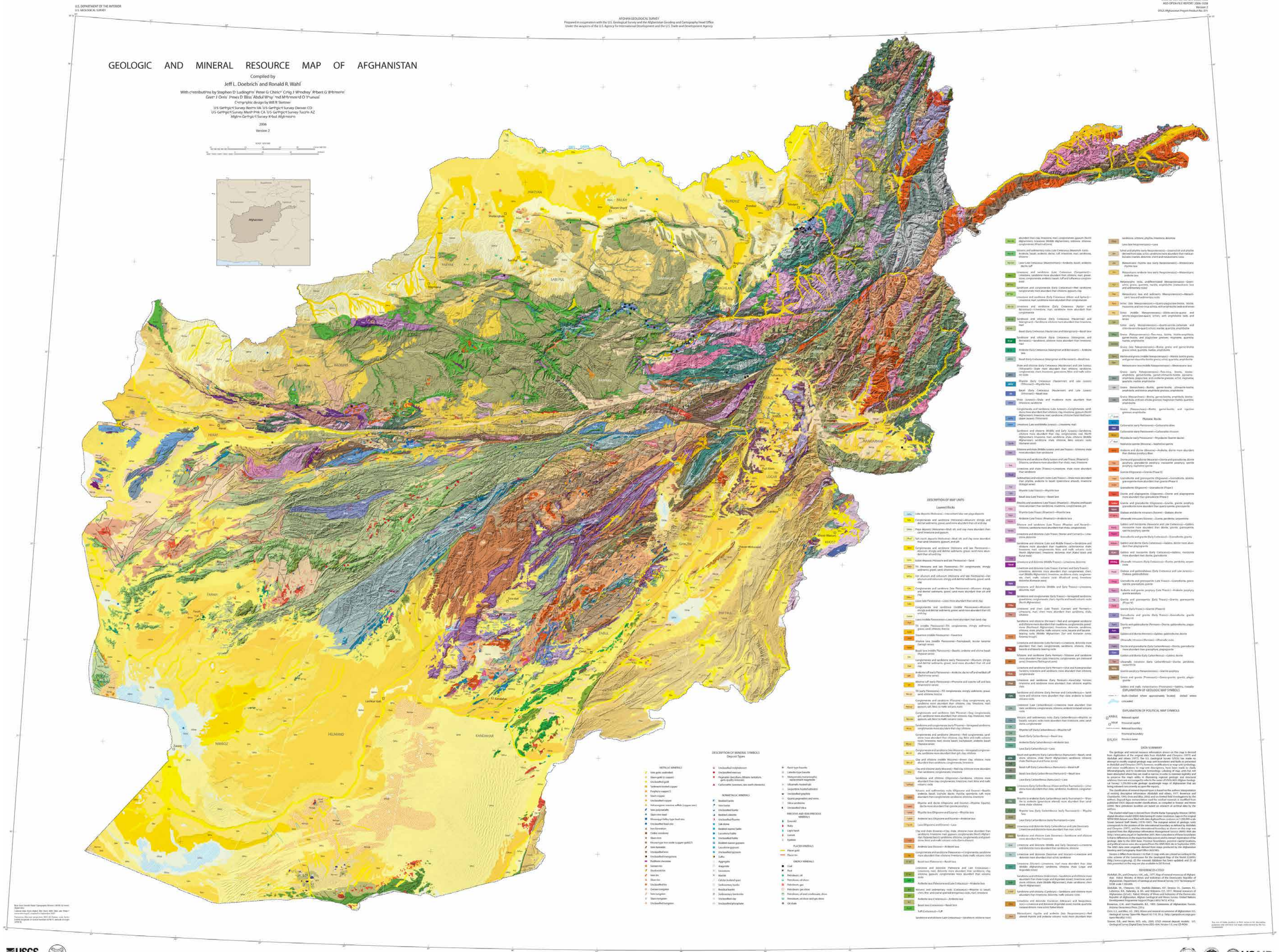
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GEOLOGIC AND MINERAL RESOURCE MAP OF AFGHANISTAN
Compiled by
Jeff L. Doebrich and Ronald R. Wahl
With contributions by Stephen D. Ludington, Peter G. Chirico, Craig J. Wandrey, Robert G. Bohannon, Greta J. Orris, James D. Bliss, Abdul Wasy, and Mohammad O. Younusi
Cartographic design by Will R. Stettner
U.S. Geological Survey, Reston, VA; U.S. Geological Survey, Denver, CO
U.S. Geological Survey, Menlo Park, CA; U.S. Geological Survey, Tucson, AZ
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Band-e-Amir National Park, Bamyan – *Photo Credit:* Dr. Hassan Malestani

INTRODUCTION

Afghanistan is endowed with abundant natural resources that remain largely untapped. The country has world-class deposits of iron ore, copper, gold, rare-earth minerals, and a host of other natural resources. Similarly, the presence of petroleum resources has long been known in Afghanistan but these resources were exploited only to a limited extent.

Bulk metals, such as iron ore, copper, aluminum, tin, lead and zinc, are located in multiple areas of the country. And, gemstones, rare-earth metals, sulfur, talc, gypsum and chromite, are predominant across Central Afghanistan, Baghlan, Kunduz, Logar, Khost, among other places.

Much of the petroleum resource potential of Afghanistan and all of the crude oil and natural gas reserves are in northern Afghanistan, located in parts of two petroliferous geologic basins – the Amu Darya Basin to the west and the Afghan Tajik Basin to the east.

The Government of Afghanistan sees Afghanistan's vast mineral and hydrocarbon resources as a catalyst of long-term economic growth. Accordingly, the Ministry of Mines and Petroleum (MoMP) designed several consequential documents, including the Mining Sector Roadmap, a new Minerals Law, and a new Hydrocarbons Law as part of its commitments to open the mining and hydrocarbon sectors for private investment.

To sustainably utilize our natural resources, the Ministry of Mines and Petroleum intends to tender new large-scale mining and hydrocarbon projects. The ministry is rigorously focused on attracting domestic and foreign investors to exploit Afghanistan's plethora of mineral and hydrocarbon resources. This document will focus on the bankable investment opportunities in the mining sector which are ready for tendering.

GOLD

Background

Gold has been worked in Afghanistan from ancient times and small-scale artisanal mining is still being carried out on placer gold deposits in Takhar Province. There are a number of other prospects, which have been evaluated by Soviet and Afghan teams in the 1970's and there is a high probability that some of these could be developed into working mines. Improved exploration methods and modern metallogenetic models, coupled with knowledge that Afghanistan lies on a continuation of the Tethyan Metallogenic Belt, have greatly improved the potential of the country. Several areas of the country have potential for new deposit types, such as fine-grained epithermal gold, not sought by the Soviet-Afghan teams, and have been largely unexplored.

The reports of the earlier Soviet exploration are now available in Kabul. BGS and USGS have published summaries of the geology and re-interpreted the earlier data in the light of remote sensed information (*Peters et al., 2007* and *2011*).

Afghanistan has a complex geology due to its position on the junction between the Indo-Pakistan and Eurasian crustal plates. Its geology is composed of a series of terranes that broke away from the main Gondwana Supercontinent before colliding, with each other or, with the Eurasian Plate. Ultimately, all the terranes became accreted onto the southern margin of the Eurasian plate. The final closure of the Neo-Tethys Ocean between the Indo-Pakistan and Eurasian plates produced the Himalayan orogeny. During this oblique collision NW-directed subduction occurred beneath the Tirin-Argandab zone and a number of calc-alkaline granite bodies were intruded, accompanied by porphyry copper-gold mineralisation of the Tethyan Metallogenic Belt (*TMB*). Further north in Badakhshan there are a number of prospects and occurrences of metamorphic lode gold in areas of Hercynian and later Cimmerian folding. This zone may extend southward into Parwan as shown in Figure 1 and even further to the west associated with folding related to the closure of Palaeo-Tethys along the Herat terrane boundary.

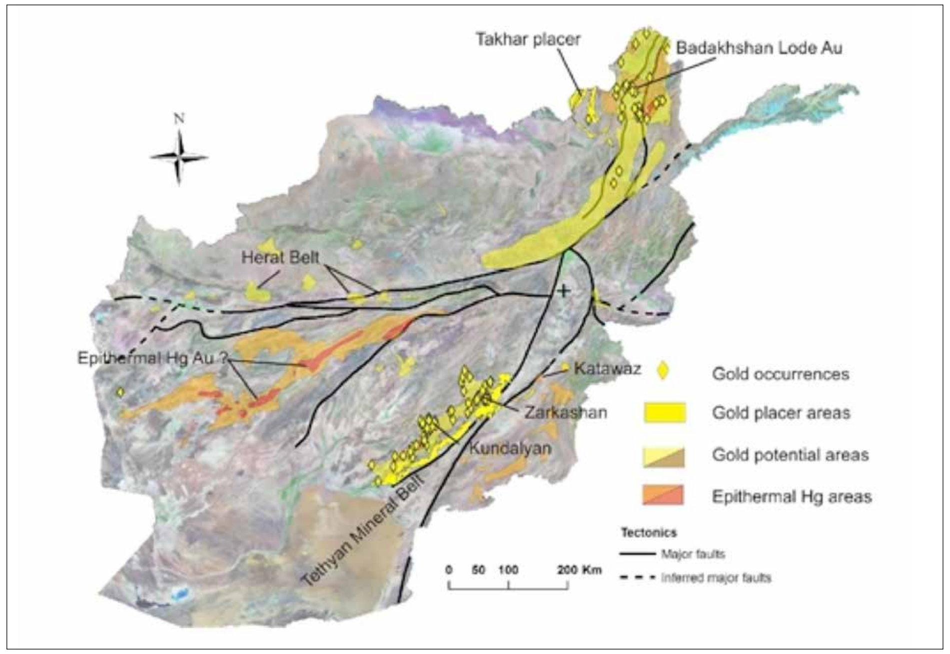


Figure 1. Gold occurrences in Afghanistan on a low-resolution Landsat image, with areas of enhanced gold and mercury potential (after Peters et al., 2007).

Orogenic Gold Deposits

Potential for shear-zone vein-gold mineralisation exists along the major trans-crustal structural breaks representing remnant terrane collisional boundaries. Gold potential also occurs within Phanerozoic rocks in moderate to gently dipping fault/suture zones related to continental margin collisional tectonism. Suture zones characterised by ophiolitic remnants between diverse assemblages of island arcs, subduction complexes and continental margin clastic wedges are also prospective. The zone of late Hercynian folding on the eastern end of the North Afghan platform, in the provinces of Badakhshan and Takhar, are prospective for shear-zone gold mineralisation, with a number of deposits identified to date, including the Vekadur Au-Ag deposit (*Figure 2* and *Deposit Profile 1*). The Vekadur gold deposit has been explored by five adits, eight pits, and 10 or more trenches (*Gugenev et al., 1967*). The adits are excavated from the hanging wall west of the outcrop of the vein and tunnel eastward into the mountain. There is little overburden in the hanging wall side of the vein and the deposit could be worked as an open pit.

A number of other occurrences are known in the Ragh District and, like Vekadur, are found in shatter zones containing gold-bearing quartz veins with a low-sulphide mineral content. These features are common to a number of productive cratons where several hundred small deposits of about one tonne of gold are present as structurally controlled stockworks and massive veins.

DEPOSIT PROFILE 1	
Deposit Name	Vekadur
Location	Badakhshan Province
Deposit Style	Orogenic / Metamorphic lode gold
Host geology	Silicified and ochreous brecciated schist, diabase and keratophyre dykes in vicinity (*Proterozoic*)
Ore minerals	Gold, arsenopyrite, galena, chalcopyrite and scheelite
Deposit geology	Podiform orebody average 2m thick and 300m extent. Traced for 100m down dip
Estimated Resources	960 kg contained gold at grade of 4.1g/t Au, 46.7g/t Ag

Information: Abdullah et al. 2008; Peters et al. 2011

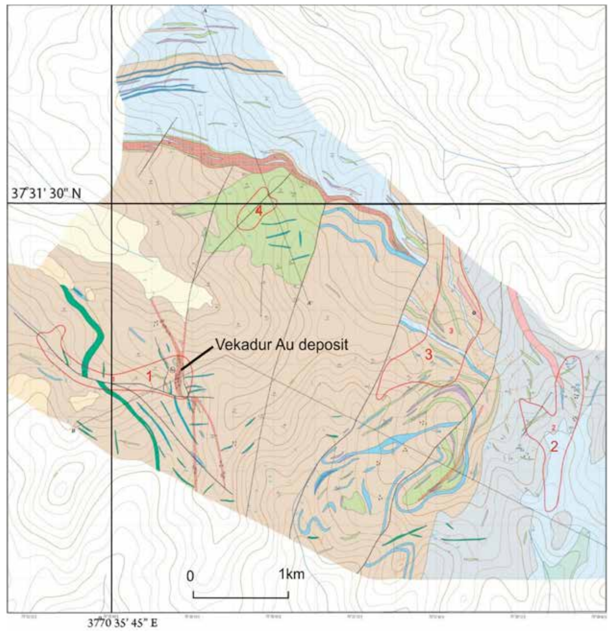


Figure 2. Geological map of the Vekadur gold deposit. Red hatched areas are zones of crushing and hydrothermal alteration in Proterozoic quartz-mica (*light brown and grey*) and chlorite schists (*pale blue*) Red outline shows gold heavy mineral anomalies (*after Peters et al., 2011*).

Figure 3. Afghanistan Geological Survey field work conducted in 2010 at Furmorah gold prospect, Fayzabad district, including prospect evaluation and trench digging. Photographs by the Afghanistan Geological Survey (*Figure 3c Peters et al., 2011*).

No modern exploration has been carried out in the Badakhshan region since the 1960's.

Other prospective districts such as Baharak and Fayzabad as well as having lode gold deposits, also contain iron skarns some of which contain gold. The Furmorah pluton is surrounded by several iron skarns, one of which grades as much as 3.3g/t Au.

Placer Gold
Small-scale placer gold mining appears to have been conducted in the streams and rivers of the Hindu Kush for many centuries and continues locally today in both placers and paleoplacers in Takhar Province. Reports persist of local people putting sheepskins in mountain streams in Badakhshan Province to serve as fleece sluices capable of catching fine gold, reminiscent of tales of the 'Golden Fleece'.

Soviet and Afghan geologists undertook the first industrial-scale exploration for placer gold and made some major discoveries (*Galchenko et al., 1972*), notably Samti, Nuruba, Chah-i-Ab and Jar Bolshi and a large number of smaller occurrences (Figure 4).

It is clear the grades and extent of the placer gold has been underestimated by the Soviet geologists due to limitations in the Soviet exploration methods:

Firstly, it is apparent the Soviet-driven exploration effort was limited to areas with good water supplies in order to facilitate wet washing of the placer ores by wash-plants such as PgSh sluices that require water cannons. Accordingly, less than 10% of Afghanistan was explored for placer gold. Indeed, no evidence has been found of drywashers having been used for prospecting for placer gold in Afghanistan. This is being remedied in 2014 with the introduction of USA drywashers by the USAID MIDAS project, and making by the Ministry of small recirculating sluices based on a USA design that requires minimal water.

Secondly, the Soviet drillers used numerous placer drilling rigs of a single type—Soviet churn drills—that while being the respected industry standard for terraces and dryish floodplains are known to systematically lose most of the gold when used in waterlogged ground such as wet floodplains. This fact has been known for many decades in the Russian placer gold industry.

Samti Gold Dredge Resource
An outstanding success was the systematic proving of a resource of 30 tonnes of placer gold by churn drilling on the active floodplain of the Amu Darya near the village of Samti in Takhar Province. The United States Geological Survey confirms the manual Soviet estimated resource of 30 tonnes, which is large by current world standards. Nevertheless it is believed to be a substantial underestimate of the true magnitude of the Samti gold resource.

The heavy gold losses of Soviet churn drills was familiar to Soviet placer geologists, and indeed the remains of an unused Soviet bucket drill has been identified at the AGS Khair Khana Engineering Warehouse. A Soviet-Canadian data set of more than 1,000 boreholes in Mongolia proved the gold recovery of Soviet bucket drills to be close to 100%, while Soviet churn drills usually lost more than 65% of the gold in the same wet ground (*Grayson 2014*). Applying the correction factor to the Samti churn drilling indicates that the actual gold resource is likely to be in the region of 100 tonnes, with an in-the-ground value of about 4 billion USD, which would rank Samti among the largest gold dredge projects in the world. A limited programme of repeat drilling by a Russian bucket drill would suffice to confirm the appropriate correction factor to be applied to the gold grade, so enabling the resource envelope to be identified and the dredge envelope to be calculated. The appropriate method of mining would be a civil engineering cutter-suction dredge pumping the overburden away to raise flat land several kilometres away so creating a large dredge pond to hold a large mineral dredge such as a Russian, Dutch or USA bucket-line dredge with on-board wash-plant to recover the gold. Accordingly a modified German Ruhr grab dredge may be an attractive alternative, having a reach of more than twice the depth of the placer gold. Finally a large civil cutter suction dredge might be considered, having the merit of wide availability and lower cost, albeit at some peril of losing some gold.

Discovery of Other Deposits of Placer Gold
There is large potential for further discoveries of large placer gold deposits on the Afghan side of the Amu Darya river, as well as discovery of large extensions of the Samti placer itself. Drilling on wet floodplains must only be done with Russian bucket drills to ensure gold grades are reliable and gold losses avoided.

Copper-Gold Porphyry Deposits
The Soviet-Afghan teams identified a number of Cu-Au prospects and occurrences in the Tirin-Argandab zone which forms part of the Tethyan Metallogenic Belt (*Figure 1*) of world-class porphyry copper-gold deposits, which stretches from Europe, through Turkey, Iran, Pakistan, Afghanistan, Tibet and into SE Asia. The prospective tracts have been identified by a distinctive group of Cretaceous-Paleocene intrusive rocks that are spatially related to the known Cu skarn deposits and prospects, alteration

zones from ASTER and aeromagnetic anomalies. Within them two deposits, Zarkashan in the north and Kundalyan in the south, have been investigated by detailed sampling, trenching and drilling.

ZARKASHAN

The Zarkashan area of interest surrounds the Late Cretaceous-Paleocene Zarkashan diorite, granodiorite to adamellite intrusion and consists of a number of gold and copper occurrences (*Figures 6* and *7*). The deposit is hosted by the Triassic and Cretaceous sediments and is associated with garnet-vesuvianite-diopside and with irregular zones of diopside skarns. The mineralisation consists of chalcopyrite, pyrite, sphalerite, chalcocite, bornite, and native gold in the hydrothermally altered skarns. Preliminary exploration, including rock sampling, trenching and underground adits, has indicated the presence of several ore-bearing zones of 400-600m long and 1-15m thick, with lenticular and nest-shaped bodies of 1.5-50m long and 0.5-3.8m thick. Gold mineralisation is traceable for 80m down dip, assaying from 0.10 to 16g/t Au. Category C1+C2 resources are 7,775kg and speculative resources are 12,000 to 15,000kg of contained gold. Copper grades vary from 0.01 to 15%. Recent sampling by USGS (*Peters et al., 2011*) has shown that disseminated mineralisation is extensive within a large contact aureole zone and holds potential for large, medium to low grade ore bodies that are amenable to bulk mining and ore processing methods, during this period of prevailing high copper and gold price.
A number of other prospects, such as Zardak, Dynamite, Choh-i-Surkh and Sufi Kademi, around the Zarkashan intrusive are also highly prospective for porphyry copper gold deposits and worthy of further investigation. Peters et al., (*2007*) predicted that in the Zarkashan-Kundalyan tract there is a high probability (*50%)* of one porphyry copper-gold deposit and a 10% probability of two deposits.

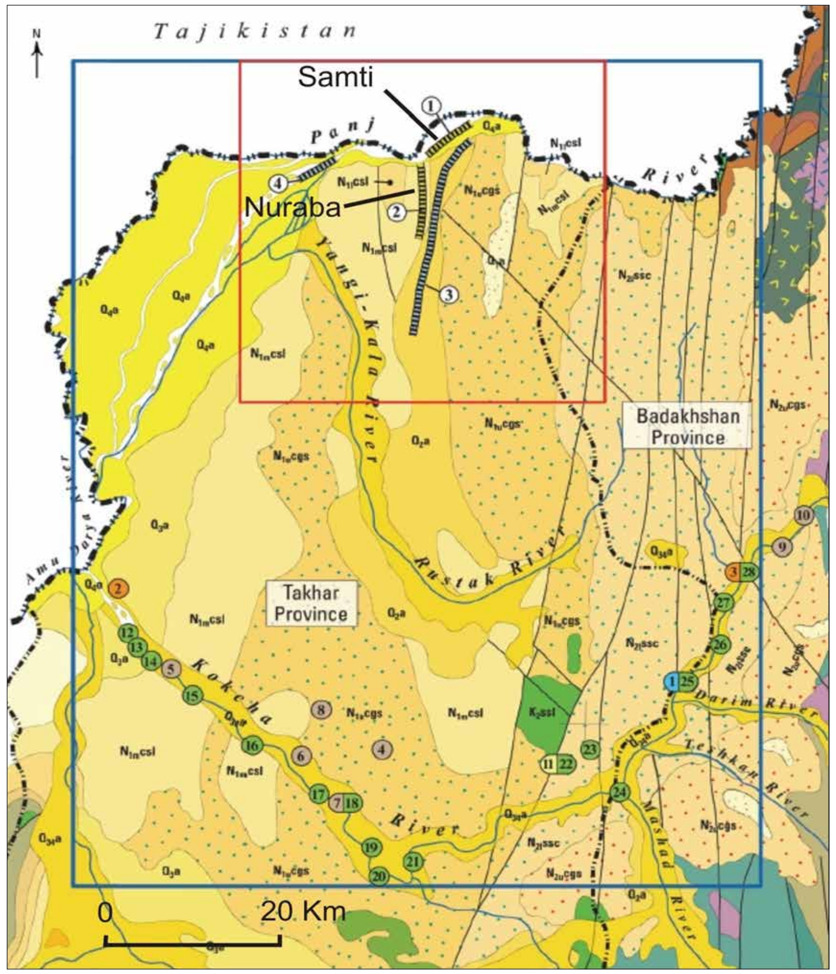


Figure 4. Geological map of northern Takhar showing the distribution of Neogene and Quaternary strata and major gold placers (hatched lines). Colored circles are placer gold occurrences from earlier authors. (*Peters et al., 2011*).

DEPOSIT PROFILE 2	
Deposit Name	Zarkashan
Location	Ghazni Province
Deposit Style	Porphyry Cu-Au and related Skarn
Host geology	Late Triassic dolomites in the contact zones of the Zarkashan gabbro, monzonite and syenite intrusion
Ore minerals	chalcopyrite, pyrite, sphalerite, chalcocite, bornite and gold
Deposit geology	Skarns occur in pockets or as sheetlike deposits. Several ore-bearing zones occur 400- 600m long and 11–75m wide. The richest gold is found in phlogopite skarns
Estimated Resources	7.7t Gold contained in C1 and C2 categories

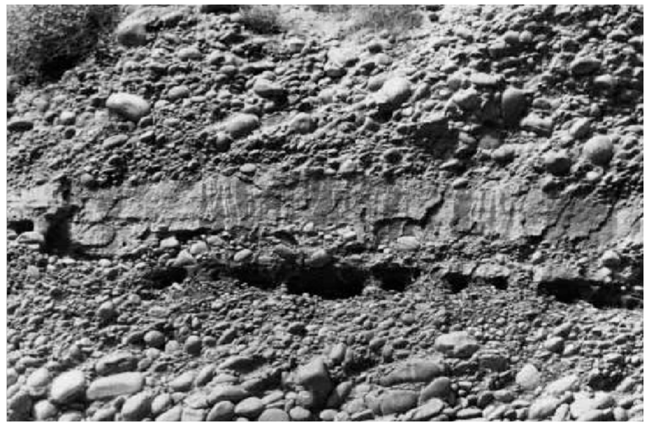


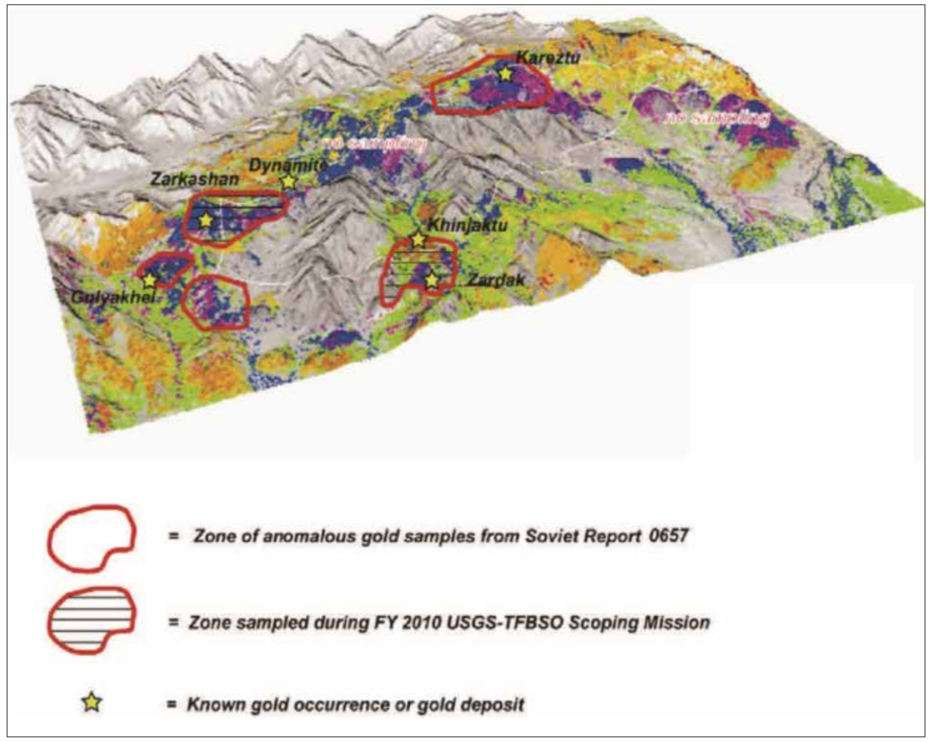
Figure 5. Placer gold deposit consisting of alluvial sand and conglomerate of the Panj River.

KUNDALYAN

The Kundalyan copper-gold skarn deposit is localized along a 400-metre long, 1.5km wide wide inlier that consists of altered limestone, chert, and skarn (*Peters et al., 2011 after Soviet authors*). The chief minerals in the skarn are pyroxene, garnet, amphibole, phlogopite, and magnetite. Mineralisation is present both in skarn and chert. There are 13 ore bodies along the Kundalyan Fault Zone (*Figure 8A*) that are from 2.65 to 12.3m thick and from 36 to 175m long, containing 0.62-1.2% Cu and 0.5-2.0g/t Au. The mineralisation is predominately chalcopyrite and pyrite and more seldom sphalerite, gray copper ore, and enargite. The Category C1+C2 reserves in the Soviet classification system, are 13,600 t of contained copper and 1.1t gold at grades of 1.07% Cu and 0.9g/t Au. The Kundalyan copper-gold skarn deposit area was explored by a series of trenches, adits, and drill holes. Data were presented on cross sections (*Figure 8B*) for about 5 km of strike length along a NNW-trending zone that is exposed in a valley. The Kundalyan copper-gold deposit has been explored where a northwest-striking stream has eroded through colluvial cover and exposed a granodioritic intrusive intruding Precambrian, Cambrian, and Carboniferous limestone. The skarn zone contains brecciated, stromatolitic limestone and contains large areas of layered calc-silicate rock related to skarn formation and metasomatic kaolin-carbonate rock. Malachite-stained siliceous skarn and porphyroblastic marble also are common in the mineralised zone. Despite the extensive trenching and the boreholes in the main zone there seems to have been little exploration of colluvium covered areas to west and east. Several copper and copper-gold and gold prospects and occurrences are present peripheral to or away from the main Kundalyan copper-gold skarn deposit. Prospects generally cluster near and around the Kundalyan group of deposits in these areas: Kaptarghor, Shela-i-Surkh, Baghawan-Garangh, Kunar and Chasu-Ghumbad. Further details can be found in Peters et al., (*2011*).

Hot-spring epithermal gold deposits have not been positively identified but there are indications that they may be present in the epithermal mercury zone of central Afghanistan and Katawaz basin (*Figure 1*).

Figure 6. Three-dimensional view of the Zarkashan copper and gold area of interest showing hyperspectral anomalies surrounding the Zarkashan intrusive (white outline). The blue and purple zones represent alteration zones with goethite and jarosite. These alteration zones are coincident with anomalous gold areas from earlier Soviet sampling (*Peters et al., 2011*).



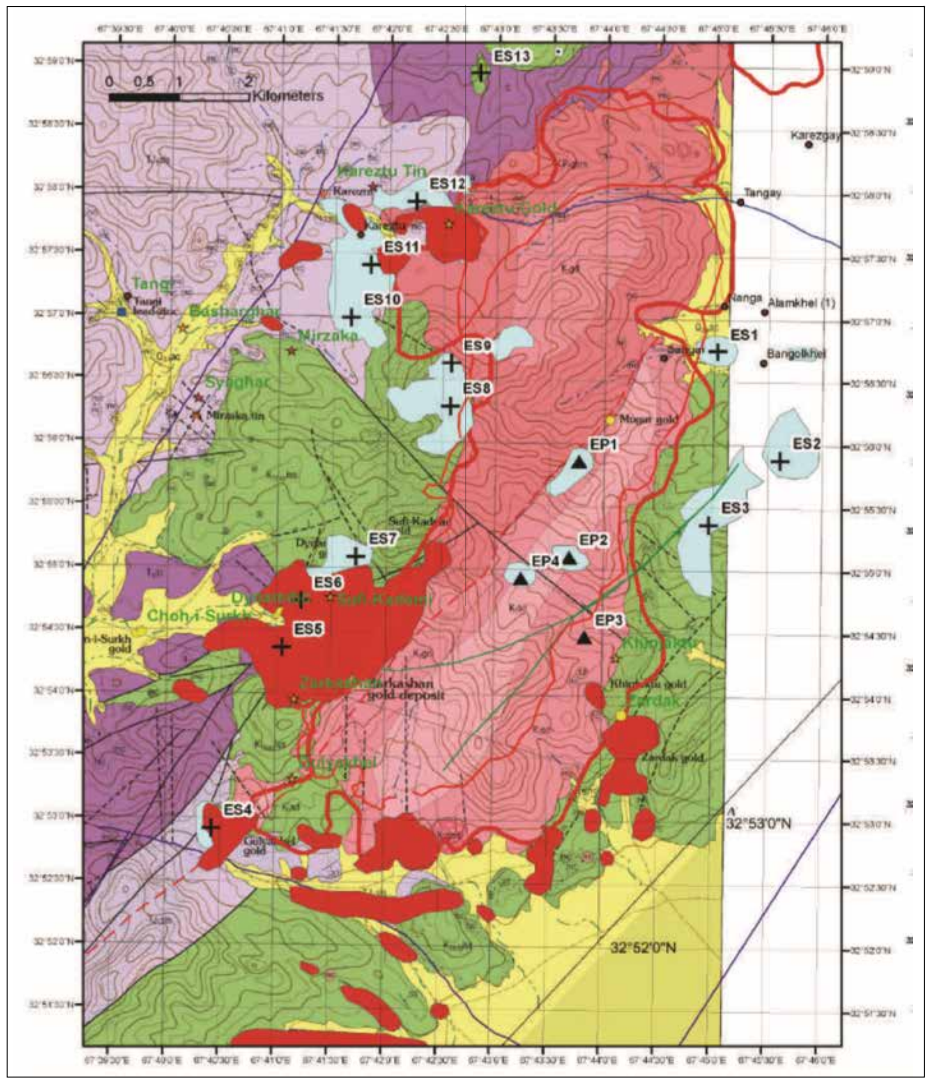


Figure 7. Geological map of the Zarkashan area showing the mineralised areas (bedrock gold anomalies in red) surrounding the Zarkashan pluton (lighter shades of red). (Peters et al., 2011).

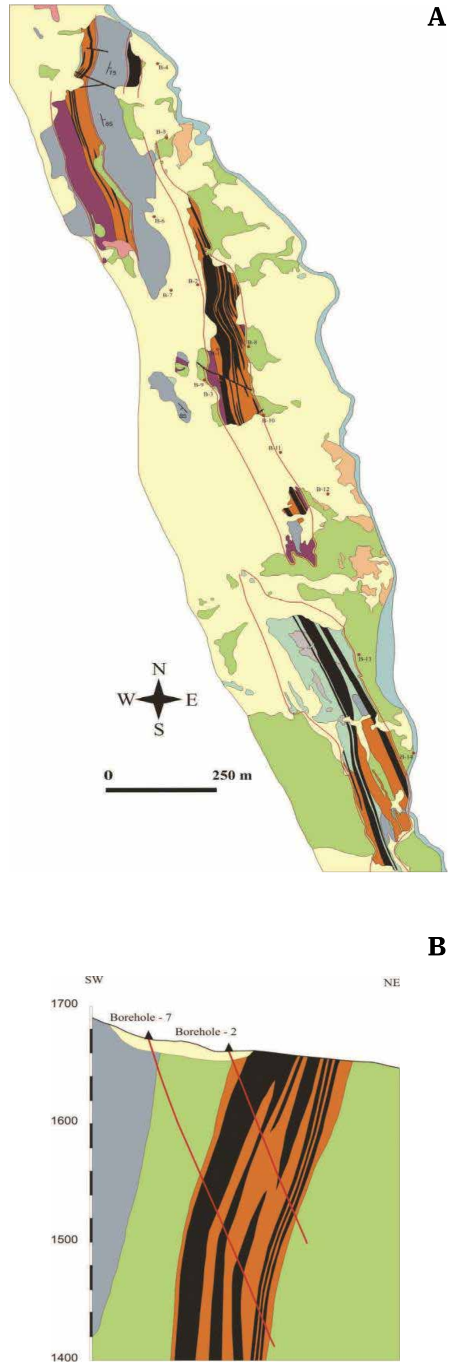


Figure 8. (A) Geological map of the Kundalyan area showing the ore zone (black), skarn (orange), kaolin-carbonate rock (grey), altered granitoids (pale blue), granodiorite (green) and colluvium (pale yellow). (B) Illustrative cross section through boreholes 2 and 7 at Kundalyan (key as above).

Epithermal Gold

In central Afghanistan in the Kharnak-Kanjar area, (*Figure 9*) disseminations and veinlets of cinnabar accompanied by carbonate, dickite and silica alteration and lesser pyrite, chalcopyrite and arsenic minerals are found in early Cretaceous calcareous rocks intruded by Eocene to Oligocene porphyry diorite dykes and volcanics. The features indicate the presence of a very large low-temperature hydrothermal system. Elsewhere in the world, such systems host significant gold resources and are the focus of major exploration investment (*Peters et al., 2007, 2011*). In the Katawaz basin Abdullah et al. (*2008*) observed telethermal (*epithermal*) lead, zinc, mercury and gold mineralisation belonging to the orogenic (*Miocene*) stage of the basin's evolution.

KATAWAZ GOLD

The Katawaz gold area of interest (*AOI*) lies along the northwestern margin of the Katawaz Basin in eastern Afghanistan. Although no known mineral occurrences or deposits are present in the AOI, geologic and remote-sensing data suggest that the environment is conducive to the occurrence of epithermal gold deposits. The Katawaz AOI encompasses 1 of more than 19 geochemical halo zones in the Katawaz Basin area that are anomalous in mercury, tungsten, gold and (or) lead. Studies of Advanced Spaceborne Thermal Emission and Reflection Radiometer (*ASTER*) imagery have identified linear phyllic and argillic alteration zones on Cenozoic sedimentary and volcanic rocks within the AOI. Mapping of the ASTER imagery in the Katawaz gold AOI has specifically identified illite, ferric iron, and clay with local calcite and smectite along a northwest structure that is likely a splay of the Chaman Fault zone. Airborne magnetic data also indicate that small igneous bodies may underlie or be proximal to this altered zone.

Evidence of hydrothermal mineralization occurs along the western margin of the Katawaz Basin to the south of the Katawaz gold AOI where phyllic and argillic alteration zones are spatially associated with Miocene plutons and stocks. In addition, base-metal mineralization is present along the eastern faulted margin of the Katawaz Basin. The presence of geochemical anomalies of mercury and hydrothermal zones in the Katawaz Basin suggests that a mineralizing hydrothermal system may have been active either during or after the development of the basin. Because there are no known mineral deposits within the Katawaz gold AOI and because this is a speculative AOI, the area requires ground visits, field mapping, and sampling to authenticate remotely-sensed indications of mineralization.

DEPOSIT PROFILE 3	
Deposit Name	Kundalyan
Location	Zabul Province
Deposit Style	Cu-Mo-Au-Ag skarn
Host geology	Proterozoic and Vendian–Cambrian metamorphosed limestones and cherts
Ore minerals	Chalcopyrite, magnetite, pyrite,sphalerite, molybdenite, chalcocite, bornite, covellite, native Cu, malachite
Deposit geology	Three deposits up to 155m long and 2.59–3.89 m thick. Mineralization restricted to hematite-kaolin-quartz and meta-carbonates
Estimated Resources	C1+C2 resources 13600t Cu @ 1.07% Cu; 1.1t Au, @ 0.9 g/t Au; 127.3t Mo @ 0.13% Mo

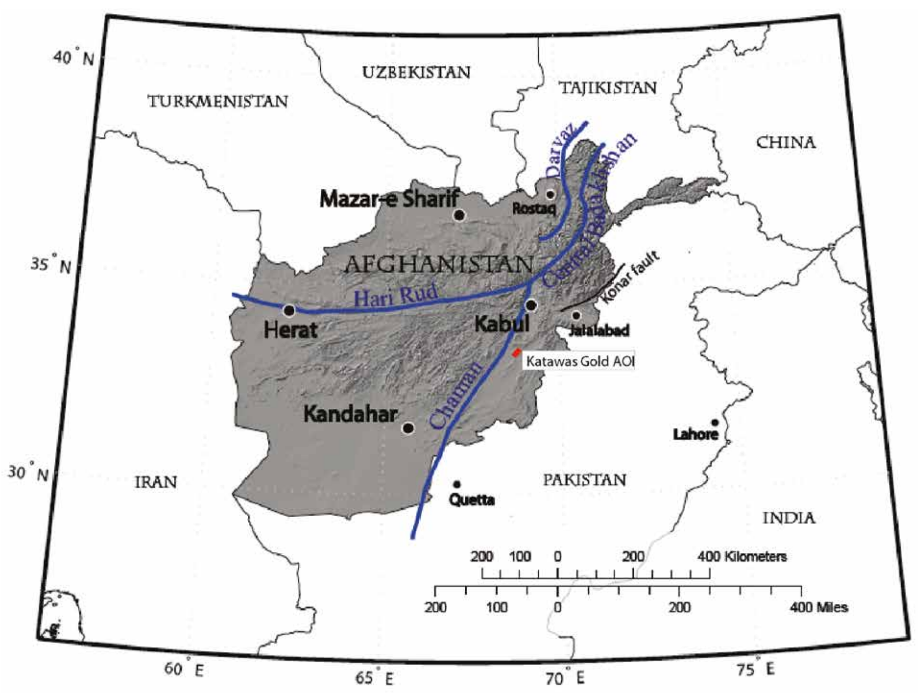


Figure 9. Shaded relief map of Afghanistan showing major earthquake faults from Boyd and others (2007) and proximity of the Katawas gold area of interest to the Chaman Fault.

COPPER

Introduction
Copper is an essential commodity in today's digital and electronic age and in recent years has seen a dramatic increase in its value. Increased demand from the rapidly growing developing economies of Asia has led to a rise in mineral exploration and the opening of new mines in adjacent regions. Afghanistan is well placed to meet this demand and the Aynak copper deposit, one of the largest in Asia, is currently being developed by a Chinese company. The country has a wealth of other copper prospects, most notably a number of porphyry copper deposits along part of the Tethyan Metallogenic Belt (*TMB*) and a recently discovered volcanogenic massive sulphide deposit (*VMS*) at Balkhab.

Recent geological fieldwork by the Afghanistan Geological Survey aided by international advisors has improved the knowledge of these deposits and made the information available to the global mining industry.

Geology of Afghanistan
Afghanistan has a complex geology due to junction position between the Indo-Australasian and Eurasian plates. Its geology is composed of a series of small terranes that broke away from the main Gondwana supercontinent before colliding, with each other or, with the Eurasian plate. Ultimately, all terranes accreted onto the southern margin of the Eurasian plate. The final closure of the Neo-Tethys ocean between the Indo-Australasian and Eurasian plates produced the Himalayan orogeny. During this oblique collision, NW directed subduction occurred beneath the Tirin-Argandab zone and calc-alkaline granite bodies were intruded, accompanied by porphyry copper mineralization. The exotic terrane of the Kabul Block brought with it sedimentary copper deposits like Aynak.

Copper Deposits
There are around 300 documented copper deposits, occurrences and showings in Afghanistan (*Abdullah and Chmyriov, 2008*). A variety of styles of copper mineralization occur in rocks ranging in age from Proterozoic to Neogene. These include sediment-hosted, skarn, porphyry, and vein-hosted. The largest and best-known copper discovery in Afghanistan is the world-class Aynak stratabound deposit hosted within Vendian-Cambrian quartz-biotite-dolomite metasedimentary rocks 30km southeast of Kabul. Soviet surveys in the 1970s and 1980s outlined an indicated resource of 240Mt grading 2.3% Cu. However, Afghanistan has yet to be evaluated in the light of modern mineral deposit models and improved analytical methods. From a global perspective, Afghanistan is relatively under explored and the potential for further discoveries of copper and other minerals is high. A ranking of significant known deposits and prospects is given below.

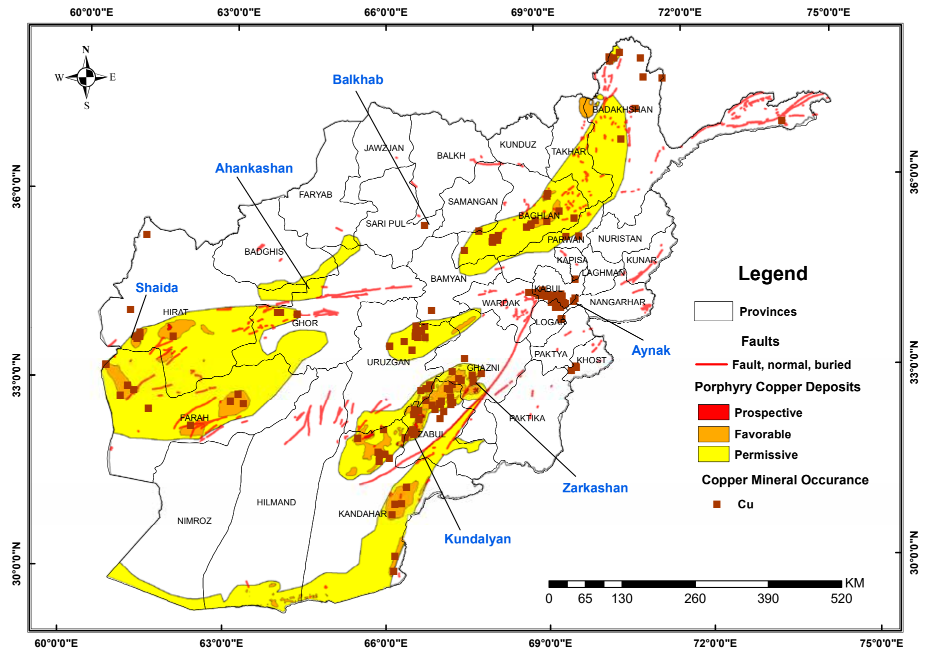


Figure 1. Map of Afghanistan, showing major deposits and prospects, and permissive tracts for porphyry copper deposits (ppycu01-12) (after Peters et al., 2007).

Ranking of Known Cu Deposits

1. Aynak
2. Zarkashan
3. Kundalyan
4. Balkhab
5. Shaida
6. North Aynak
7. Ahankashan
8. Darrah-i-Alansang
9. Gologha

DEPOSIT PROFILE 1	
Deposit Name	Aynak
Status	Tendered
Location	Logar Province
Deposit Style	Stratiform Cu, metasediment-hosted
Host geology	Vendian–Cambrian metamorphosed limestones and volcanics
Ore minerals	Bornite, chalcopyrite, chalcocite, native Cu, malachite, covellite, tenorite
Deposit geology	Deposit divided into Central and Western areas. Mineralisation traced for 2km, up to 1km wide and 60-210m thick to max depth of 1000m
Metal content	Drill-indicated reserves >240Mt @ 2.3% Cu

Sediment-Hosted Stratiform Copper Deposits

AYNAK

Sediment-hosted stratiform copper (*SHSC*) deposits are a large and diverse group that includes some of the richest and largest copper deposits in the world. The largest and best-known copper deposit in Afghanistan is the SHSC type Aynak deposit located in the Kabul Block 30 km southeast of Kabul (*Deposit Profile 1*). The deposit is of Vendian-Lower Cambrian age and is divided into two areas, Central Aynak and Western Aynak. Mineralization is characterized by stratabound disseminated bornite and chalcopyrite in dolomite marble and quartz-biotite dolomite schists of the Loy Khwar Formation. The deposit is thought to have formed by circulating hypersaline solutions leaching metals from underlying volcanic rocks (*BGS, 2005*).

The Aynak Copper Deposit is a well-explored resource, defined by extensive geological data and preliminary feasibility study work prepared by the Russian authorities and later on by MCC. The deposit has known to be truly "world class," being regarded as the second-largest known, unmined deposit in the world and of exceptionally high grade.

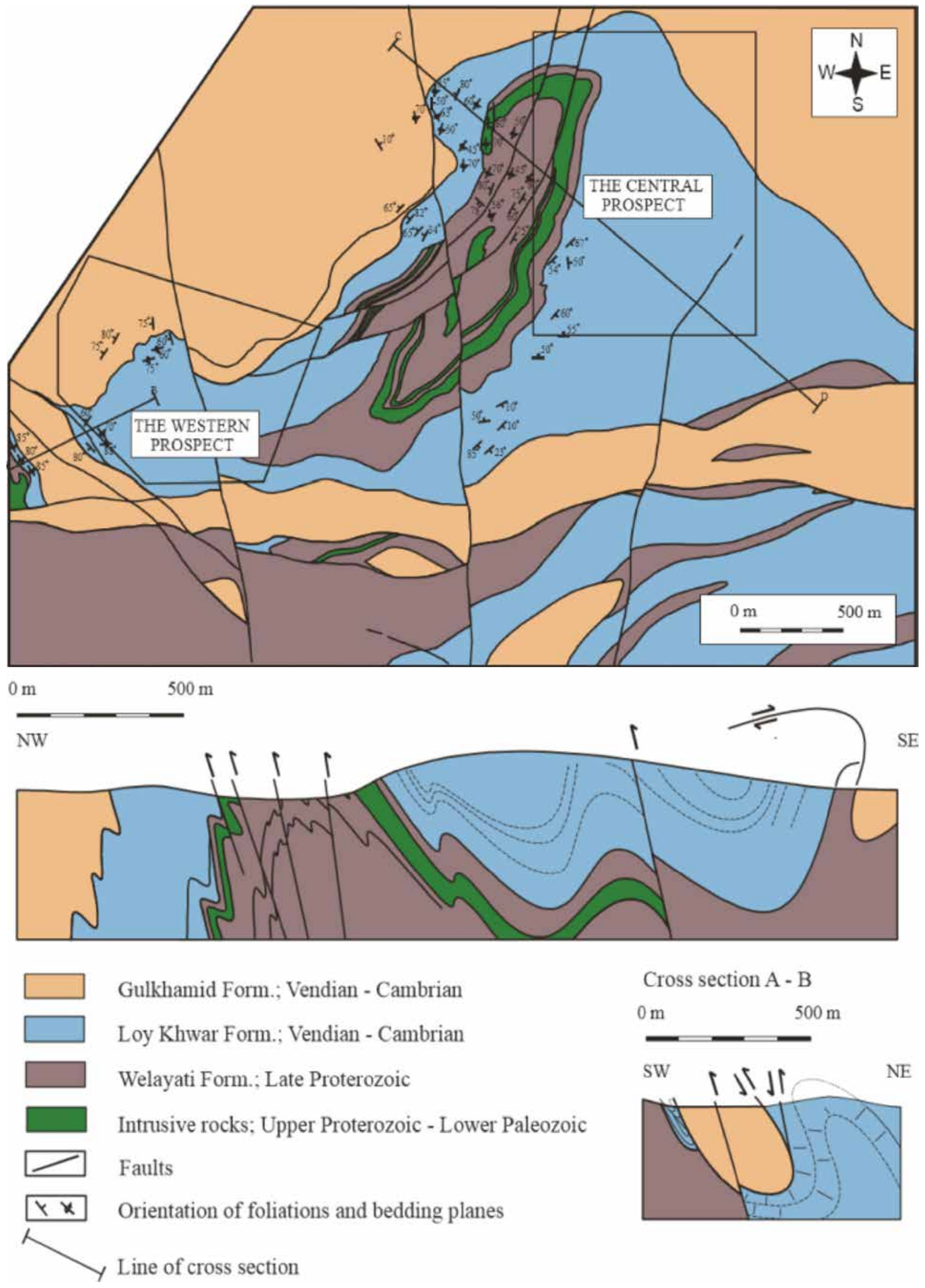
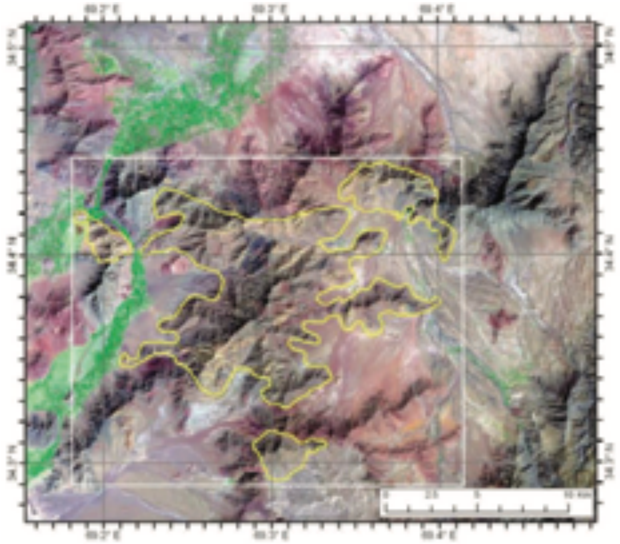


Figure 2. Geological sketch map and sections of the Aynak copper deposit. The deposit is hosted by the Loy Khwar formation shown in blue (BGS 2005).

Figure 3. North Aynak Landsat TM enhanced color image. TM bands 1-4-7 are shown in blue-green-red. Yellow outline is the Loy Khwar Formation that hosts copper deposits. Spectral analyses of ASTER and HyMap images, shows that the distinctive tan-colored outcrops within the Loy Khwar Formation are dolomite members, which host the Aynak copper deposit further south.



The resource was measured at 240Mt @ 2.3% Cu. Recently the contractor MJAM exploration has doubled the stated resource from 5.5Mt to 11.1Mt-contained Cu.

The Aynak Copper project was awarded in May 2008 to two Chinese state-owned companies, the China Metallurgical Group Corporation (*MCC*) and the Jiangxi Copper Company Limited. The consortium later called itself MCC-JCL Aynak Minerals (*MJAM*) to formally operate the project.

As per the Aynak 2014 Feasibility report, mineral resource statement, resulting in the value of the deposit being doubled:

- MJAM 662Mt @ 1.67% Cu containing 11.1Mt Cu
- RUSSIAN STUDIES 240Mt @ 2.3% Cu containing 5.5Mt Cu

NORTH AYNAK

Recent geological mapping of the North Aynak area (*Bohannon, 2010*) and interpretation of high quality remote sensed data (*Peters et al., 2011 and Department of Defense, 2011*) have improved the potential of this area and the latter estimate that more than half of the copper deposit could lie outside of the MCC area. One example of a known occurrence in North Aynak is described below. The Katasang occurrence is an 800m long, 3.6 to 13.8m thick (*average 7.2m*) mineralized zone within steeply dipping, albitized marble containing disseminated bornite, chalcopyrite, chalcocite and minor malachite. Limited exploration conducted at this site included 1:2,000-scale geological mapping, trenching, and geochemical sampling, and resulted in the calculation of a potential resource containing 42,100 tonnes of copper at an average grade of 1.04% Cu (*Kutkin and Gusev, 1977*).

Volcanogenic Massive Sulphide

BALKHAB

This poorly described occurrence has been reinvestigated by AGS and mapped using remote sensing data (*Peters et al., 2011*). The Balkhab copper volcanogenic massive sulfide (*VMS*) prospect lies within the Balkhab copper

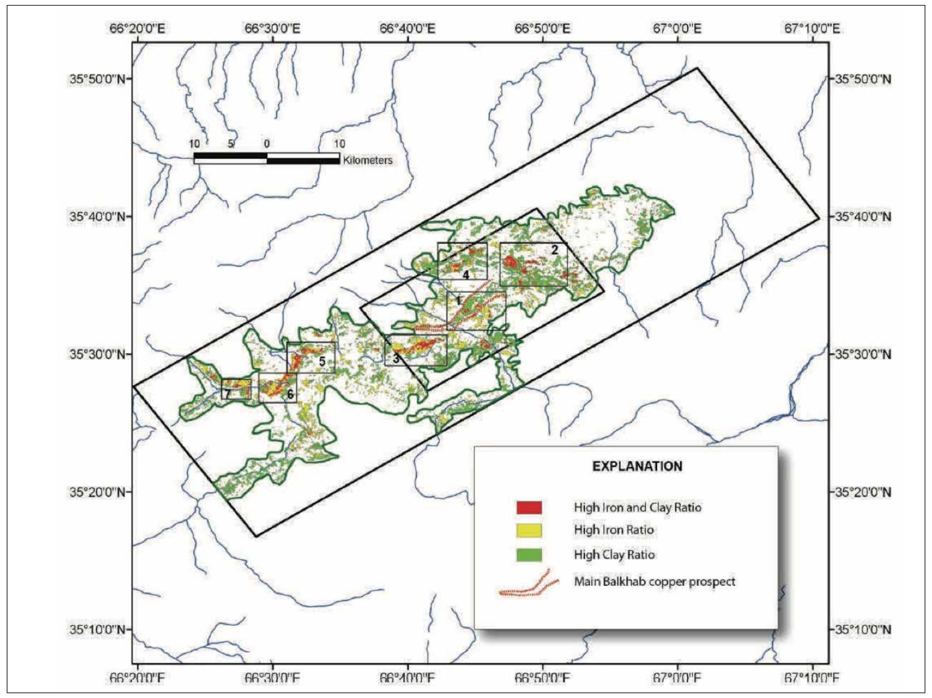


Figure 4. Anomalous zones (1-7) determined from Landsat TM alteration patterns in the Balkhab copper area (Peters et al., 2011).

Figure 5. Malachite- and azurite-coated phyllite from Balkhab copper prospect (Peters et al., 2011).

DEPOSIT PROFILE 2	
Deposit Name	Balkhab
Location	Sari-i-Pul Province
Deposit Style	Volcanogenic Massive Sulphide
Host geology	Ordovician schist and phyllite with bimodal felsic volcanics
Ore minerals	Pyrrhotite, chalcopyrite, bornite, galena, malachite, azurite
Deposit geology	Copper mineralisation consists of a silicified limonite-bearing zone 4 to 5m long by 300 to 400m wide
Metal content	Zone grades 0.25 to 1.34% Cu but no estimate of tonnage

area of interest and is part of an eroded inlier of deformed pre-Triassic, mainly Ordovician rocks, in Sar-i-Pul Province. It lies in a canyon unconformably below horizontal Mesozoic sedimentary rocks (*Peters et al., 2011*). Copper mineralization consists of a silicified limonite-bearing zone 4,000 to 5,000m long by 300 to 400m wide of deformed and faulted rock that contains at least four areas of extensive malachite, azurite, pyrite, and disseminated chalcopyrite, bornite, and galena grading from 0.25 to 1.34% Cu.

Remote sensing studies suggest that the mineralization may extend for over 40km (*Figure 4*).

Copper Porphyry Deposits
Soviet-Afghan teams identified a number of Cu-Au prospects and occurrences in the Tirin-Argandab zone and Peters et al., (*2007*) defined this as their prospective tracts ppycu05-07 (*Figure 1*). The zone forms part of the Tethyan Metallogenic Belt of world-class porphyry copper-gold deposits, which stretches from Europe, through Turkey, Iran, Pakistan, Afghanistan, Tibet and into SE Asia. The prospective tracts have been identified by a distinctive group of Cretaceous-Paleocene intrusive rocks that are spatially related to the known Cu skarn deposits and prospects, alteration zones from ASTER and aeromagnetic anomalies. Within them two deposits, Zarkashan in the north and Kundalyan in the south, have been investigated by detailed sampling, trenching and drilling.

ZARKASHAN

The Zarkashan Area of Interest surrounds the Late Cretaceous-Paleocene Zarkashan diorite, granodiorite to adamellite intrusion and consists of a number of gold and copper occurrences (*Figures 6* and *7*). The mineralization consists of chalcopyrite, pyrite, sphalerite, chalcocite, bornite, and native gold in the hydrothermally altered skarns. Preliminary exploration, including rock sampling, trenching and underground adits, indicates the presence of several ore-bearing zones 400-600m long and 1-15m thick, with lenticular

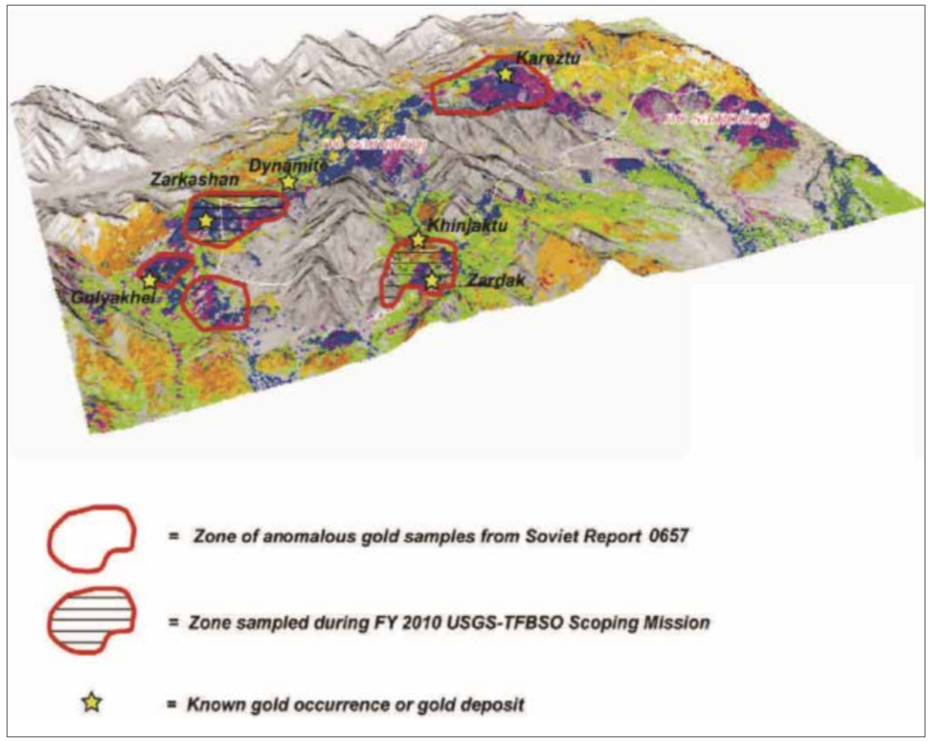


Figure 6. Three-dimensional view of the Zarkashan copper and gold area of interest showing hyperspectral anomalies surrounding the Zarkashan intrusive (white outline). Blue and purple zones represent alteration zones with goethite and jarosite. These alteration zones are coincident with anomalous gold areas from earlier Soviet sampling (Peters et al., 2011).

DEPOSIT PROFILE 3	
Deposit Name	Zarkashan
Location	Ghazni Province
Deposit Style	Porphyry Cu-Au and related Skarn
Host geology	Late Triassic dolomites in the contact zones of the Zarkashan gabbro, monzonite and syenite intrusion
Ore minerals	chalcopyrite, pyrite, sphalerite, chalcocite, bornite and gold
Deposit geology	Skarns occur in pockets or as sheetlike deposits. Several ore-bearing zones occur 400– 600m long and 11–75m wide. The richest gold is found in phlogopite skarns
Metal content	7.7t Gold contained in C1 and C2 categories

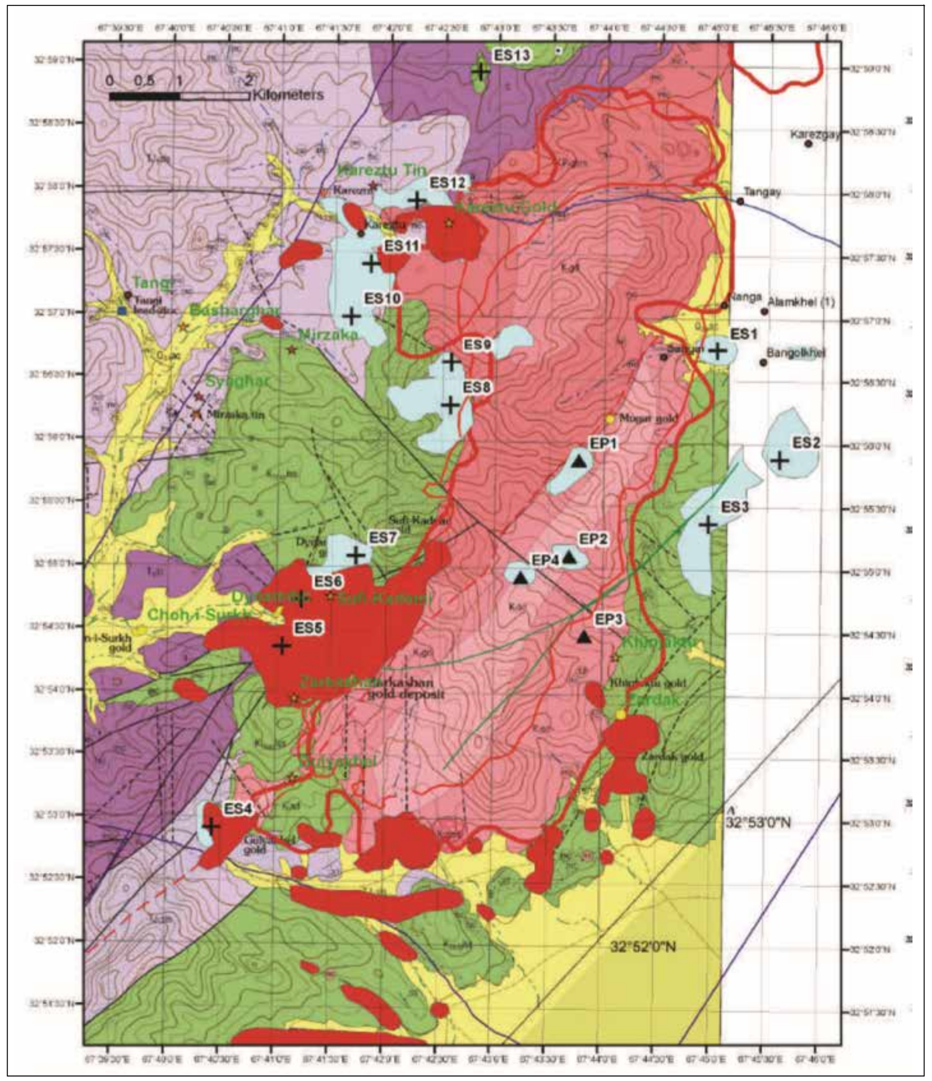


Figure 7. Geological map of the Zarkashan area showing the mineralized areas (bedrock gold anomalies in red) surrounding the Zarkashan pluton (lighter shades of red). (Peters et al., 2011).

and nest-shaped bodies of 1.5-50m long and 0.5-3.8m thick. Gold mineralization is traceable for 80m down dip, assaying from 0.10 g/tonne to 16 g/tonne gold. Category C1+C2 resources contain 7,775kg Au and speculative resources are 12 to 15 tonnes of gold. Copper grades vary from 0.01 to 15%. Recent sampling by USGS (*Peters et al., 2011*) has shown that extensive, disseminated mineralization is present in the large contact (*hornfels*) zones indicating large medium- to low-grade ore bodies that are amenable to modern excavation methods at current gold and copper prices.

A number of other prospects, such as Zardak, Dynamite, Choh-i-Surkh and Sufi Kademi, around the Zarkashan intrusive are also highly prospective for porphyry coppergold deposits and worthy of further investigation. Peters et al., (*2007*) predicted that in the Zarkashan-Kundalyan tract there is a high probability (*50%)* of one porphyry copper-gold deposit and a 10% probability of two deposits.

DEPOSIT PROFILE 4	
Deposit Name	Kundalyan
Location	Zabul Province
Deposit Style	Cu-Mo-Au-Ag skarn
Host geology	Proterozoic and Vendian-Cambrian metamorphosed limestones and cherts
Ore minerals	Chalcopyrite, magnetite, pyrite,sphalerite, molybdenite, chalcocite, bornite, covellite, native Cu, malachite
Deposit geology	Three deposits up to 155m long and 2.59-3.89m thick. Mineralization restricted to hematite-kaolin-quartz and meta-carbonates
Metal content	C1+C2 resources 13600t Cu @ 1.07% Cu; 1.1t Au, @ 0.9 g/t Au; 127.3t Mo @ 0.13% Mo

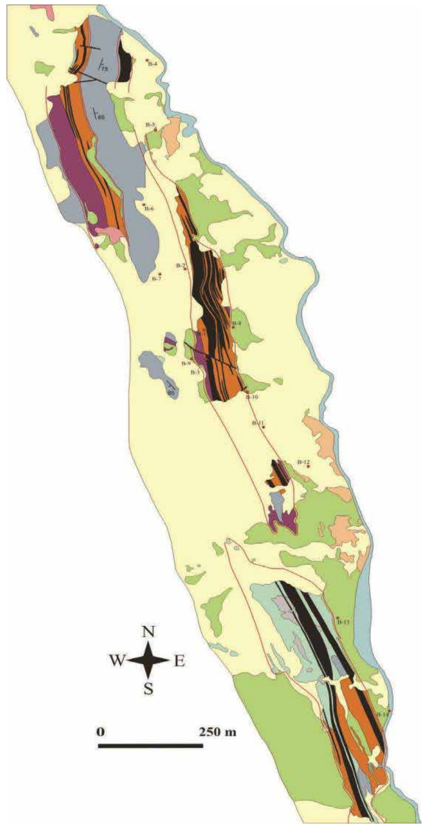
KUNDALYAN

The Kundalyan copper-gold skarn deposit is localized along a 400 meter long, 1.5km wide inlier that consists of altered limestone, chert, and skarn (*Peters et al., 2011 after Soviet authors*). The chief minerals in the skarn are pyroxene, garnet, amphibole, phlogopite, and magnetite. Mineralization is present both in skarn and chert. There are 13 orebodies along the Kundalyan Fault Zone (*Figure 8A*) that are between 2.65 to 12.3m thick and from 36 to 175m long, containing 0.62-1.2% Cu and 0.5-2.0 g/t Au. The mineralization is predominately chalcopyrite and pyrite and more seldom sphalerite, gray copper ore, and enargite. The Category C1+C2 reserves in the Soviet classification system, were reported as 13,600 tonnes of coppergrading 1.07% Cu and 1.1 tonnes of gold grading 0.9 g/t Au.

The Kundalyan copper-gold skarn deposit area was explored by a series of trenches, adits, and drill holes. Data was presented on cross sections (*Figure 8B*) for about 5km of strike length along a NNW-trending zone that is exposed in a valley. The Kundalan copper-gold deposit has been explored where a northweststriking stream has eroded through colluvial cover and exposed a granodioritic intrusive intruding Precambrian, Cambrian, and Carboniferous limestone. The skarn zone contains brecciated, stromatolitic (?) limestone and contains large areas of layered calcsilicate rock related to skarn formation and metasomatic kaolin-carbonate rock. Malachite-stained siliceous skarn and porphyroblastic marble also are common in the mineralized zone. Despite the extensive trenching and the boreholes in the main zone there seems to have been little exploration of the colluvium covered areas to the west and east.

Several copper and copper-gold and gold prospects and occurrences are present peripheral to or away from the main Kundalyan copper-gold skarn deposit. Prospects generally cluster near and around the Kundalan group of deposits in the Kaptarghor, Shela-i-Surkh, Baghawan-Garangh, Kunar and Chasu-Ghumbad areas. Further details can be found in Peters et al., (*2011*).

A



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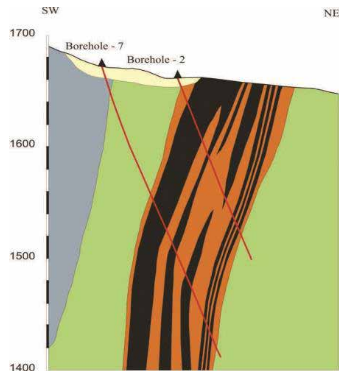


Figure 8. (A) Geological map of the Kundalyan area showing the ore zone (black), skarn (orange), kaolin-carbonate rock (grey), altered granitoids (pale blue), granodiorite (green) and colluvium (pale yellow). (B) Illustrative cross section through boreholes 2 and 7 at Kundalyan (key as above).

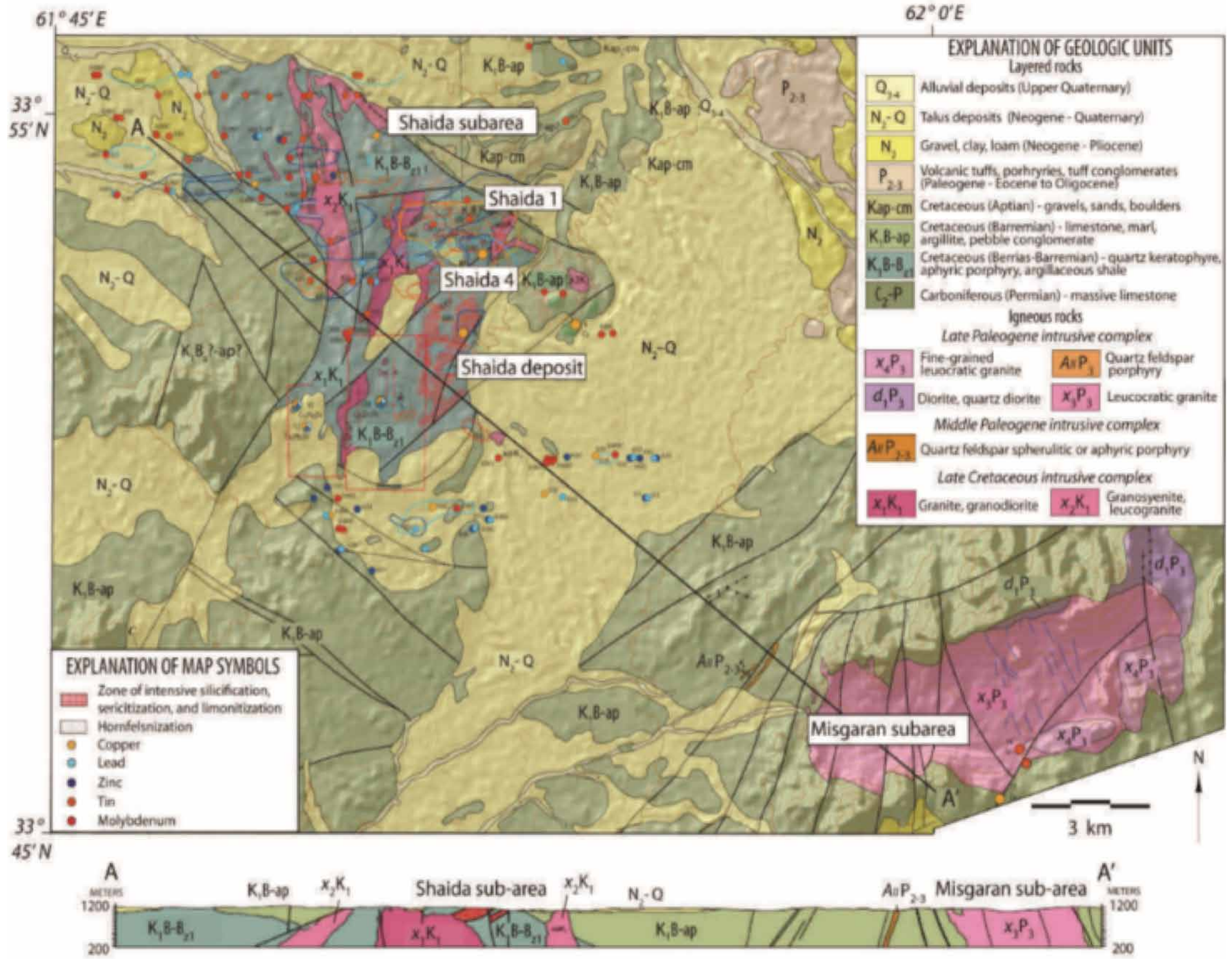


Figure 9. Geologic map and cross section of the Shaida and Misgaran subareas. All of these sites are within heavily mineralized (copper) volcanic rocks of Early Cretaceous age, as indicated by the cross-hatch pattern. (Peters et al., 2011).

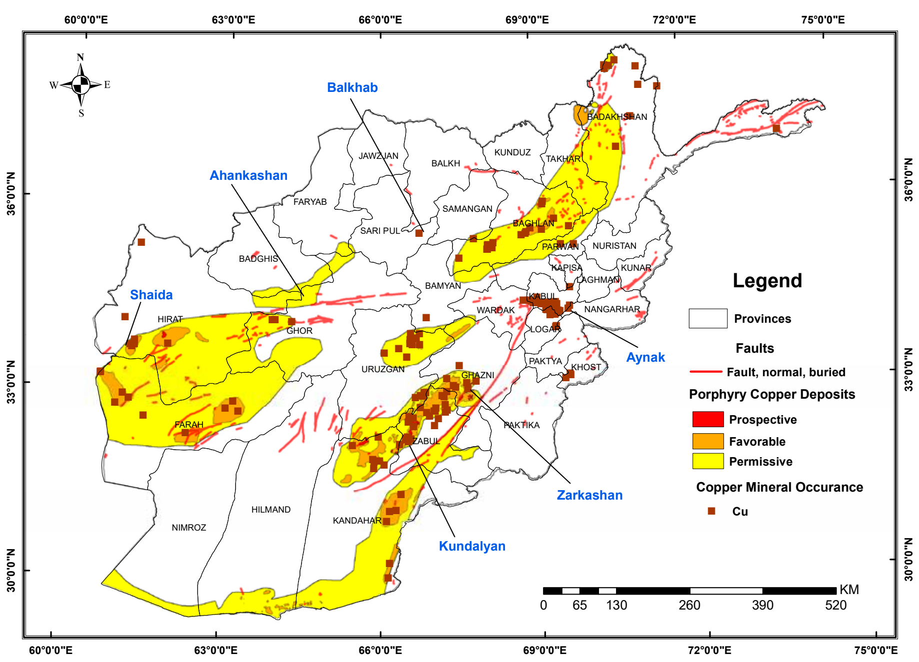
SHAIDA

Shaida and its related prospect Dusar lies SW of Herat in permissive tract ppycu09 (Figure 1). The Shaida subarea is classified as a highly prospective copper porphyry deposit. The host rocks are early Cretaceous volcanics. The copper mineralization coincides with a 200 to 300m wide, strongly fractured, limonitized and kaolinitized fault zone, where six steeply dipping mineralized bodies and a Cu- pyrite gossan are present. The main zone of mineralization, 2.6km long and 300 to 500m wide, consists of secondary copper minerals assaying 0.27 to 3.02 % Cu and 0.02 to 0.37 % Zn The grade was confirmed by the USGS in August 2010. Based on diamond drilling the individual occurrences are 1 to10m thick (average ~4m) and up to 2400m long. Minerals are pyrite, pyrrhotite, sphalerite and minor chalcopyrite in massive veinlets and disseminated ores that assay between 0.04-1.6% Cu (average 0.63%), between 0.09-7.0% Zn (average 1.3%), between 0.01-0.5% Pb (average 0.08%), and between 0.20.03 g/t Au. Potential ore resources are estimated at 4.8 Mt assaying 1.1% Cu and 1.2% Zn.

PORPHYRY CU-MO-AU

Background
Globally, one of the most important types of mineral deposits associated with subduction complexes and continental collisions are porphyry Cu-Au-Mo deposits. Often these deposits are large in resources but modest in ore grade and they account for world production of more than 60% copper, 95% molybdenum and 20% gold.

Afghanistan hosts two belts highly prospective for porphyry style mineralization. These belts cut central and SE Afghanistan passing into the Hindu Kush and southern Pamir (*Figure 1*).



MOLYBDENITE IN BAMYAN PROVINCE

During recent fieldwork by staff of the Afghanistan Geological Survey (*AGS*) in the southwest reaches of the Saighan valley in Bamyan Province, local villagers told them of an exposure of soft metallic mineral after a recent landslide. Upon investigation the AGS team identified a quartz-feldspar brecciated zone containing extensive molybdenite mineralization (*Figure 2*). The zone is at least 2 metres thick but as much of it is concealed by thick landslide debris and recent sediments, the extent of it could not be determined. This was the first significant discovery of molybdenite in the Northern Cu Porphyry Belt. Further fieldwork in summer and fall of 2011 revealed molybdenite associated with the upper Triassic (*T3*) granitoids, 5km to the east of the brecciated zone. At two locations (*Figure 3, points 1* and *2*), disseminated molybdenite is hosted in quartz-monzonite/ granodiorite stocks (*Figure 4*).

NORTHERN COPPER PORPHYRY BELT

The northern belt is the western extension of the Alborz Island Arc occurring from Herat to Panjshir, along the Hindu Kush in Afghanistan.

SOUTHERN COPPER PORPHYRY BELT

The southern belt is an extension of the Zagros Island Arc. This belt is exposed in the Chagai Hills in Pakistan, and extends northwards through Helmand and Khandahar in the south to Ghazni and Zabul in central Afghanistan. Comprehensive reviews of Afghanistan Porphyry Belts is given in Kafarskiy et al. 19751 and by Peters et al 2007.

Figure 1. Porphyry Cu belts within Afghanistan

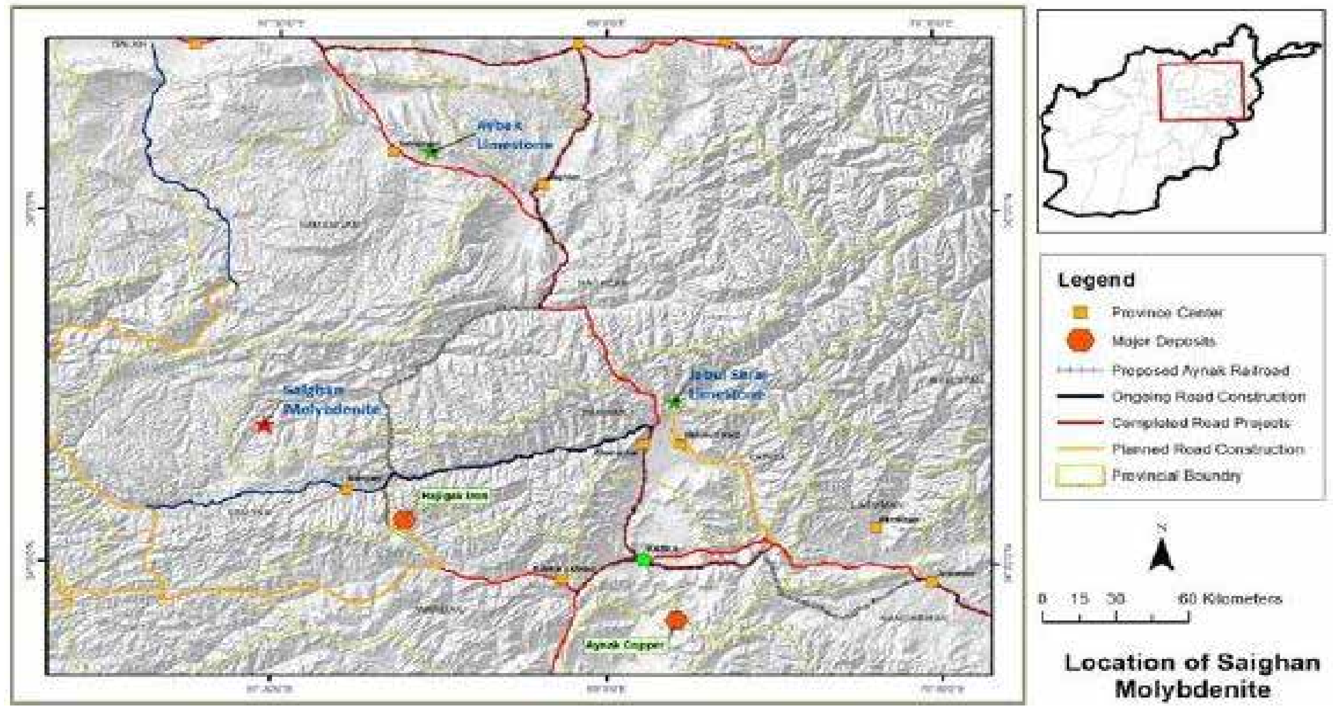
Location
The prospective area is located about 45km northwest of the city of Bamyan, capital of Bamyan Province. The province also hosts the world-class Hajigak Iron ore deposit and abundant coal resources (*Figures 1, 2* and *3*). The area of molybdenum mineralization occurs approximately 50km distance from the juncture of Saighan River with Dari Shikari River (*Figure 2*) along which a railroad is planned to be built as part of the Aynak copper development project. At the moment information is being collected for the feasibility study of the railroad project by the developer of the Aynak copper deposit. The anticipated railroad will connect Afghanistan with the Central Asian Republics and major ports on the Indian Ocean.

Geology
According to the 1:500,000 scale geological map of Afghanistan published by the USGS in 2007 and based on the original Soviet map of 1977, the granitoids (*granodiorite, granosyenite, and quartz monzonite*) that host the porphyry copper and molybdenum are of Upper Triassic to Lower Jurassic age. The oldest sedimentary units in the area are limestones and dolomites of Carboniferous and Permian age (*Figure 2*). These are unconformably overlain by Middle-Upper Triassic *(T2-3)* sandstones, siltstones and mudstones and Upper Cretaceous and Paleocene (*K2-P1*) limestones and dolomites. The Middle-Upper Triassic and Cretaceous rocks form a NE-SW trending anticline structure in the area of molybdenum mineralization, intersected by series of faults (*Figure 2*). Granodiorite stocks that host the molybdenum occurrences are not shown on the 1:500,000 geological map.

Based on field observations, the Saighan area has high potential for the discovery of economic porphyry copper, gold and molybdenum deposits. In addition, there are halos of heavy fraction assessment that indicated presence of bismuth, copper and other metals.

In addition to the molybdenum mineralization, 10km to the northwest of the area, there are artisanal excavation tunnels (*up to 30m long*) indicating gold mining in the recent past, exploiting auriferous quartz veins at the site.

Figure 2. Location of Saighan molybdenum and other mineral projects.



Resource Estimation
A preliminary estimate of molybdenum resources was made by applying outcrop dimensions (*4,300m length, 300m width*) and a depth of 200m (*taking into account that the granite stock continues at a depth of 200m*) and applying an average concentration of 0.08% Mo in the ore.

Specification	Area in Block in Figure 2
Area (4,500*3)	1,350,000 m^2
Depth	200 metres
Volume	270,000,000 m^3
Specific weight of MoS	10.22 grams/cm^3
Molybdenum in ore	0.08%

Table 1. Saighan Molybdenum Resources

Figure 3. Quartz-monzonite mass with 15% disseminated molybdenite, Saighan.

CHROMITE

Background
Volin (*1950*) evaluated ten known chromite bodies in the Logar ultramafic body, using surface mapping and sampling and a limited programme of shallow diamond drilling. He also calculated reserve figures based on the results of this drilling. Hunger (*1955a* and *b*) recorded two further chromite localities. Siebdrat (*1971*) undertook further surface mapping of the ultramafic rocks of the Logar Valley, and he identified 18 chromite localities in the Logar ophiolite (*Figure 1*).

Abdullah (*1980*) in his comprehensive review of the geology and mineral occurrences of Afghanistan catalogued 15 areas of chromite mineralization scattered throughout the country, most in the Logar Valley, south of Kabul. The other areas include Jurgati in Parwan Province, Werek in Logar Province, Sperkay and Shandal in Paktia Province. In addition, minor occurrences of chromite in eluvial deposits and of small chromite lenses in situ were reported by Abdullah in Kandahar Province associated with Early Cretaceous ultramafic rocks. Chromite grains were also observed in concentrates from Kandahar Province collected by the Russian reconnaissance surveys.

THE LOGAR OPHIOLITE

The largest and best-known chromite deposits in Afghanistan are in the Logar Valley in the Muhammed Agha District about 35km south of Kabul. The Logar ophiolite complex has an ellipsoidal outcrop, elongated in a north-westerly direction, about 65km long and up to 45km wide. The external contacts are mostly tectonic: the steep-dipping north-south Pagman Fault forms the western contact, while to the east and south-east the complex is bounded by the Altimur Fault. To the north the Abparan Thrust separates the allochthonous ultramafic rocks from the autochthonous rocks of the Kabul Block.

The largest part of the ophiolite comprises ultramafic rocks in a sequence up to about 2,800m thick. The basal part comprises about 2,400m of dunite and subordinate harzburgite, overlain by a thick pyroxenite about 200m thick with minor intercalated dunite at its base. This passes up into a thin unit of troctolite and pyroxenite, passing up into a 50 m thick gabbronorite. The chromite bodies occur predominantly in the harzburgite within small dunite pods according to Siebdrat (*Figure 1*).

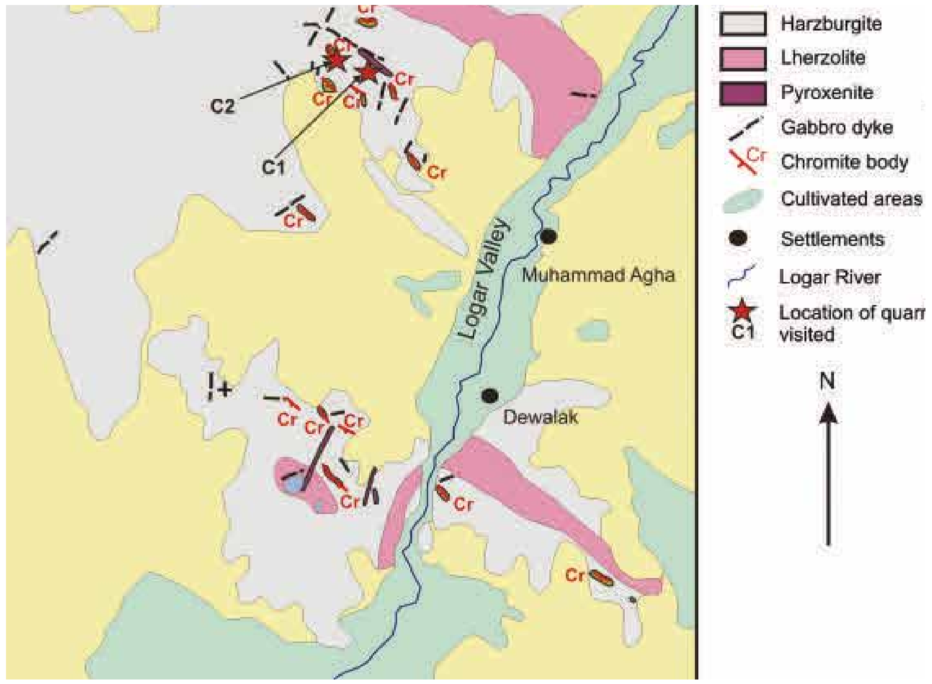


Figure 1. Chromite occurrences in the Logar area showing the association of the chromite bodies with lenses of dunite within the harzburgite (modified after Siebdrat, 1971. Visited sites C1 and C2 are from Benham et al., 2009).

Resource Assessment
The chromite deposits of the Logar Valley (*Figure 2*) occur in two main groups about 10km apart, all bar two being on the west side of the valley. The northern cluster is within 5km north-west of Muhammad Agha. The southern cluster is close to Karez-Sha-Ghazi, about 10km south of Muhammad Agha. All are within easy reach of Kabul via the surfaced Kabul-Gardez road. These deposits were studied in detail by the U.S. Bureau of Mines (*USBM*) in 1949-50. Volin made investigations aimed at estimating reserves of chromite ore of suitable quality for the prevailing market conditions. No exploration for additional deposits was carried out.

Subsequent reassessment by the German Geological Mission (*Siebdrat, 1971*) increased Volin's estimates by a significant amount, but it is unclear whether this was based on any additional drilling or new geophysical data.
The chromite deposits consist of massive lenses, pods and irregular-shaped masses of dominantly massive chromitite. Textural variations are few with minor development of patchy 'leopard skin' type ores. The largest deposit (*No.5 of Volin*) comprises two lenses, one 97.5m long and up to 10m wide and the other 65m long and up to 5m wide. Most of the other deposits are considerably smaller. The margins of the chromite bodies are sharp, knife-edge and generally highly irregular in form, rarely planar. Immediate wallrocks are generally serpentinised and show development of a close-spaced planar fabric/fracturing parallel to the contact with the chromitite. The USBM exploration programme included mapping and sampling outcrops, trenching in shallow overburden, sampling by shallowercussion drilling and the drilling of 27 diamond drill holes with an aggregate length of 975m. The diamond drilling tested three of the largest deposits on surface and a small high grade deposit, all in the northern cluster of deposits. Volin estimated a total resource of 181,000 tonnes, concentrated in three deposits (*1, 2* and *5*). Of this about 15% (*27,000 metric tonnes*) is high grade metallurgical ore with 55.9% Cr_2O_3 and Cr:Fe ratio of 3.5:1. The remainder of the estimated resource contains less than 45% Cr_2O_3 and high levels of Al_2O_3. 92% of the total resource occurs in the three largest deposits (*2, 5* and *7*), and, of these, only deposit 2 contains high-grade ore.

Composition of Logar Chromite Ore
Most chromite exported from Afghanistan is handpicked on site. Based on 18 such samples collected from sites in Logar and elsewhere in the Kabul Block, analyses were performed by AGS staff supervised by GTZ using a Niton portable-XRF analyzer and gave a median content of 35.56% Cr (*equivalent to 52%* Cr_2O_3) and a Cr/Fe ratio of 4.2 (*Table 1*). The statistical distribution is lognormal and slightly lower than Volin reserve estimate given above, but higher than the median grade of 44% Cr_2O_3 for minor podiform deposits given by Albers (*1986*).

Element	Median (%)	25th Percentile	75th Percentile
Chromium	35.56	31.40	37.41
Iron	8.45	8.18	9.68

Table 1. Median and quartile range of Chromium and Iron in Chromitite samples from Logar.

Platinum Group Element Potential of Logar
Benham et al. (*2009*) published the only recent analyses of Platinum Group Elements (*PGE*) in rocks of the Logar Complex. Concentrations of PGE in the Logar chromitites are low with maxima of 6.5ppb and 5.5ppb palladium. Rhodium values are relatively high, with two samples exceeding 10ppb. In dunites, platinum and Pd values are generally <10ppb, although one sample LGR 012 contains the maximum reported values of 11.3ppb Pt and 9.4ppb Pd. The pyroxenite samples have relatively high Pt values with an average of 13ppb, whilst they have very low Pd and Rh values. These observations are based on limited data and further sampling would be needed to identify any significant patterns in the data.

KABUL BLOCK NORTHERN PART

North-East of Kabul another ophiolite complex was obducted onto the Kabul Block and is named the Kohi Safi Complex after the district it is found (*Figure 2*). The Jurgati chromite occurrence is located in Parwan province about 45km N.N.E. of Kabul near the peak of Sarpokhi Ghar within the Complex. The known mineralization is 20m by 30m in size and found in the western part of an Eocene peridotite (*Denikaev and others, 1971*).

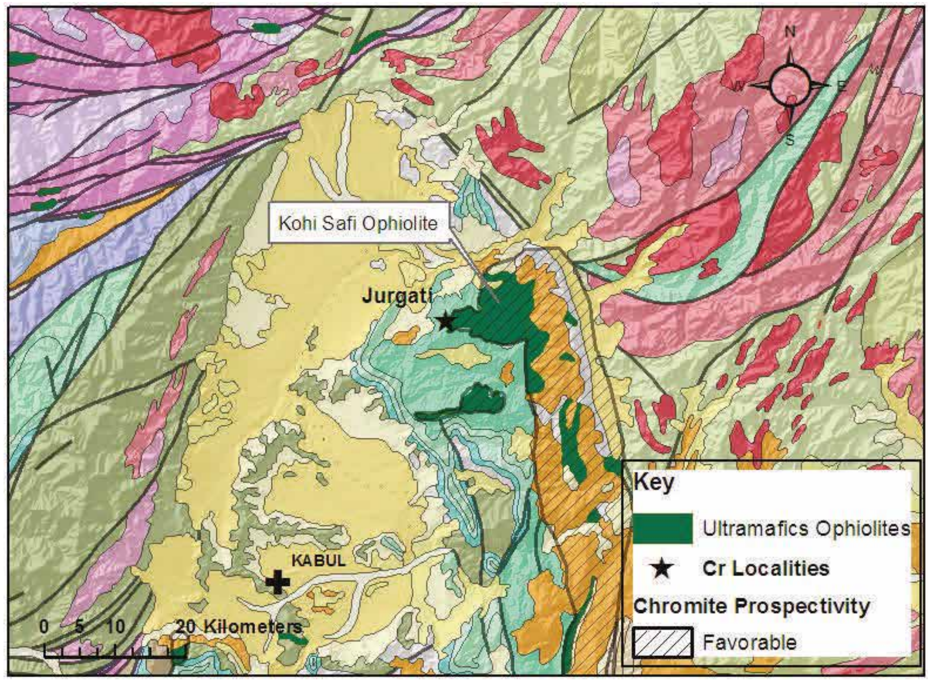
Chromite mineralization and small-scale mining was reported in 2008 from this area by Bräutigam (*pers. comm.*) but its areal extent is unknown. Compared to the Logar complex, Kohi Safi is about ¼ the size but it has been poorly studied so therefore the economic potential is difficult to assess.

KHOST AND PAKTIA

Sperkay chromite occurrence just west of Teragharay near the border with Khost Province, consists of ten massive chromite bodies are found in Eocene peridotite (*Figure 3*).
The chromite bodies are as much as 110m long and 1 to 10m thick. They assay from 43.11 to 53.48% Cr_2O_3 and from 5.57 to 7.23% Fe.
Shandal (*Shodal*) chromite occurrence is south west of Teragharay and is about a kilometre south of Sperkay.
It consists of 34 known chromite-bearing lenses ranging from 3 to 40m in length and 0.2 to 0.4m thick plus thin veinlets with disseminated chromite. All the chromite-bearing lenses occur in Eocene peridotite.

The massive chromite lenses have minor olivine grains, and assay 44.36% Cr_2O_3. Nitikin and others (*1973*) speculate that the chromite resource is about 4,000 tonnes.

Figure 2. Geological map of the area north of Kabul showing the Jurgati locality and favorable prospective areas from Peters et al., (2007).



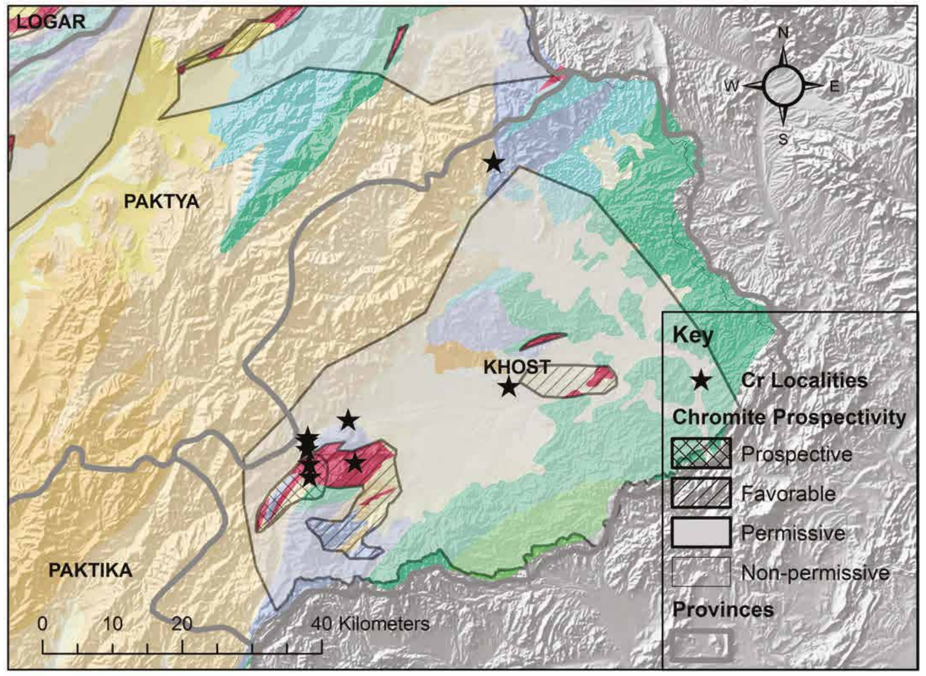


Figure 3. Chromite localities in Khost province. Prospective areas from Peters et al., (2007) on a background of the geological map and shaded relief.

Summary of the Chromite and PGE potential of Afghanistan

- A large number of small deposits have been worked at surface
- There is a large potential for the discovery of further deposits at surface and at deeper levels
- The PGE potential has been largely untested but grains of PGE minerals have been discovered
- Exploration for PGE should be focussed on areas with sulphide minerals

IRON ORES

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*).

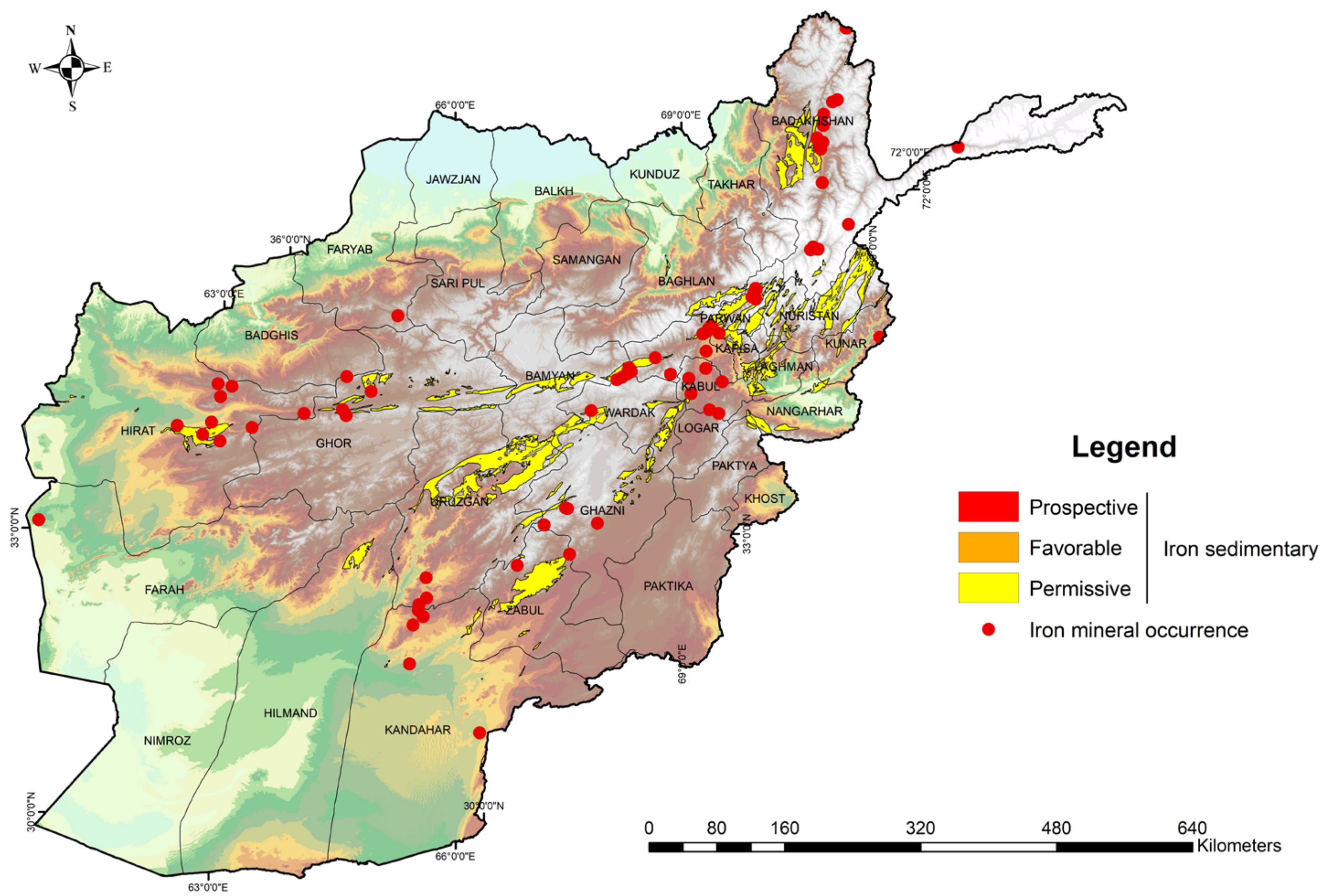


Figure 1. Geological map of Afghanistan showing location of stratabound iron ore occurrences within Middle to Upper Proterozoic formations.

SYADARA IRON ORE

Large massive magnetite bodies were discovered by the Afghanistan Geological Survey (*AGS*) at Syadara during the 2010 field season 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. 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 45º 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. 1*) from composite grab samples returned grades ranging from 50-67% Fe (*mean of 65% Fe*) and are consistent with grades at Hajigak.

Figure 2. 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)

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 1. Shows the results of identified samples.

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 5*). 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.

Mineralization
The Syadara iron ore body consists of massive magnetite with weak specular hematite, pyrite and with minor to trace chalcopyrite. Intense oxidation represented by limonite (*goethite-hematite*) is well developed in places, with trace malachite-azurite and neotocite (*proven by H_2SO_4 test*). The ore body extended at both ends NE-SW, for more than 10km along strike. 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. 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*).

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 Syadara 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 *(Figure 3)*.

Recently the AGS remote sensing experts cared 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 4)*.

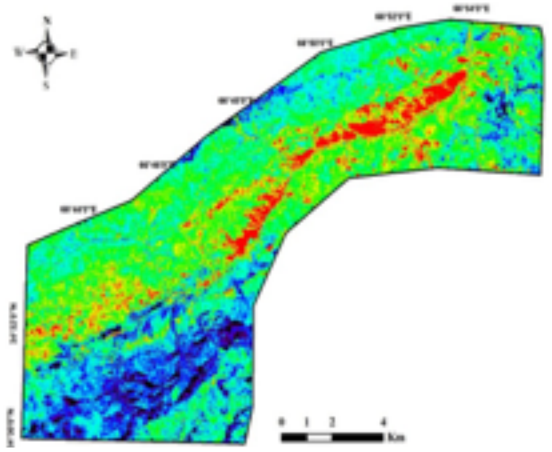


Figure 4. Remote sensing map of Syadara area, Bamyan Province. Red colored area shows the iron oxide spots.

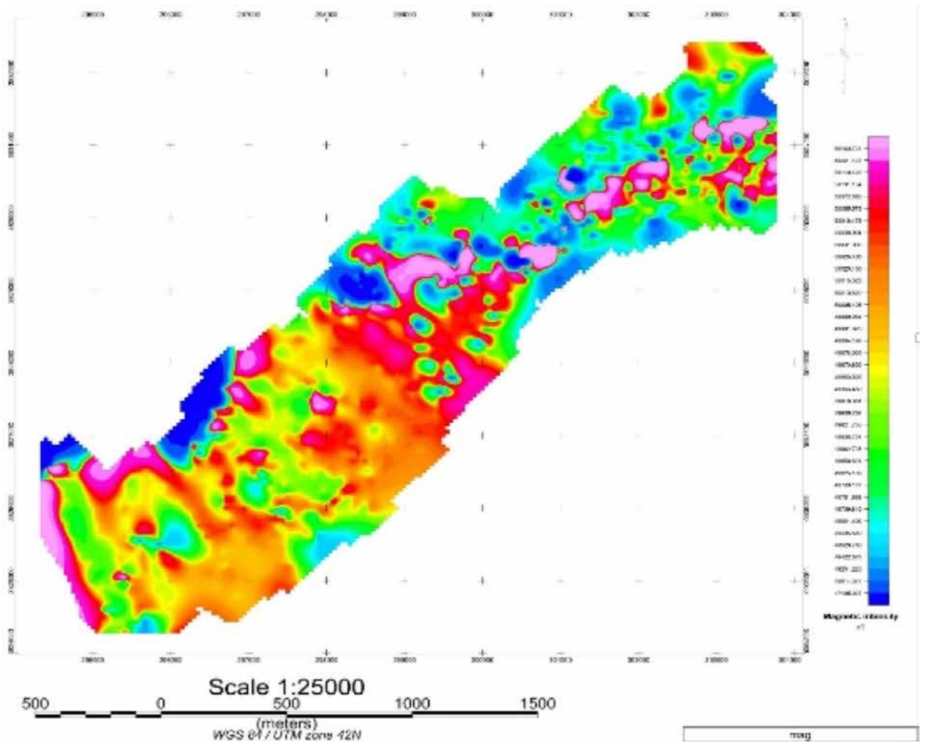


Figure 3. Magnetic anomaly map Syadara area of interest: The pink and red colored areas show the high magnetic intensity zones (magnetic ore bodies) and the green and blue colored areas show the low magnetic intensity zones (host rocks).

HAJIGAK IRON ORE

Geology

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 4,500 m thick *(Figure 6)*.

Mineralization

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.

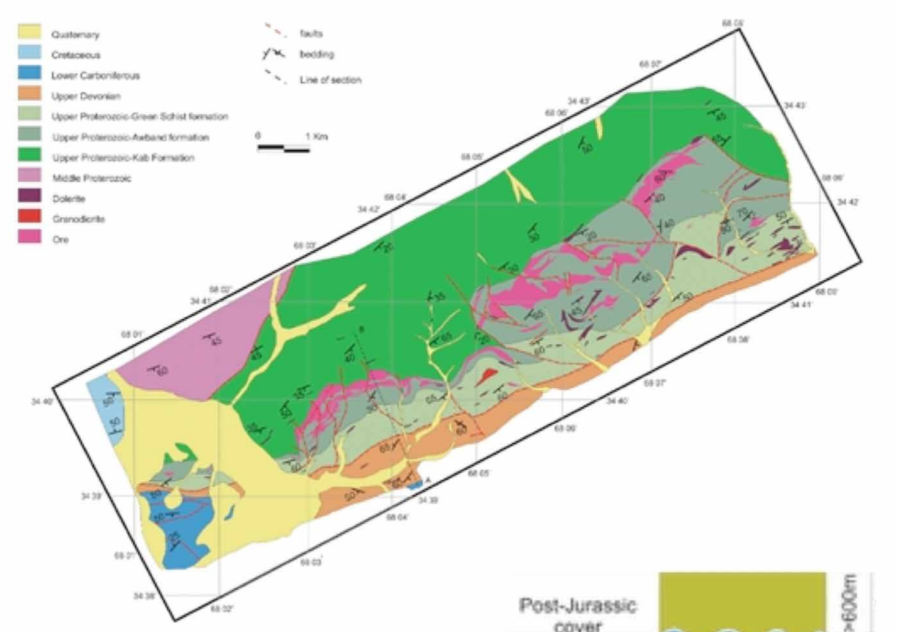


Figure 5. Simplified geological map of the Hajigak area (after Kusov et al., 1965).

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.

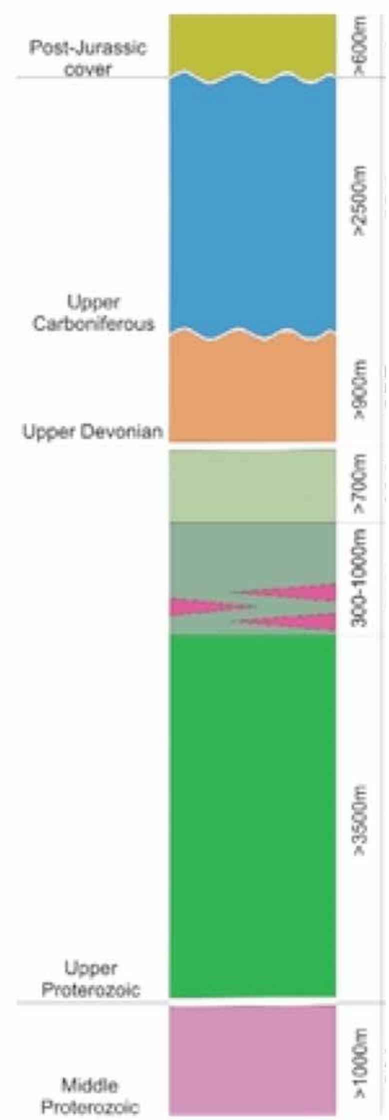


Figure 6. Stratigraphic log of the Hajigak area. (after Kusov et al., 1965).

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 5*). 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 5), 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.

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

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 2*). 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 NE of 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 3 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*).

Other Proterozoic Iron

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

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 1km. 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 7.2Mt (*Abdullah et al. 2008*).

PANJSHIR IRON ORE

The Panjshir iron occurrences and deposits are hosted by Proterozoic metamorphic carbonate and volcanic rocks. The iron deposits are both hematite-magnetite, siderite-magnetite, and ferruginous quartzite types. The hematite-magnetite type is the most common deposit.
The deposits of the siderite-hematite (*ferrocarbonate*) in the Panjsher Valley subarea are thick and extensive bed-shaped lenticular bodies or pods of siderite-hematite that are as much as 30 m thick and several kilometers long. These orebodies occur in Proterozoic carbonate rocks, and examples are present in the Panjsher River basin in the Panjsher Valley area. The principal constituents of the ores are hematite and siderite.

The inferred reserves of iron ore from the deposits of this group have been estimated to be hundreds of million metric tons. However, the Noqra khana iron ore deposit is estimated to have 68 million tons and the Dara-e Tol about 34 million tons of iron resources. Based on the studies, 49 blocks and hematite mineral appearances were determined. Hematite that are as much as 30 m thick and several kilometers long. These orebodies occur in Proterozoic carbonate rocks. Based on Lab analysis the percentages of FeO is 47,8%.

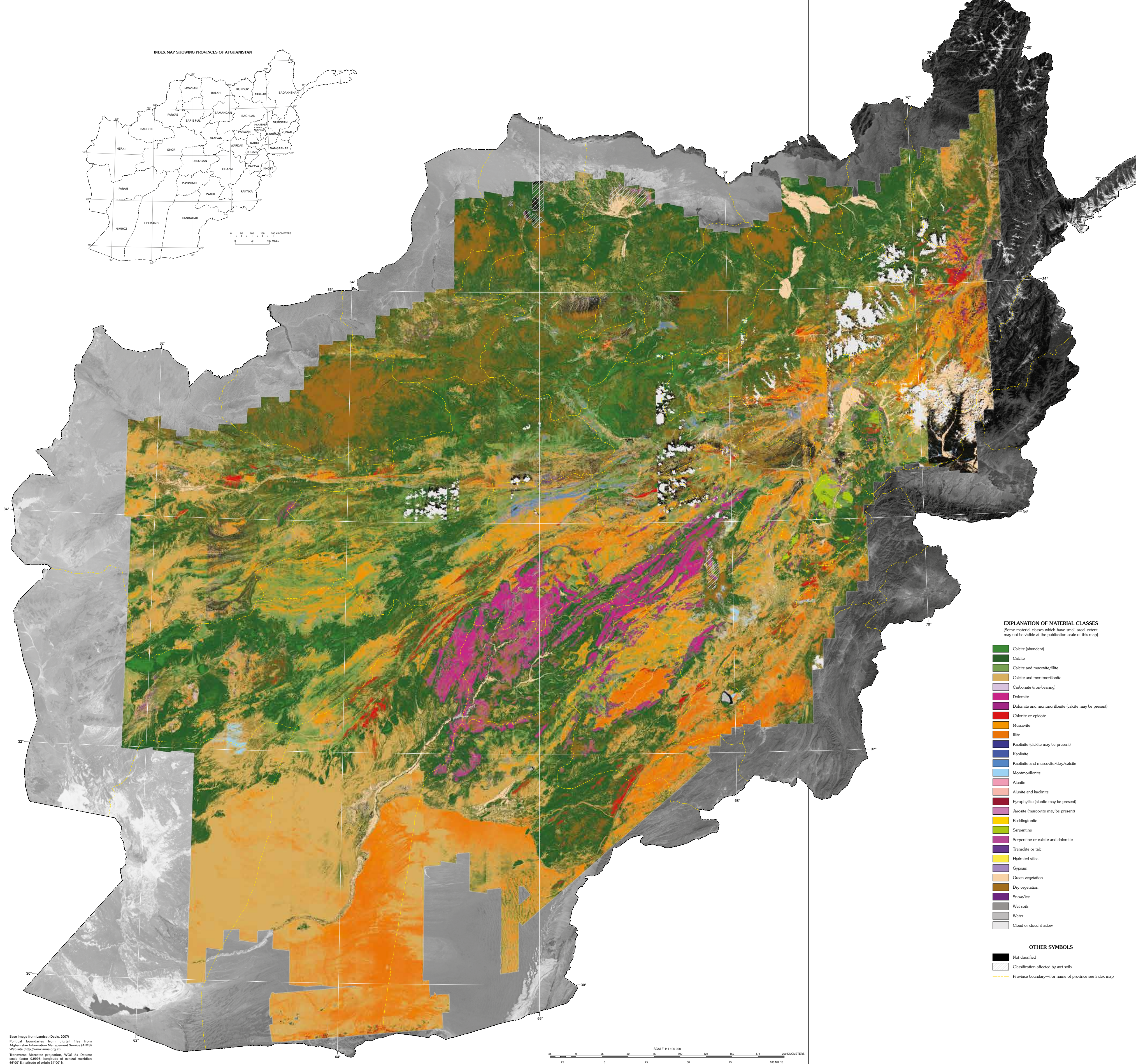
Noqra Khana Iron Ore: Noqra Khana iron ore is located in Parian district of Panjshir province with a distance of 65 km from Gulbahar and 180 km from Kabul province. A geological and mapping survey has been conducted for 20 km2 on the specified mine area, and sampling has been done to determine presence of any other minerals in iron ore in the area. The Noqra Khana iron ore prospect contains 45 deposits identified to date. The total is estimated, assuming a conservative, uniform width of 50m, to contain some 68 million tons with average of 47.6% Fe and a maximum of 55.91%.

Tol Valley Iron Ore: The Tol Valley iron ore deposit is located in Parian district of Panjshir province, about 60 km from the center of province and 180 km from Kabul province. Survey and geological mapping and sampling have yielded 54 hematite deposits with an average grade of 47.56% Fe and a maximum of 59.98%. The deposits cover an area of some 284,700 m2 and the resource has been estimated, over a conservative, uniform width 50m at 34 million tons.

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 2km 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 $0.3km^2$ (*Abdullah et al. 2008*). Abdullah also records an occurrence at Mangasak, Maydan Province, where a zone of 50 to 100m thick and 1,200m 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 50m thick and extending for 20 to 250m, 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.

Prepared in cooperation with the
AFGHANISTAN MINISTRY OF MINES AND INDUSTRIES



EXPLANATION OF MATERIAL CLASSES

[Some material classes which have small areal extent may not be visible at the publication scale of this map]

- Calcite (abundant)
- Calcite
- Calcite and mucovite/illite
- Calcite and montmorillonite
- Carbonate (iron-bearing)
- Dolomite
- Dolomite and montmorillonite (calcite may be present)
- Chlorite or epidote
- Muscovite
- Illite
- Kaolinite (dickite may be present)
- Kaolinite
- Kaolinite and muscovite/clay/calcite
- Montmorillonite
- Alunite
- Alunite and kaolinite
- Pyrophyllite (alunite may be present)
- Jarosite (muscovite may be present)
- Buddingtonite
- Serpentine
- Serpentine or calcite and dolomite
- Tremolite or talc
- Hydrated silica
- Gypsum
- Green vegetation
- Dry vegetation
- Snow/ice
- Wet soils
- Water
- Cloud or cloud shadow

OTHER SYMBOLS

- Not classified
- Classification affected by wet soils
- Province boundary—For name of province see index map

DATA SUMMARY

This map shows the distribution of selected carbonates, phyllosilicates, sulfates, altered minerals, and other materials derived from analysis of HyMap imaging spectrometer data of Afghanistan. Using a NASA (National Aeronautics and Space Administration) WB-57 aircraft flown at an altitude of ~15,240 meters (m) or ~50,000 feet (ft), 218 flight lines of data were collected over Afghanistan between August 22 and October 2, 2007 (Kokaly and others, 2008). The grayscale background image, visible in the area of no data around the country's perimeter, is from Landsat Enhanced Thematic Mapper Plus (ETM+) (Davis, 2007).

The HyMap imaging spectrometer measures 128 channels of reflected sunlight at wavelengths between 0.4 and 2.5 µm (Cocks and others, 1998). The HyMap data were converted to apparent surface reflectance using ACORN (*A*tmospheric *COR*rection *N*ow) version 6lx software (developed by ImSpec LLC), then further empirically adjusted using ground-based reflectance measurements. Each flight line was georeferenced to Landsat base imagery in Universal Transverse Mercator projection (Davis, 2007).

HyMap reflectance data were processed using MICA (*M*aterial *I*dentification and *C*haracterization *A*lgorithm), a module of the U.S. Geological Survey PRISM (*P*rocessing *R*outines in *I*DL for *S*pectroscopic *M*easurements) software (Kokaly, 2011). Subsequently, the classified HyMap results were projected to a Transverse Mercator projection and mosaicked, with 23-m pixel spacing. Using MICA, the reflectance spectrum of each pixel of HyMap data was compared to the spectral features of reference entries in a spectral library of minerals, vegetation, water, ice, and snow. For each pixel, MICA determined the reference material having the best matching spectrum. MICA analysis resulted in a "Not classified" determination for a pixel when comparisons with reference spectra produced no viable match (see Kokaly, 2011).

This map shows the spatial distribution of minerals that have diagnostic absorption features in the shortwave infrared wavelengths. These absorption features result primarily from characteristic chemical bonds and mineralogical vibrations. A complementary map showing the distribution of iron-bearing minerals and other materials having diagnostic absorption features at visible and near-infrared wavelengths has also been created (King and others, 2011).

Several criteria, including (1) the reliability of detection and discrimination of minerals using the HyMap spectrometer data, (2) the relative abundance of minerals, and (3) the importance of particular minerals to studies of Afghanistan's natural resources, guided the selection of entries in the reference spectral library and, therefore, guided the selection of mineral classes shown on this map. Minerals occurring abundantly at the surface and those having unique spectral features were easily detected and discriminated. Minerals having similar spectral features were less easily discriminated, especially where the minerals were not particularly abundant and (or) where vegetation cover reduced the absorption strength of mineral features. Thus, some map classes include several minerals having similar spectra, for example, the "Chlorite or Epidote" class. In addition, some identified minerals were grouped to reduce the total number of classes, in order to allow the assignment of discernible map colors.

Complications in reflectance calibration also affected the detection and identification of minerals. Complications arose because of (1) the large magnitude of the imaging spectrometer dataset, which covers an area over 480,000 km^2, (2) surface elevations that range from 280 to 5,642 m (920–18,510 ft), and (3) a protracted data-collection period lasting 43 days. In addition, variations in daily weather, in solar angles, and in airborne dust levels affected reflectance calibrations. In cloud-contaminated areas, it was not possible to completely remove atmospheric effects in the conversion of the data to reflectance because of significant variation in water-vapor content of the atmosphere. As a result, some differences in identified material classes exist between adjacent flight lines that differed in extent of cloud cover. Similarly, minor differences in identified material classes occur between adjacent flight lines having large differences in solar illumination angles (see Kokaly and others (2008) for flight-line data collection times and dates). On October 2, 2007, the last day of data collection, a large dust storm blanketed southern Afghanistan (see Kokaly and others, 2008). No correction for airborne dust, beyond extension of the ground calibration factor, was applied to the data collected along these lines.

Hatched lines identify areas where mineral identification was adversely affected by soil moisture. Material classification in these areas is less accurate due to the distortion of reflectance spectra by the strong absorption of light in the infrared wavelengths by the water in the soil. In some limited areas, the MICA analysis misidentified wet, bright soils as snow, because both are highly reflective in the visible wavelengths but are strongly absorbing at longer wavelengths. Pixels classified initially as snow-covered for land surfaces whose elevation is lower than a threshold elevation of 3,150 m (10,334 ft) were reclassified as wet soils.

The 31 classes in the list of materials represent a necessary compromise between striving for the highly focused level of detail achievable in the best calibrated flight lines, on the one hand, and, on the other hand, seeking identifications that were reliably detected across the entire country and that occurred in large enough areas to be perceptible at a national map scale. Each class name specifies a mineral, or several minerals, whose reflectance spectra match the HyMap data. However, minerals having slightly different chemical compositions may have very similar reflectance spectra. Therefore, the material classes represented on this map should be evaluated giving consideration to the effects of mineral chemical composition on reflectance spectra.

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COLOR COMPARISON CHART

- Serpentine
- Calcite (abundant)
- Calcite
- Calcite and muscovite/illite
- Calcite and montmorillonite
- Alunite and kaolinite
- Alunite
- Jarosite
- Serpentine or calcite and dolomite
- Dolomite
- Dolomite and montmorillonite
- Gypsum
- Carbonate (iron-bearing)

- Dry vegetation
- Green vegetation
- Hydrated silica
- Buddingtonite
- Muscovite
- Illite
- Chlorite or epidote
- Pyrophyllite
- Snow/ice
- Tremolite or talc
- Kaolinite (dickite)
- Kaolinite
- Kaolinite and muscovite/clay/calcite
- Montmorillonite

- Not classified
- Wet soils
- Water
- Cloud or cloud shadow

SURFACE MATERIALS MAP OF AFGHANISTAN: CARBONATES, PHYLLOSILICATES, SULFATES, ALTERED MINERALS, AND OTHER MATERIALS

By
Raymond F. Kokaly, Trude V.V. King, Todd M. Hoefen, Kathleen B. Dudek, and Keith E. Livo

2011

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LEAD & ZINC

Geological Setting
In Afghanistan eight lead and zinc deposits have been identified (Figure 1) and more than 90 other occurrences and mineral showings located mainly south of the Hindu Kush mountain range. The deposits are situated in Kandahar, Ghor, Paktia and Parwan Provinces.

Metallogenic Framework
The Tethyan orogenic zone, which stretches from Western Europe through Turkey and the Himalayas to Vietnam, marks the former site of the Tethyan Ocean and shows extensive subduction-related igneous activity in the Mesozoic and Cenozoic. The Tethyan orogenic zone is widely mineralized with both copper and gold mineralization in the centre of the zone and areas of lead-zinc-barium and tin mineralization on the flanks, typical of subduction-related mineralization (*Coats, 2009*). This Tethyan Eurasian Metallogenic Belt (*TEMB*) extends along the length of the orogen from Europe into South East Asia. Within Afghanistan the TEMB can be recognised from Helmand province in the south extending north-eastwards through Kandahar to near Kabul (*Figure 1*). An older metallogenic zone (*Hari Rod - Panjshir HRPZ*) can be recognised in central Afghanistan marking the former site of the Paleo-Tethys Ocean, which closed during the Cimmerian orogeny (*Triassic to early Cretaceous*). This zone extends from Herat and runs eastwards along the Hari Rod River to the Panjshir valley. In the Soviet literature these two metallic zones were known as the Arghandab-Tirin (*part of the TEMB*) and the Hari Rod-Panjshir Zones (*HRPZ*).

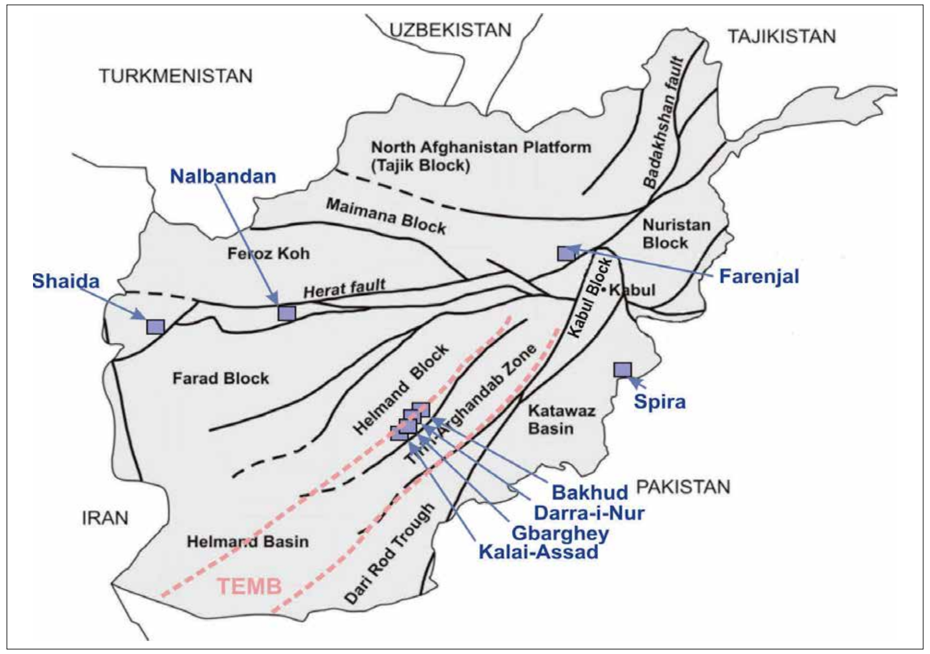


Figure 1. Tectonic sketch of Afghanistan showing the distribution of Pb-Zn deposits.

Exploration History
Ancient lead mines are known from Farenjal (*Ghorband valley*) where lead was mined together with small amounts of silver. Other ancient mining sites are known from other places in southern Afghanistan, mainly Kandahar and Herat Provinces. In nearly all cases lead was mined as galena, which was easy to melt with the available primitive methods.

The first geological description of the Farenjal deposit dates from 1838 and primitive mining continued until 1919. In the 1920's some exploration and mining work was done by the Czechs, followed by more detailed investigations carried out by Lemmon (*1950a*) and Soviet geologists drilled five boreholes between 1961 and 1965 (*Khasanov, 1967*).

Several lead-zinc deposits can be found about 70-90km northeast of Kandahar (*see Figure 1*). These deposits comprise Kalai-Assad with the main deposit Bibi Gauhar, Darra-i-Nur with Yakata Khum and Dike 41, Gbarghey copper-lead and Bakhud fluorspar-lead deposits. Old pits are known at all these places, but

shafts and galleries up to 100 m have been mined only at Darra-i-Nur and Dyke 41. The first modern exploration was carried out by Lemmon at Bibi Gauhar, which involved trenching and drilling (*Lemmon, 1950b*). Some further exploration work was done in 1965-1966 by Soviet geologists and the sites have been visited by German geologists.

Another area with several old lead workings is north of Tulak, Ghor Province, where hundreds of old pits were worked until the 1950s and Nalbandan until 1966. The most important areas are Nalbandan and Sia Sang which were visited several times by the German Geological Mission to Afghanistan in the 1960's and a large exploration programme, involving trenching, drilling, exploration adits and metallurgical testing, was carried out between 1967 and 1969 (*Scheer, 1969*). At Nalbandan additional sampling and mapping were conducted by the Soviets in 1956-1966. Old mines are also known from Regjoi, Nawad and Gawkush.

In the area of Spira several old mines and exploration shafts to 20 m depth were found. In 1972 stream sediment, rock sampling and geophysical work was carried out by Soviet geologists, followed by more detailed exploration in 1973.

All other areas with lead-zinc or polymetallic lead-zinc mineralization (*Shaida, Talah, Udmanay etc.*) were explored by geochemical stream sediment sampling and mapping by the Afghan-Soviet team in the period between 1963 and 1979. Nearly all lead mineralization shows traces of ancient mining.

Pb-Zn Mineral Deposit Styles
The following styles of lead-zinc deposits are recognized in Afghanistan.

1. Carbonate Replacement Deposits (*CRD*) and Skarns
2. Mississippi Valley Type (*MVT*)
3. Sedimentary Exhalative deposits (*SEDEX*)
4. Volcanogenic Massive Sulphide deposits (*VMS*)
5. Vein-style deposits

The five deposits or major prospects have been identified in Afghanistan: Darra-i-Nur, Kalai Assad, Nalbandan, Spira, Farenjal are described using the above classification. Two further major prospects - Shaida and Bakhud have lead and zinc associated with primary copper and fluorite mineralization respectively.

Carbonate Replacement Deposits & Skarns

DARRA-I-NUR AND KALAI-ASSAD

The Darra-i-Nur and Kalai-Assad lead-zinc deposits are located in Kandahar Province, Karkhez Disrict and can be classified as skarn or replacement deposits related to contact zones of the Oligocene granitic Arghandab pluton. The Kalai-Assad deposit also known as Bibi Gauhar deposit can be divided in five ore areas (*Bibi Gauhar, Central, Southern, Western and Eastern area*), the Darra-i-Nur deposit is located about 20km to the northeast and comprises the deposits/occurrences of Darra-i-Nur, Yakata Khum, Dyke 41 and Dailanar.

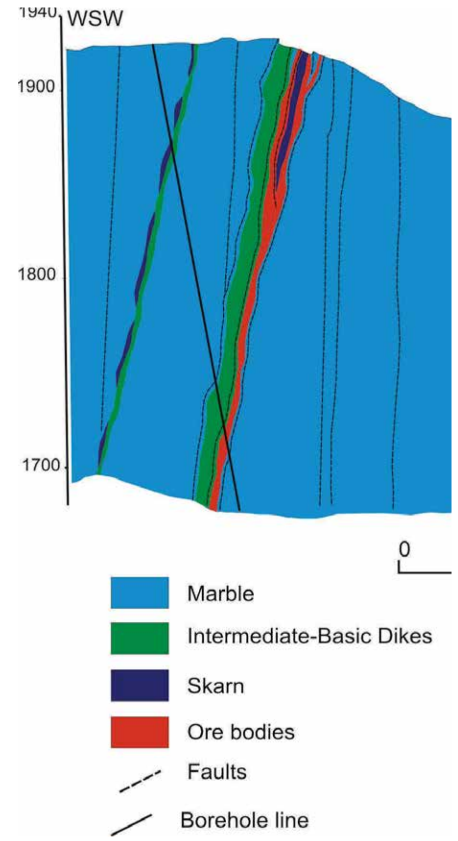


Figure 2. Geological Cross Section of Dyke 41, after Khasanov, (1967).

The mineralized area is represented by carbonate rocks of Late Triassic and Jurassic ages strongly metasomatised to skarns (*Kalai Assad, Dailanar*) or invaded by basic dykes of Oligocene age (*Figure 2*). The ore bodies in the skarn zone are lens shaped, up to 10m thick and explored to 100m depth at Bibi Gauhar (*Figure 3*).

The largest of all dykes (*Dyke 41*) ranges in thickness from 5.5 to 13m and is 950m long. The ore varies from massive ore consisting of sphalerite and galena (*Bibi Gauhar*) to disseminated sulphides with magnetite and/or copper carbonates. The upper few metres of the ore zones are mainly oxidized and consist of cerussite, smithsonite and hydrozincite. High metal contents were found in Bibi Gauhar: 30.4% Zn, 7.8% Pb (*sulphide ore*) and 22.2% Zn, 9.5% Pb (*oxidized ore*) with silver content up to 178ppm. The highest zinc content 36.49% Zn is reported from Yakata Khum. The metal content of the other areas varies between less than 1 to 5% lead, 0.5 to 21% zinc and up to 1.45% copper.

According to Table 1 the speculative resources for the Kalai Assad - Darra-i-Nur lead-zinc area amount to about 125,000t zinc and 32,000t lead with probable reserves of 13t silver.

Mississippi Valley Type

NALBANDAN AND SIA SANG

The Nalbandan stratiform deposit is hosted by Triassic calcareous and clayey siliceous sedimentary rocks. It consists of a 850m long by 3 to 9m thick stratiform mineralized zone containing sphalerite, galena, and minor boulangerite with pyrite, chalcopyrite, and pyrrhotite. The Sia Sang lead-zinc mineralization is connected to sandstone lenses within Lower to Middle Jurassic limestone within a 1,700m long and up to 7.5m thick shear zone containing galena and sphalerite, accompanied by chalcopyrite and pyrrhotite (*Peters, 2007; Scheer, 1969; Wirtz, 1963*).

Resources / Reserves	Tons	Grade	
JORC/CIM		**Zn %**	**Pb %**
Bibi Gauhar			
Proven Ore Reserves	26,600	30.4	7.8
Probable Ore Reserves	42,800	30.4	7.8
Indicated Ore Reserves			Trace
Total	86,200		
Kalai Assad Area			
Speculative Metal Resources (Zn+Pb)	100,000		
Dyke 41			
Speculative Metal Resources (Zn+Pb)	40,000 Zn 100,000 Pb	9.6	2.4
Darra-i-Nur			
Inferred Ore Resources	70,000	7.0	3.0

Table 1. Details of the mineral resources and grades of the Kalai Assad - Darra-i-Nur Pb-Zn mineralization.

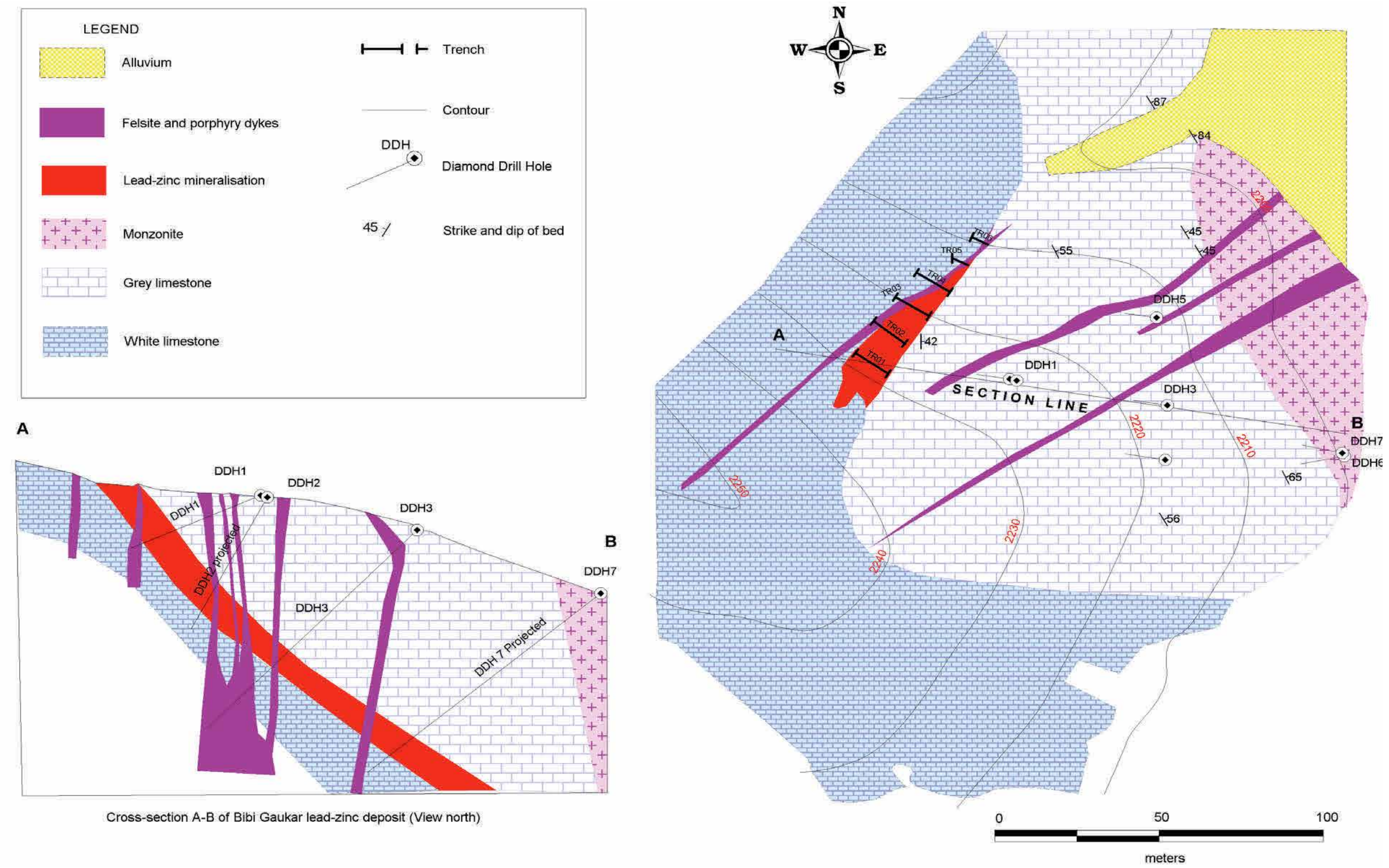


Figure 3. Geological Map and Cross Section of the Bibi Gauhar Pb-Zn Deposit, after Lemmon (1950b).

BAKHUD

The Bakhud carbonate-hosted fluorite deposit consists of a number of tabular zones dipping 5° to 20° located at the base of an angular unconformity between Upper Triassic dolomitic limestone and Lower Jurassic clay-marls. There are four discontinuous mineralized zones with 0.66-0.99% Zn and 0.17-0.34% Pb and galena contains 100 g/t silver (*Abdullah, 1980*). Taking into account the calcareous fluorspar occurrences which constitute 60 to 70 volume % of the ore and the total fluorite resources (*B+C1+C2 categories*) of about 8.8Mt, the contained inferred metal resources can be calculated: zinc 55,000t, lead 20,000t, and silver 2t.

Resources / Reserves	Tons	Grade	
JORC/CIM		**Zn %**	**Pb %**
Nalbandan			
Probable Ore Reserves	105,000	4.4	0.5
Indicated Ore Resources	315,000	4.4	0.5
Inferred Ore Resources	1,300,000	1.3	0.25
Total	1,720,000		
Sia Sang			
Potential Resources	1,500,000	(3% Pb + 17% Zn)	

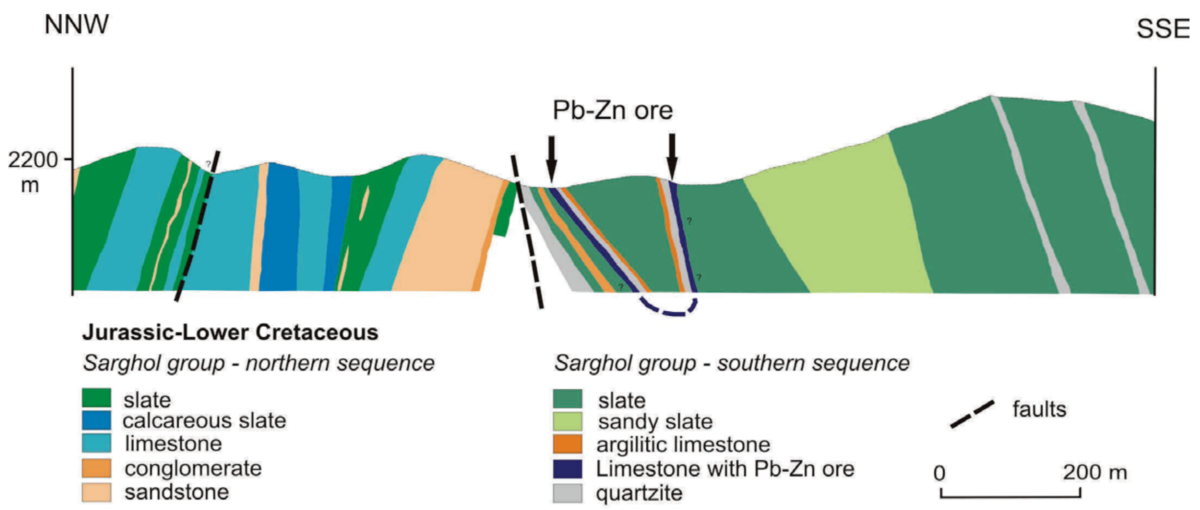
Table 2. Mineral resources and grades of the Nalbandan and Sia Sang lead-zinc mineralization.

Sedimentary Exhalative (SEDEX)

FARENJAL

The main Farenjal baryte deposit lies in Ordovician brecciated limestone and contains baryte-bearing bodies with lead and zinc disseminated mineralization over an area containing 16 fine-grained barite lenses that are 10 to 70 m long and 1 to 9m wide and grade 84% baryte. The proximal Pb/Zn mineralization associated with the baryte is 500x100x10-20m. The occurrence of bedded baryte and proximal Pb-Zn deposits indicates that at least in part this is a SEDEX deposit.

Figure 4. Section through the strait form Nalbandan lead-zinc deposit, after Scheer (1969).



Resources / Reserves	Tons	Grade	
JORC/CIM		Zn %	Pb %
Farenjal			
Potential Resources	25000-3000	10% (Pb+ Zn)	7.8

Table 3. Mineral resources and grades of the Farenjal lead-zinc mineralization.

Vein-type Deposits

SPIRA

The Spira lead-zinc occurrence is located in the faulted contact between Triassic sandstone, slate, and limestone and Paleocene conglomerate and sandstone; the Pb/Zn occurrence is in a 40 to 60m-wide, brecciated, hydrothermally altered zone (*Nikitin, 1973*).

Resources / Reserves	Tons	Grade	
JORC/CIM		Zn %	Pb %
Spira			
Speculative Metal Reserves	8,800 3,100	3.28	1.12

Table 3. Mineral resources and grades of the Spira lead-zinc mineralization.

VMS Deposits

SHAIDA

The Shaida copper deposit has been interpreted to be either a simple vein deposits or volcanogenic massive sulfide deposit (*VMS*). The deposit and nearby occurrences include a number of polymetallic veins and skarn copper deposits.
It is unclear whether the mineralization is associated with a Late Jurassic to Lower Cretaceous quartz porphyry and Jurassic quartz keratophyre volcanic rocks that are intruded by Oligocene granite porphyry forming silicified lenses that contain chalcopyrite and oxide minerals or related to Cretaceous volcanic activity.
Based on a resource of 4,800,000t of ore (*probable resources*) grading 1.1% Cu, 1.3% Zn, 0.08% Pb, and 0.3ppm Au (*Abdullah, 1980*) the metal content is calculated as follows: 50,000 t Cu, 60,000t, Zn, Pb and 14t Au. There are other potential areas for VMS deposits and one at Balkhab with Cu and Zn recorded in massive sulphide bodies hosted by Ordovician metamorphic rocks.

Future Potential

A reassessment of non-fuel mineral resources was carried out by Peters (*2007*) using modern mineral deposit models to estimate undiscovered resources to a depth of 1km beneath the surface of the Earth. The largest lead-zinc prospects in Afghanistan are sedimentary, rock-hosted and related both to the southern suture of the TEMB and the northern equivalent, the Hari Rod-Panjsher metallogenic zone (*HRPZ*). The TEMB has high potential for CRD and skarn deposits and the exploration model used in Mexico and Peru (*Figure 5*) should be used to drive modern exploration for further discoveries.

Most of the currently known deposits in Afghanistan are in the skarn zone but in other areas of the world the chimney and manto zones are the most productive, particularly when the high silver content increases their value. The prospective tracts have been indicated by Peters (*2007*) and within these areas detailed geological mapping to discover the extent of favorable carbonate lithologies and alteration haloes. This zone should also be investigated for near surface, supergene-enriched zinc carbonate and oxide deposits, which are known in comparable areas in Iran (*Angouran*) and China.

Mineral Resources in Afghanistan
Lead and Zinc

The sedimentary rock-hosted, MVT lead-zinc prospects within the KRPZ occur in carbonate rocks of Jurassic-Cretaceous age. Three prospective tracts were delineated by (*Peters, 2007*) that are permissive for sediment-hosted lead-zinc deposits.
The most promising area is within tract along the KRPZ (*Herat fault*) in the central parts of Ghowr Province (Nalbandan area). Newer models of basin dewatering, the importance of faulting to provide channels for the evolving hydrothermal fluids and the lithological and structural traps controlling the deposition of the base metal sulphides, are important guides to the discovery of new deposits.
MVT deposits may be transitional into SEDEX deposits, such as Farenjal, if the fracture channel reaches the surface and the fluids do not react with carbonate rocks at lower levels. An origin for the deposits by escape of basinal fluids from basins of Triassic and Jurassic age south of the suture and their expulsion during collision with the Eurasian continent and closure of Paleo-Tethys ocean.
Some SEDEX deposits and occurrences are closely associated with large accumulations of bedded barite, such as Farenjal, that may be of additional economic importance. Detailed knowledge of the local geology and the importance of growth faults in the formation of the brine pools, where such deposits are

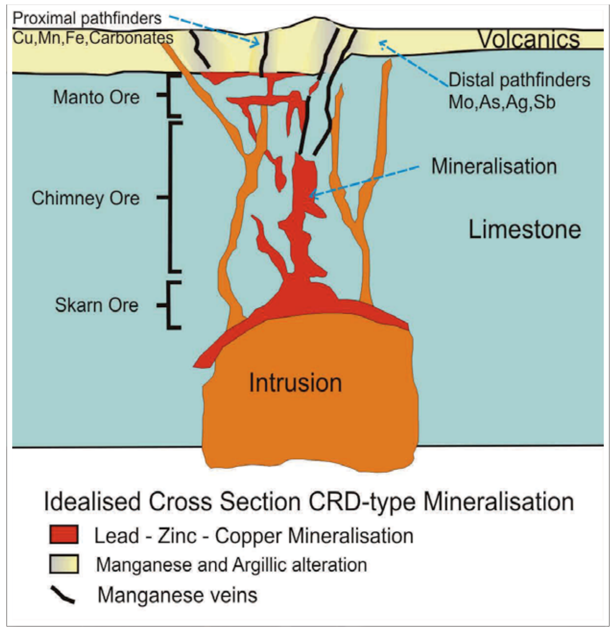


Figure 4. Section through the strait form Nalbandan lead-zinc deposit, after Scheer (1969).

formed, are key to the discovery of new orebodies. Geochemical exploration can also locate these deposits because of their stratabound nature and long strike length. Economic VMS deposits can be difficult to locate because there is often a large number of small satellite bodies but because of the massive, pyritic nature of the Ore; they respond well to geophysical methods, such as EM.
The carbonate-hosted lead-zinc and barite occurrences present in several Phanerozoic stratigraphic units have been interpreted as been remobilized from lower levels, and redeposited in upper sequences within veins, shear and stratabound zones (*Peters, 2007*). It is possible thatthese types of deposits and occurrences may also be present within Proterozoic sedimentary and volcano-sedimentary sequences of Afghanistan. However, the missing link between TEMB in central/ south/west Afghanistan and the continuation of the TEMB in the north/northeast of Afghanistan and the high metamorphic grade of the wall rocks generally indicate that the erosion levels are deeper than the level at which most magmatic-hydrothermal deposits are formed (*Peters, 2007; Coats, 2009*).

Summary of the potential for Lead and Zinc in Afghanistan

- High potential for CRD and skarn deposits in the TEMB area

- Potential for MVT and SEDEX deposits in the Hari Rod-Panjshir zone

- Potential for Zn carbonate and oxide deposits in supergene zones above these prospects

MAGNESITE/TALC

Introduction

The Achin magnesite deposit occurs in Nangarhar Province at the northern foot of the east-west trending Spinghar Range of mountains, 70km SE of the Jalalabad. The deposit is located at 34°03'N and 70°43'E about 10 km south of Achin, a small village with a population of several hundred. Generally, the deposit can be divided into two distinct parts. The northwestern unit is composed of a large, oval-shaped magnesite body accompanied by several small ones. The south-eastern part consists of several, relatively small, lensoid magnesite and talc bodies, which are elongated in NW-SE direction. The host rocks of the magnesite and talc bodies are Proterozoic meta-sedimentary and metavolcanic rocks, predominantly dolomitic marble. A general study in the 1970's demonstrated the potential of the area and estimated resources for the Achin magnesite talc deposit to 66 million tonnes of magnesite and 5.5 million tonnes of talc.

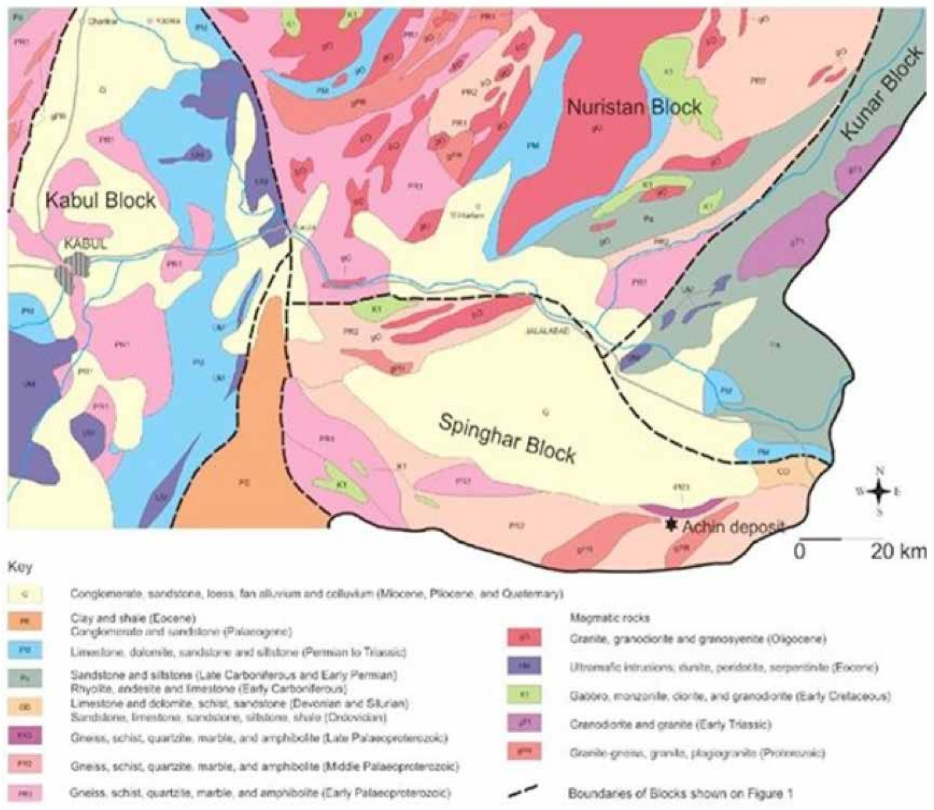


Figure 1. Regional geology of Eastern Afghanistan with the location of Achin.

Geology of the Achin area

The Achin deposit is located in the Spinghar block, which consists of rocks of Palaeoproterozoic, Ordovician and Silu-rian-Devonian age (*Figure 1*). The ca. 2000 Ma Palaeoproterozoic complex, also called the "Lower Complex" by Lednev (*1977*), is composed of three groups. The Lower Group (*Early Palaeoproterozoic*) is situated in the anticlinal core of the Spinghar block and it crops out pre- dominantly in the western part of the mountains. It consists mainly of dark-grey to grey fine-grained limonitic quartzite alternating with biotite flaser- and leaf-gneisses. The Lower Group is overlain by a thick metasedimentary sequence of the Middle Group (*Middle Palaeoproterozoic*), which consists of mainly dark-grey to grey biotite-garnet-graphite schist and schistose amphibolite with intercalations of quartzite, andesite, basalt, and amphibolite bodies. Pyrrhotite occurs in minor amounts in the quartzite and amphibolite bodies of this sequence.

In addition, the Middle Group includes dolomitic marble bodies, 50-100 to 400-600 metres thick, which contain magnesite and talc mineralisation in their upper part. The group is cut by Proterozoic gneiss-granite, granite, and migmatite and by Proterozoic ortho-amphibolite, gabbro-amphibolite, and gabbro-diabase. The Upper Group (*Late Palaeoproterozoic*) crops out at the northern foot of the Spinghar Mountains. And consists of a monotonous sequence of grey, dark-grey to black biotite-garnet-staurolite metamorphosed schist with sporadic intercalation of marble. The boundary between the Middle and Upper Groups is marked by an angular discordance. In the eastern part of the area, Ordovician sequence of siltstone, phyllitic shale and sandstone with common lensoid, dark-grey metamorphosed limestone bodies is overlain by carbonate formation of Silurian-Devonian age.

Mineralization

The Achin magnesite deposit is composed of stratiform lenses and layers (*Figure 2*). In addition to magnesite, the deposit also contains talc and dolomite. On the basis of summary mineralogical and chemical analysis there are two types of magnesite-rock:

Table 1. Sparry and medium grained crystalline magnesite, often cataclastic and recrystallized, with a small talc content magnesite (I. and II. generation)	
Magnesite (I. and II. generation)	97-99.5%
Talc	0.3-2.5%
Dolomite	0.2-1.0%
Calcite	0.1-0.2%

Table 2. Sparry crystalline magnesite, often with talc, recrys tallized, dolomitized with marked admixture of fine grained	
Magnesite (I. and II. generation)	80-90 %
Talc	10-15%
Dolomite	2-4 %
Calcite	0.3-0.5 %

Exploration

The first geological observations in the area were carried out by C.L. Griesbach during 1880-1892, who sketched a geological map of the Spinghar Range.

The magnesite and talc deposits first became known in the 1920's when artisanal mining of talc in the Achin deposit started. The Achin deposit was then known as the Tanga deposit and for a long period it was not the object of serious research and prospecting. The Achin deposit was studied in detail during the 1970's by Afghan and Soviet geologists who wrote a number of reports on the area. These reports are documented in a final report (*V.V. Lednev, 1977*), which is archived in the Afghanistan Geological Survey. The Afghan-Soviet work included two adits (*adit No.1 - 340m*; and *No.2 - 281*m), 39 trenches on a grid of 80-120m and a surface geological mapping survey (*Figure 2*).

Metallogenetic Model

The magnesite bodies are hosted by dolomitic marbles and form a series of 1 to 120m-thick bodies within the approximately 2000 Ma (*Middle Palaeoproterozoic*) formation of the Spinghar block. These marbles are due to greenschist to amphibolite grade metamorphism. The marbles are considered to be an altered sequence of stromatolites in a complex mix of shallow-marine and non-marine, evaporitic environments (*Melezhik et al., 2001*). The depositional environment is thought to be similar to the Holocene magnesite deposit at Lake Walyungup, Australia coastal playa magnesite described by Coshell et al., (*1998*). In this sabkha to playa-lake environment primary dolomite was deposited under evaporitic conditions, but later altered to magnesite, by reaction with Mg-bearing, hypersaline brines derived from seawater. The Achin deposit includes two generations of magnesite. Initially laminated and structureless, micritic magnesite replaced primary dolomite during early diagenesis before the major phase of burial. Late in the diagenetic/metamorphic history crystalline and coarsely crystalline magnesite replaced the micritic magnesite.

It is thought that the magnesite bodies were not derived by carbonation of serpentinite bodies or by deposition from ground waters derived by surface weathering of serpentinite.

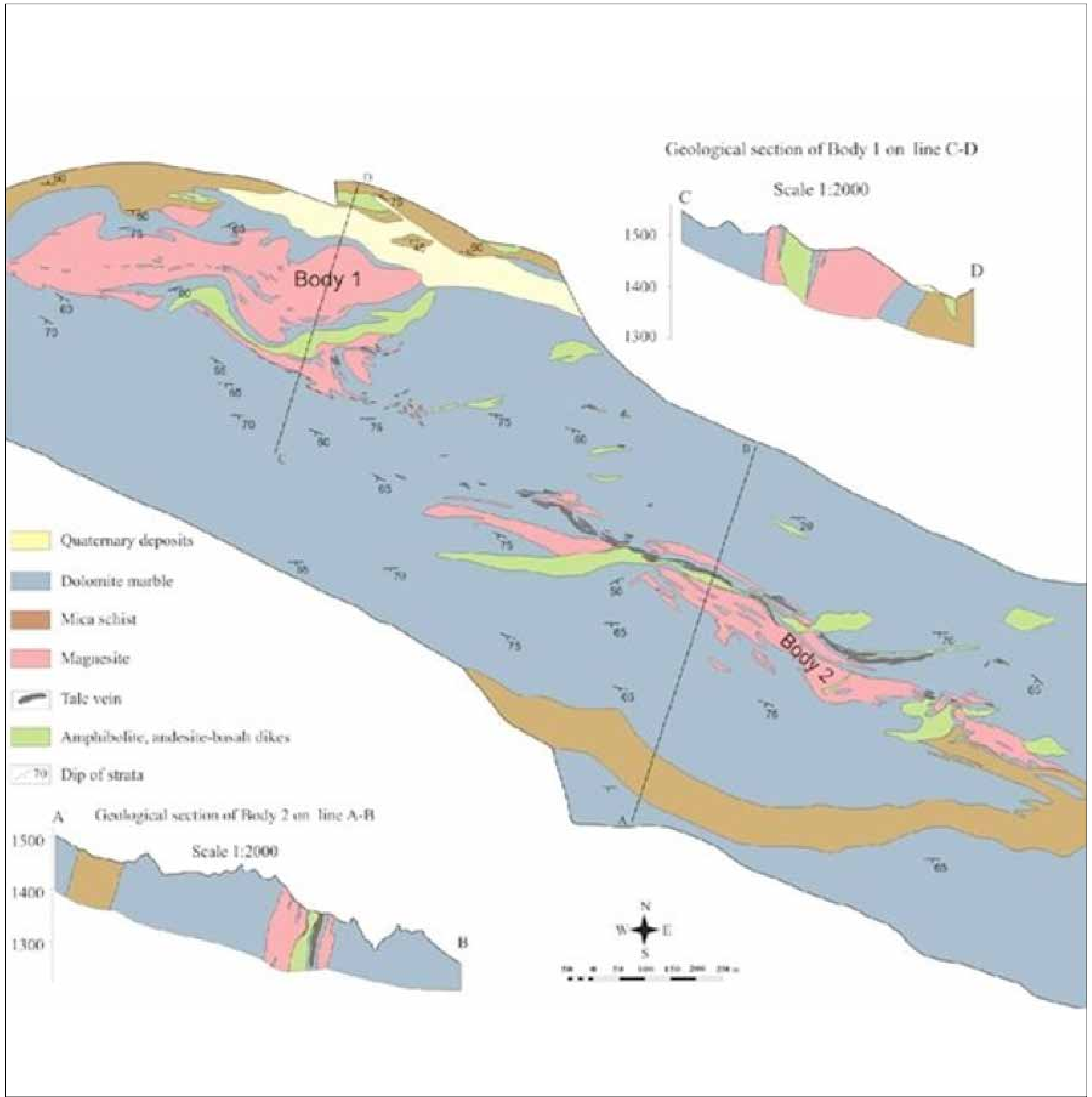


Figure 2. Detailed geological map and cross sections of the Achin magnesite deposit.

Future Development

The earlier exploration as described above was very detailed and comprehensive in nature. One main body of the Achin deposit is very attractive for open-pit mining. It is situated at the north-western part of the deposit, dips at 60° to 75° to the south and has a constant thickness of approximately 120m the south-eastern part of the Achin deposit is composed of several magnesite bodies and talc veins, which are roughly Parallel to the bedding in the host dolomitic marble. This part of the deposit is rich in talc and the magnesite bodies have irregular lensoid shapes. A number of resource calculations were carried out to Soviet standards (*Table 2*) but these do not easily conform to modern western resource classifications.

Body	Soviet Category	Length m	Width m	Height m	Projection plane m^2	Volume m^3	Resources Mt
No.1	B-I	440	136	69	30,160	4.1	9.3
No.1	C1-I	660	118	84	55,330	6.5	15.5
No.1	C2-I	820	118	147	120,160	14.2	33.7
No.2	C2-I	320	21	140	44,880	1.0	2.6
No.2	C2-II	565	44	90	50,840	2.2	5.1
Explanation: Bodies 1 and 2 shown on Figure 3.					**Total**	**28.0**	**66.2**

B-I category - measured or proved;
C1-I category - indicated or probable;
C2-I and **C2-II** - inferred or possible resources.

Table 2. Summary of resources of the Achin deposit. (Source: Lednev, 1977)

Components		**Ore Bodies**	
		Magnesite Body 1	Magnesite Body 2
MgO	From	40.01	40.10
	To	47.12	46.57
	Mean	43.86	43.68
SiO_2	From	0.10	1.71
	To	25.00	12.59
	Mean	5.38	5.89
CaO	From	0.10	0.30
	To	8.10	7.51
	Mean	2.58	2.19
R_2O_3	From	0.10	0.40
	To	0.93	1.40
	Mean	0.87	0.82
Insoluble in HCl Remaining Solid (Talc)	From	0.97	6.64
	To	37.84	14.40
	Mean	8.03	9.33

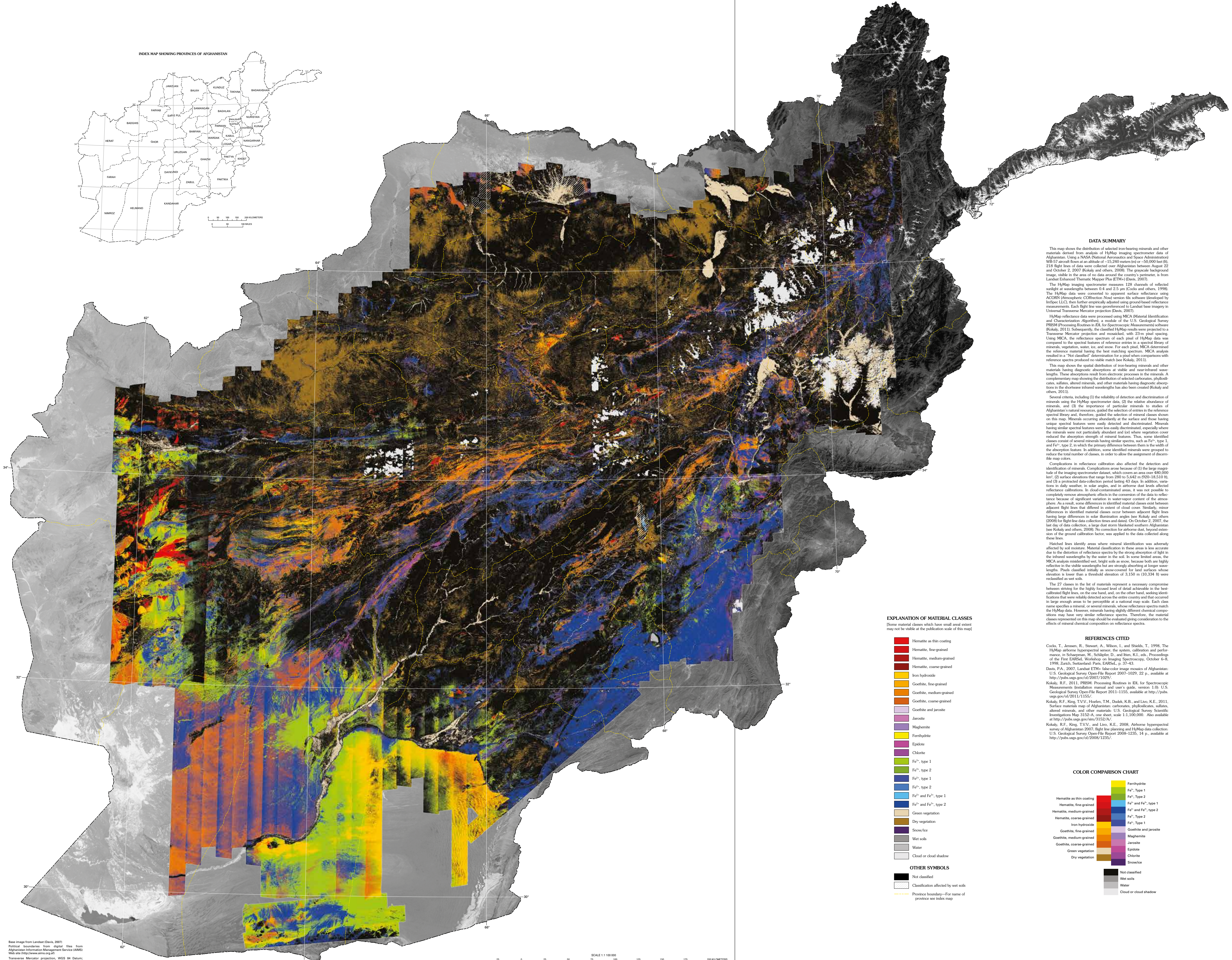
Table 1. Chemical composition of the two magnesite bodies

Note: Values were calculated from selected samples with more than 40% MgO.

Summary of the Achin Deposit

- Estimated resources of 66 million tonnes of magnesite and 5.5 million tonnes of talc
- One main magnesite body and a number of smaller lenses
- Amenable to open pitting
- Convenient location for transport by road to Pakistan (*30km to border at Torkham*)

INDEX MAP SHOWING PROVINCES OF AFGHANISTAN



DATA SUMMARY

This map shows the distribution of selected iron-bearing minerals and other materials derived from analysis of HyMap imaging spectrometer data of Afghanistan. Using a NASA (National Aeronautics and Space Administration) WB-57 aircraft flown at an altitude of ~15,240 meters (m) or ~50,000 feet (ft), 218 flight lines of data were collected over Afghanistan between August 22 and October 2, 2007 (Kokaly and others, 2008). The grayscale background image, visible in the area of no data around the country's perimeter, is from Landsat Enhanced Thematic Mapper Plus (ETM+) (Davis, 2007).

The HyMap imaging spectrometer measures 128 channels of reflected sunlight at wavelengths between 0.4 and 2.5 µm (Cocks and others, 1998). The HyMap data were converted to apparent surface reflectance using ACORN (Atmospheric CORrection Now) version 6lb software (ImSpec LLC), then further empirically adjusted using ground-based reflectance measurements. Each flight line was georeferenced to Landsat base imagery in Universal Transverse Mercator projection (Davis, 2007).

HyMap reflectance data were processed using MICA (Material Identification and Characterization Algorithm), a module of the U.S. Geological Survey PRISM (Processing Routines in IDL for Spectroscopic Measurements) software (Kokaly, 2011). Subsequently, the classified HyMap results were projected to a Transverse Mercator projection and mosaicked, with 23-m pixel spacing. Using MICA, the reflectance spectrum of each pixel of HyMap data was compared to the spectral features of reference entries in a spectral library of minerals, vegetation, water, ice, and snow. For each pixel, MICA determined the reference material having the best matching spectrum. MICA analysis resulted in a "Not classified" determination for a pixel when comparisons with reference spectra produced no viable match (see Kokaly, 2011).

This map shows the spatial distribution of iron-bearing minerals and other materials having diagnostic absorptions at visible and near-infrared wavelengths. These absorptions result from electronic processes in the minerals. A complementary map showing the distribution of selected carbonates, phyllosilicates, sulfates, altered minerals, and other materials having diagnostic absorptions in the shortwave infrared wavelengths has also been created (Kokaly and others, 2011).

Several criteria, including (1) the reliability of detection and discrimination of minerals using the HyMap spectrometer data, (2) the relative abundance of minerals, and (3) the importance of particular minerals to studies of Afghanistan's natural resources, guided the selection of entries in the reference spectral library and, therefore, guided the selection of mineral classes shown on this map. Minerals occurring abundantly at the surface and those having unique spectral features were easily detected and discriminated. Minerals having similar spectral features were less easily discriminated, especially where the minerals were not particularly abundant and (or) where vegetation cover reduced the absorption strength of mineral features. Thus, some identified classes consist of several minerals having similar spectra, such as Fe^{3+}, type 1, and Fe^{3+}, type 2, in which the primary difference between them is the width of the absorption feature. In addition, some identified minerals were grouped to reduce the total number of classes, in order to allow the assignment of discernible map colors.

Complications in reflectance calibration also affected the detection and identification of minerals. Complications arose because of (1) the large magnitude of the imaging spectrometer dataset, which covers an area over 480,000 km^2, (2) surface elevations that range from 280 to 5,642 m (920–18,510 ft), and (3) a protracted data-collection period lasting 43 days. In addition, variations in daily weather, in solar angles, and in airborne dust levels affected reflectance calibrations. In cloud-contaminated areas, it was not possible to completely remove atmospheric effects in the conversion of the data to reflectance because of significant variation in water-vapor content of the atmosphere. As a result, some differences in identified material classes exist between adjacent flight lines that differed in extent of cloud cover. Similarly, minor differences in identified material classes occur between adjacent flight lines having large differences in solar illumination angles (see Kokaly and others (2008) for flight-line data collection times and dates). On October 2, 2007, the last day of data collection, a large dust storm blanketed southern Afghanistan (see Kokaly and others, 2008). No correction for airborne dust, beyond extension of the ground calibration factor, was applied to the data collected along these lines.

Hatched lines identify areas where mineral identification was adversely affected by soil moisture. Material classification in these areas is less accurate due to the distortion of reflectance spectra by the strong absorption of light in the infrared wavelengths by the water in the soil. In some limited areas, the MICA analysis misidentified wet, bright soils as snow, because both are highly reflective in the visible wavelengths but are strongly absorbing at longer wavelengths. Pixels classified initially as snow-covered for land surfaces whose elevation is lower than a threshold elevation of 3,150 m (10,334 ft) were reclassified as wet soils.

The 27 classes in the list of materials represent a necessary compromise between striving for the highly focused level of detail achievable in the best-calibrated flight lines, on the one hand, and, on the other hand, seeking identifications that were reliably detected across the entire country and that occurred in large enough areas to be perceptible at a national map scale. Each class name specifies a mineral, or several minerals, whose reflectance spectra match the HyMap data. However, minerals having slightly different chemical compositions may have very similar reflectance spectra. Therefore, the material classes represented on this map should be evaluated giving consideration to the effects of mineral chemical composition on reflectance spectra.

EXPLANATION OF MATERIAL CLASSES

[Some material classes which have small areal extent may not be visible at the publication scale of this map]

- Hematite as thin coating
- Hematite, fine-grained
- Hematite, medium-grained
- Hematite, coarse-grained
- Iron hydroxide
- Goethite, fine-grained
- Goethite, medium-grained
- Goethite, coarse-grained
- Goethite and jarosite
- Jarosite
- Maghemite
- Ferrihydrite
- Epidote
- Chlorite
- Fe^{3+}, type 1
- Fe^{3+}, type 2
- Fe^{2+}, type 1
- Fe^{2+}, type 2
- Fe^{2+} and Fe^{3+}, type 1
- Fe^{2+} and Fe^{3+}, type 2
- Green vegetation
- Dry vegetation
- Snow/ice
- Wet soils
- Water
- Cloud or cloud shadow

OTHER SYMBOLS

- Not classified
- Classification affected by wet soils
- Province boundary—For name of province see index map

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COLOR COMPARISON CHART

- Ferrihydrite
- Fe^{3+}, Type 1
- Fe^{3+}, Type 2
- Hematite as thin coating
- Hematite, fine-grained
- Hematite, medium-grained
- Hematite, coarse-grained
- Iron hydroxide
- Goethite, fine-grained
- Goethite, medium-grained
- Goethite, coarse-grained
- Green vegetation
- Dry vegetation
- Fe^{2+} and Fe^{3+}, type 1
- Fe^{2+} and Fe^{3+}, type 2
- Fe^{2+}, Type 2
- Fe^{2+}, Type 1
- Goethite and jarosite
- Maghemite
- Jarosite
- Epidote
- Chlorite
- Snow/ice
- Not classified
- Wet soils
- Water
- Cloud or cloud shadow

Base image from Landsat (Davis, 2007)
Political boundaries from digital files from Afghanistan Information Management Service (AIMS) Web site (http://www.aims.org.af)
Transverse Mercator projection, WGS 84 Datum; scale factor 0.9996; longitude of central meridian 66°00' E; latitude of origin 34°00' N.

SCALE 1:1 100 000

SURFACE MATERIALS MAP OF AFGHANISTAN: IRON-BEARING MINERALS AND OTHER MATERIALS

By
Trude V.V. King, Raymond F. Kokaly, Todd M. Hoefen, Kathleen B. Dudek, and Keith E. Livo

2011

FLUORSPAR

Fluoraspar Potential
The fluorspar potential of Afghanistan has not been studied in detail, but the best-known fluorspar districts are in Uruzgan Province in southern Afghanistan. Other areas of fluorspar potential are reported from Bamyan, Badakhshan and Baglan Provinces.Local demand for fluorspar is negligible, but when the large iron ore deposits are developed such as Hajigak and Sydara, it is expected that an integrated iron and steel industry will develop then this would benefit from a local source of metallurgical grade fluorspar. Export potential for metallurgical grade fluorspar concentrate is considerable, and likewise for chemical grade fluorspar concentrate after processing.

Metallogenic Framework
Afghanistan's main fluorspar district is in Uruzgan Province, and is mostly within a terrane known as the Helmand Block (*Figure 1*) composed of sedimentary and igneous rocks ranging in age from Precambrian to Oligocene. The fluorspar ore is hosted by Triassic-Jurassic platform carbonate rocks, which overlie Precambrian and Paleozoic metsediments. The fluorspar ores include both stratiform and vein-type; and both calcareous and siliceous gangue is present. The platform carbonate rocks extend northeastwards from Helmand towards Wardak Province and host not only the fluorspar bodies but also contain the Tangi stratiform lead-zinc carbonate occurrence which is classed as Mississippi-Valley Type (*MVT*) mineralization.

Exploration History
Exploration for fluorspar in the Uruzghan Fluorspar District was conducted from 1969 to 1975 by Afghan and USSR geologists (*Avtonomov et al., 1975*). The work carried out covered an area of nearly 500km² and included detailed geological mapping, sampling, trenching, geochemical surveys, the drilling of 27 exploration holes, and estimation of resources. Some metallurgical testing for fluorspar and lead was also conducted. Later, Peters et al. (*2007*) plotted a boundary for a fluorspar prospective tract based on fluorspar occurrences, geology and aeromagnetics (*Figure 2*).

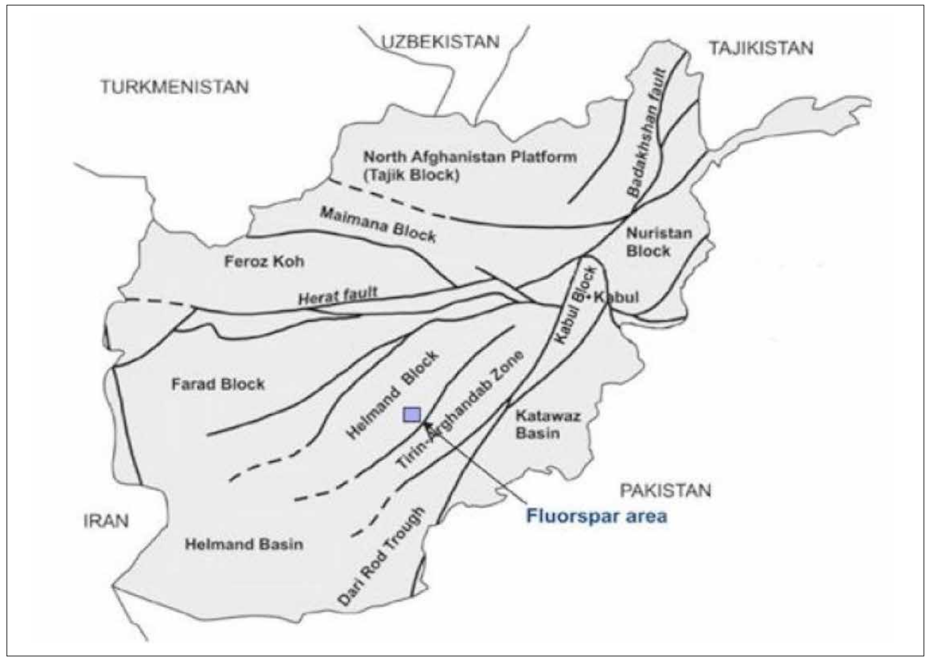
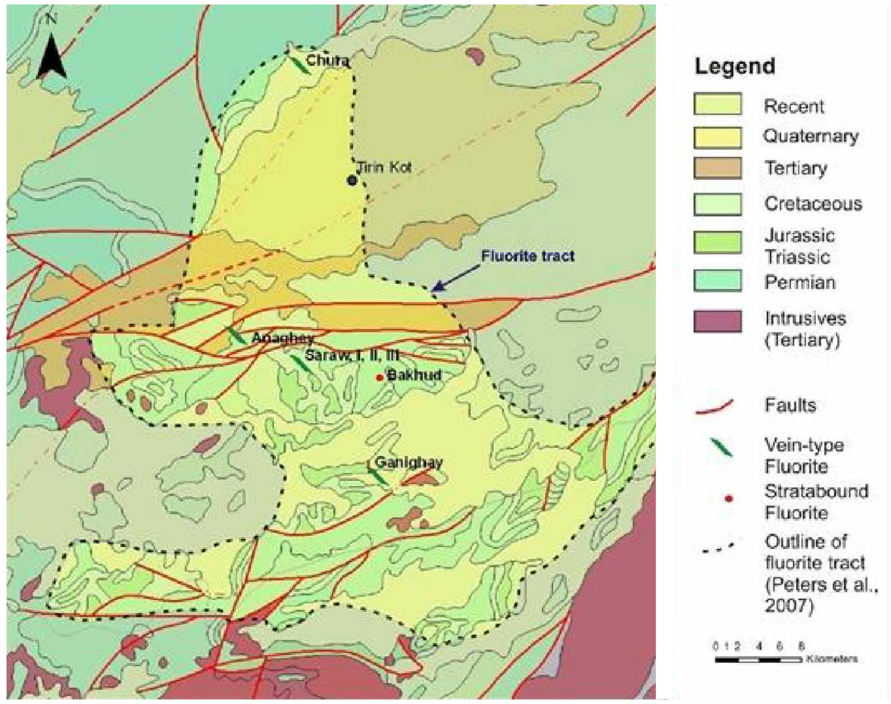


Figure 1. Tectonic sketch-map of Afghanistan showing the main terranes and the location of the Uruzgan Fluorspar District.

Figure 2. Simplified geology of the Uruzgan Fluorspar District, showing location of the stratiform Bakhud Fluorspar Deposit, the boundary of the fluorspar tract, and the locations of the main vein-type fluorspar occurrences.

BAKHUD FLUORSPAR DEPOSIT

Bakhud is a stratiform, while other fluorspar occurrences in the Uruzgan Fluorspar District are Vein-Type. Bakhud ore bodies are in a fault breccia at the base of an angular unconformity between Late Triassic dolomitic limestone and overlying Late Triassic to Middle Jurassic marl sediments of the Arghasu Formation. Mineralisation consists of a number of tabular flat-lying ore bodies. Four discontinuous mineralized zones are recognized at Bakhud: the Eastern, Western, Northern and Southern Areas, and the ore zones range between 80 and 860m long, 10 to 200m wide and 1.1 to 2.8m thick. Mineralization consists of abundant calcareous fluorspar with lead and zinc sulphide minerals, and less commonly siliceous fluorspar. Alteration consists of recrystallized dolomite with silification that is restricted to limestones in the basal Alamghar Formation.



Fluorspar Deposit	Latitude	Longitude	Host Rock	Style of Mineralization
Bakhud	32°27'16.92"	65°53'57.84"	Late Triassic Limestones	Stratiform
Chura	32°42'57.96"	65°49'09.84"	Triassic Limestones	Vein-type
Anaghey	32°29'07.8"	65°46'00.12"	Triassic Marbles	Vein-type
Saraw I, II, III	32°28'59.16"	65°49'05.52"	Late Triassic to Upper Jurassic Limestones	Vein-type
Ganighay	32°22'58.44"	65°53'14.64"	Late Triassic to Upper Jurassic Limestones	Vein-type

Table 1. Summary of the characteristics of the fluorspar deposits in the Uruzgan Fluorspar District.

Calcareous-type fluorspar constitutes 60-70% of the ore and occurs in all four areas. The dominant structures are massive or thinly-bedded veinlets or stockworks in brecciated zones. The calcareous-type fluorspar typically grades between 34 to 64%, averaging 47% CaF_2. The fluorite is colourless, pale to dark violet or almost black. The mineral assemblage consists of a variable amount of fluorite in a calcarous matrix associated with sulphide minerals such as sphalerite, galena, chalcopyrite, tennantite and molybdenite. Gangue minerals are pyrite, barite, ankerite, dolomite and quartz. Calcareous-type fluorspar assaying at 60.28% CaF_2 was processed via a flowsheet consisting of washing, hand sorting and flotation to yield 92.8% of fluorspar concentrate that assayed at 97.38% CaF_2, 0.92% $CaCO_3$, 0.51% SiO_2 and 0.008% phosphorous.

Resources / Reserves		Tons	Grade (% CaF_2)	% of total
Soviet	JORC/CIM			
B	Proven Ore Reserves	3,222,600	44.8%	38.5%
C1	Probable Ore Reserves	1,028,300		11.5%
C2	Indicated Ore Reserves	4,441,000	48.5%	50.5%
Total		8,791,900		100%

Table 2. Summary of the resources of the Bakhud fluorspar deposit.

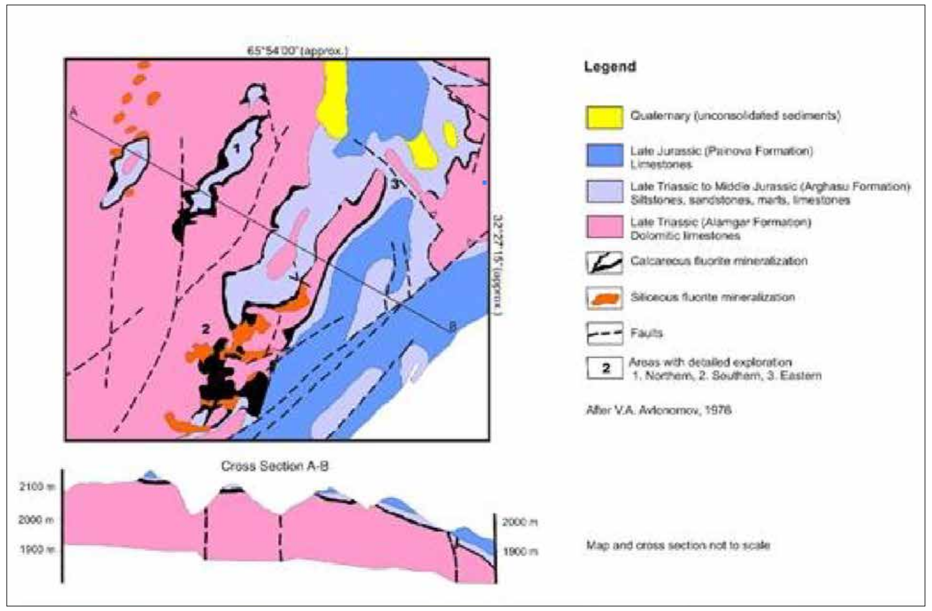
Siliceous-type fluorspar has an average grade of 37% CaF_2.and is irregular, less abundant and restricted to flat contacts with the underlying Alamghar Formation, mainly in the Southern Area. The siliceous-type fluorspar occurs as replacement bodies and as cementing material in the matrix of brecciated calcareous fluorspar. The gangue minerals are chalcedony, chlorite, calcite, ankerite and barite.

BAKHUD FLUORSPAR MINE

Amania Mining Company formed in 2010 and was recently awarded Exploitation (*Mining*) License for the Bakhud Fluorspar Deposit, and has begun mine production. The company employs 300 local people at the site, and has a substantial drilling programme planned. (ref: *www.amania-mining.com*). Potential for Investment and Employment Considerable potential exists for expanding fluorspar production at the Bakhud Mine, and elsewhere in the Uruzgan Fluorspar District. As elsewhere in the world, the fluorspar ore is suitable for very shallow open-pit mining and simple processing, enabling production to commence quickly in the open landscape (*Dore et al., 2006*).

Of importance is the interdependence between artisanal miners, SME mines and SME/large processors during both fluorspar mining and processing (*Baatar and Grayson, 2009*). This is seen worldwide due to the pivotal role of individual miners in working narrow fluorspar veins inaccessible by large machines, the requirement for miners to sort and select ore to upgrade the run-of-mine ore, and the need for teams of people to hand-sort ore during benefication. The large requirement for unskilled to semi-skilled employees creates harmony with local communities and ensures export-grades are achieved. Manual dressing of fluorspar ore to produce standard-sized lump fluorspar suitable for iron and steel processing often produces a more consistent product than mechanised crushing. Long-distance haulage by truck is economic provided the sizing of lump fluorspar takes account of reduction of size during trucking, and proper use of 2-tonne big bags for trucking chemical grade concentrates improves handling and prevents contamination.

Figure 3. Geological map and cross-section of the Bakhud fluorspar deposit.



Metallogenesis
It is not easy to assign a mineral deposit model to the fluorspar occurrences in the Uruzgan Province. The most important characteristics of the fluorspar occurrences are:

1. Confined to unconformity between Late Triassic dolomitic limestone and Late Triassic to Middle Jurassic calcareous sediments.
2. Sediments deposited in a shallow water environment.
3. Mineralisation is stratiform and/or vein type, and is massive or in veinlets, stockworks and disseminations.
4. Mineralisation is associated with faults, joints, breccias and mylonites.
5. In some places the fluorspar, particularly the stratiform mineralisation, is associated with sulphide minerals such as sphalerite and galena.
6. Mineralization is not associated with igneous activity.
7. Fluorspar associated with Pb/Zn anomalies.

Peters et. al. (*2007*) believe that the fluorspar occurrences in Uruzgan match the fluorspar vein model (*Orris and Bliss, 1992*), although they do not rule out other mineral deposit models may be applicable. As the fluorspar occurrences are situated within the SW-NE trending carbonates, which coincide largely with MVT tracts and are associated with Pb-Zn anomalies typical of MVT deposits, the fluorspar occurrences can be tentatively catalogued as Mississippi Valley Type (*MVT*) Mineralization.

Summary of potential of Bakhud Fluorspar deposit

- Reserves (*Soviet B category*) of 3.3Mt @ 44.8% CaF_2

- Total reserves and resources (*category B+C1+C2*) of 8.8Mt @ 46.7% CaF_2

- Flat-lying stratiform bodies of 1.1 to 2.8m

GEMSTONES

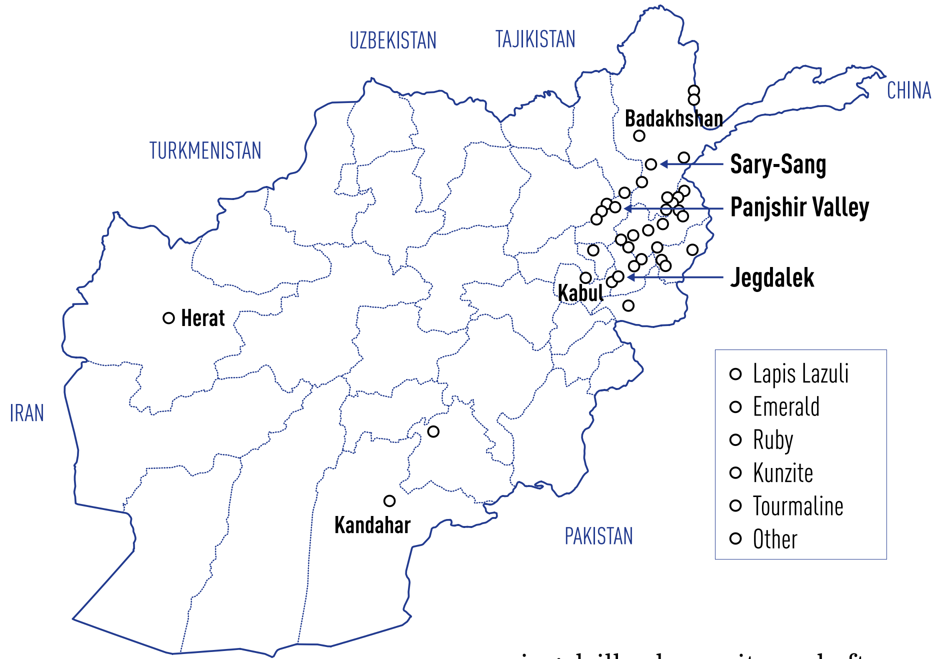


Figure 1. Location of major gemstone deposits in Afghanistan.

Afghanistan and gemstones have been inextricably linked for 6,500 years and the country remains rich in precious and semi-precious gemstone deposits (*Figure 1*). Lapis lazuli, mined in the Hindu Kush since the Neolithic Period, was transported along the ancient trade routes to Mesopotamia, Ur, Egypt and India. Precious gems including emeralds, ruby and sapphires are mined in Afghanistan, and semi-precious lapis lazuli, tourmaline, aquamarine, kunzite, topaz, garnets, fluorite and varieties of quartz are also worked. Afghanistan is also a source of quality mineral specimens sought by collectors.

Gemstone mining in Afghanistan is typically an artisanal activity, carried out by people living in villages surrounding the mines. Tunnels are excavated and gems are extracted by hand using drills, dynamite and often high explosives recycled from ordnance. These techniques lead to much waste and damage to gems, and result in low yield.

Most of the gemstones mined in Afghanistan leave the country illicitly, 90-95% of them going to Peshawar in Pakistan where they are sorted for quality.

The low-value stones are cut for the domestic Pakistan market and the medium- and high-quality stones are sent around the world for accurate cutting for the western markets. This pattern of trade ensures that Afghanistan gains little value from its gemstones, and makes the value of the annual production difficult to estimate. The World Bank has valued it as US$2.75 million (*Mining as a Source of Growth, March 2004*), and other estimates suggest a much higher figure. It has been suggested that the potential annual value is US$160 million (*UNDP, 2005*); and this could be realized if better techniques were instituted at the mines and if all known deposits were worked. Recent government initiatives are addressing the economic issues associated with gemstone production.

Regulations are being developed to provide the framework for more formal exploration and mining. Implementation of these will enable the gem trade to be legalized and this will encourage greater investment in the mines, which in turn will lead to better work practices, greater yields and less waste. The Government of Afghanistan is starting to formalize the industry by asserting its control in rural areas. Other developments that have been highlighted (*UNDP, 2005*) are capacity building and education in cutting, polishing, gemology, and the creation of the quality standards and targeted marketing campaigns in order to increase the value of Afghan gemstones before they are exported. Afghanistan has a great opportunity to increase its share of this market, particularly because of the proximity to India, the world's largest coloured gemstones import market, and also because there is an increasing demand for higher quality gems in North America, Europe, East Asia and the Middle East.

Gem Resources in Afghanistan
There are four main gemstone producing areas: the Panjshir Valley producing emeralds, the Jegdalek area producing rubies and a range of fancy coloured and blue sapphires, Badakhshan producing the world-famous and most recognized of Afghan gems, lapis lazuli, and Nuristan producing a wide range of semi-precious gems such as tourmaline, kunzite, aquamarine, spodumene and beryl.

NEPHRITE

Olly and Barchen-chen Deposit:
The Barchen-chen nephrite deposited is located with a distance of 46 km from Asad Abad, Kunar Province and 6 km south west of Khas Kunar district. The area is bordered with Ghoshta and Kama districts of Nangarhar Province.
Based on the studies done in the 1967 by professor Slavine, this area is located on the Kunar sub tectonic block of Jalal Abad block. Proterozoic, late paleozoic, neogene and quaternary rocks consist of igneous rocks such as gabbro and basalt, metamorphic rocks such as serpentinites, schists, marbles, amphibolite, slate and phyllite, and quaternary sedimentary rock exist in the area.

Based on the geological field investigations conducted by Afghanistan Geological Survey in 2019, 30 veins and 44 evidences of the gem existence were spotted in the metamorphic rocks of serpentinite and in the contact between serpentinite, schist and calcareous schist.
Kama Deposit:
The nephrite bearing site is located 37 km east of Jalal Abad city and 6 km North east of Kama district, Nangarhar province, on the left side of Kunar valley.
Based on the studies done in the 1967 by professor Slavine, this area is located on the tectonic block of Jalal Abad. Rocks in this area are consisted of sedimentary such as coarse-grained sands, mud, transported sands, travertine, limestone, dolomites and sandstone, and igneous rocks such as dunnites, peridotite, and serpentinites.
Based on the Afghanistan Geological Survey field investigation in the 2019, 11 gem bearing veins were identified in this area.

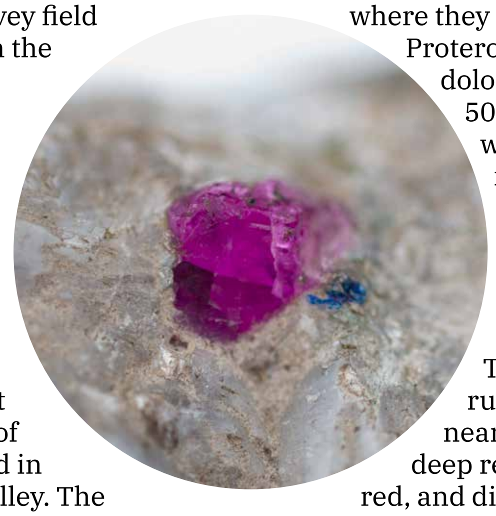
EMERALD

Emerald, a saturated green and most precious form of beryl, are found in the Panjshir Valley. The deposit is thought to have been discovered in the early 1970s by a young shepherd. However, this may be the deposit referred to in Pliny's '*Natural History*', written in the first century AD, as smaragdus (*green stones*) from Bactria.

Gem quality crystals are up to 10 mm to 15mm long, 2-3mm thick, and very rarely up to 50 mm long and 2mm wide. Estimates current production are speculative, but before the civil war productions was said to be in the US$8-10 million range (*UNDP 2005*).

RUBY

Ruby, known as the 'King of Precious Stones', is a precious gemstone form of corundum. Rubies are mined at Jegdalek-Gandamak in Kabul Province where they occur in a Proterozoic calcite-dolomite marble bed 500 to 2,000m thick within a regionally metamorphosed marble cut by Oligocene granitic intrusions.



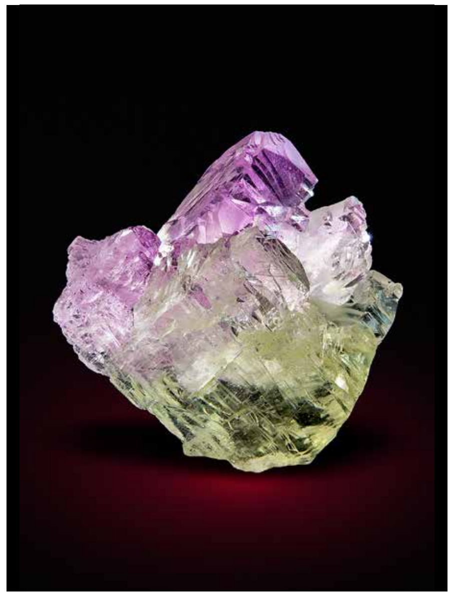
The Jegdalek rubies range from nearly colourless to deep red and purplish red, and display strong fluorescence in ultraviolet radiation. True rubies form 15% of the production at Jegdalek, along with pink sapphires (*75%*) and blue sapphire (*5%*), the remaining 5% consists of mixed blue and red-to-pink corundum (*Bowersox, 1990*). Clean faceting quality rubies are rare, but those that are found are of excellent quality and are said to match those from the very best source of rubies in the world.

LAPIS LAZULI

Lapis lazuli from Badakhshan in the north of the country is still regarded as the world's premier source in terms of quantity and quality. Its name is derived from the Latin 'lapis', meaning 'stone' and the Persian 'lazhward' meaning 'blue'. It is used to make beads, boxes and other decorative articles, is often carved into figurines and is popular for men's jewellery.

Lapis lazuli is composed of the feldspathoid minerals lazurite, hauyne, nosean and sodalite, with other minerals including calcite and pyrite and lesser amounts of diopside, amphibole, feldspar, mica and other silicates.

Lapis is mined in an area known as the ' Blue Mountain' on the right bank of the Kokcha River in Badakhshan where it occurs as skarn lenses 1-4m thick in marble. There were formerly seven mines extracting lapis lazuli but today there is only one, the Sary-Sang deposit. The mine lies at an elevation of around 3,500 metres where, on account of low winter temperatures, it is worked only between June and September. Accurate production figures are not available but an estimate is 9,000kg per year. A speculative estimate of the reserves is 1,300 tonnes.



SEMI-PRECIOUS GEMS FROM NURISTAN

Nuristan is a region on the eastern side of Afghanistan bordering Pakistan and with high mountains incised by numerous steep-sided valleys. The region is especially notable for pegmatites, a late-stage crystallisation from molten rock, comprising one of the largest pegmatite fields in the world which hosts a wide variety of minerals and gems commonly of exceptional size and quality. Gem-quality tourmalines up to 150mm long and 40mm wide occur in a wide range of colors. Pink is common though pale blue, indigo blue (*indicolite*), green, and emerald green are found. In addition, rare bi-colored stones of green-pink and blue-green are much sought after. The crystals are beautifully formed, elongate with a distinctive 'rounded triangular' cross-section. The mineral specimen market is significant as good quality mineral specimens can attract large prices. Many specimens from Afghanistan can be found at gem and mineral shows and for sale on the Internet.

Badakhshan

Afghanistan is a major world supplier of spodumene, especially the well-known pink variety kunzite. Along with other varieties of spodumene, kunzite locally occurs in crystals of great size. These are prismatic and stout, and specimens one metre in length have been found, though generally they range from 30 to 400 mm. Spodumene is found in a number of colour varieties including pink, violet, green (*hiddenite*), blue, colourless and yellowish-green. Well-cut and high clarity stones with more saturated colours command the best prices and are highly sought after. Aquamarine, a name derived from the Latin for 'sea water', is a light blue-greenish variety of beryl that has been mined near the village of Konar in Nuristan since the mid-1980s. Mined from a pegmatite, it occurs in crystals up to 75mm long, which are often of very clear gem quality. Much larger non-gem quality crystals can be found also. A rarer pale pink to deep rose variety of beryl called morganite has been mined in small quantities at Mawi in Nuristan.

Mineral Resources in Afghanistan
Gemstones

Other gem and mineral occurrences

Blue sapphire has recently been reported from Wardak Province west of Kabul. Cut stones over two carats are known though not in any great quantity. A range of garnets is known to occur. For example, spessartite garnet is known at Pachighram in Nangahar province, and dark red almandines also from Pachighram are widespread in Proterozoic schists. In 2002, dealers reported spessartites from mines in pegmatite at Darre Pech in Kunar where they are extracted along with kunzite. They are yellow-orange in color and stones up to 1.68 carats in weight are reported. Another variety from the same locality is orange-red to dark red almandine-spessartites up to 1.28 carats in weight.

Since 2002 Afghanistan has become a significant source of gem-quality hessonite (*grossular garnet*) from Munjagal in Kunar Province and Kantiwow in Nuristan Province. The hessonite varies from yellowish orange to red-orange, and the combined production from these localities is 7000 kg/year. Kandahar fluorite (*Figure 4*) is a well-known collector's gemstone that comes in a range of colours. Particularly attractive and sought after are the blue and sea-green varieties.

Figure 4. Fluorite from Kandahar.

Tourmaline

Summary

Afghanistan is a country very rich in gemstones but at the bottom of the value chain. With improvements in national security, recent changes to the legal framework for mining and the Afghan Government's strategy for legitimising the mining sector, the prospects for investment and improved yields are very good. With the new development of value added cutting and polishing centres, and Kabul gradually emerging as a centre for gem trade, Afghanistan now has the potential to develop further a major internationally recognized gemstone industry.

LIMESTONE/CEMENT

Summary

While Afghanistan is undergoing the process of stabilization and reconstruction, there is a huge demand for good quality cement. Although the country is blessed with abundant limestone resources, more than 97 percent of cement is currently being imported annually.

The Government of Afghanistan has recognized the need for developing a vibrant cement manufacturing industry as high priority target for national development in creating much needed local employment, reducing the country's dependence on foreign imports and improving building standards.

One of several major resources of limestone suitable for cement production is located in the Zandajan District of Herat Province, some 35 km to the west of the city of Herat.

The potential reserves of high quality limestone of Lower and Middle Jurassic age is estimated more than 2.5 billion tons and has excellent access to water, road electricity and other infrastructures at Heart city.

Location and Accessibility

The area is located 32 km west of the city of Herat in the Zandajan District. Most of the road to the Zandajan is asphalted. The Hariroad River with abundant water supply crosses the district.

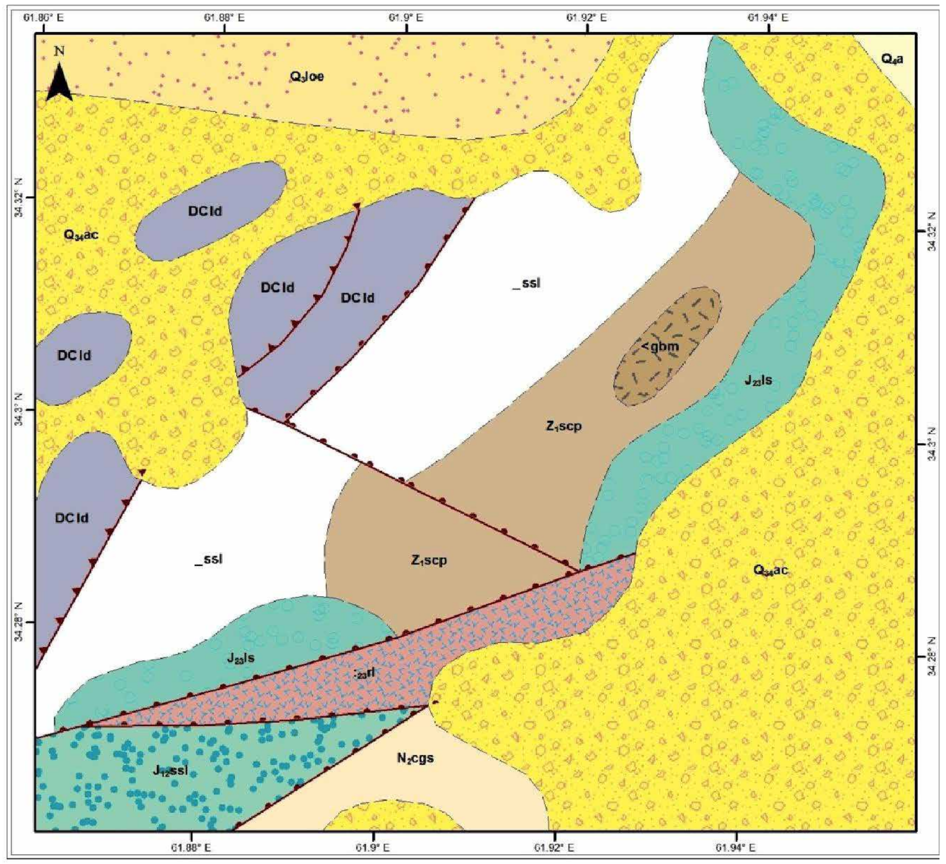
In addition, the Herat cement plant, construction of which was halted during the internal conflicts, is located in the area which could be refurbished very easily (*Figure 1*).

Figure 1. View of unfinished cement plant immediately across from the limestone-marl outcrop.

Local Geology

Based on studies conducted in 1980 mapping of 1:500,000 scale, reproduced in Figure 3, the age of the limestone-marl unit in this area is Middle Upper Jurassic (J23ls) and they are bright gray colored and in some places reddish. The unit underlies the Upper Proterozoic metamorphic rocks (Z1scp) which is composed of green schists, metaterrigenous rocks, marble, and metavolcanics; and Cambrian rocks which are composed of sandstone, siltstone, limestone, dolomite, and mafic volcanic rocks, (J12ssl). The Jurassic limestones and marls are overlain with a tectonic contact by the Eocene-Oligocene volcanogenic- terrigenous rocks (P23rl) which is made of andesitic basalts, basalt, trachyte, dacite, rhyolite, ignimbrite, tuff, conglomerates, sandstones, siltstone, and the Quaternary sediments (Q34ac) made of detrital sediments, gravel, sand, clay, clay sand, loess, and travertine. The Jurassic limestone unit strikes to the southeast-northwest between 1200 – 1500 and dips moderately between 400–550 SE.

Figure 2. Geology of Zenda Jan, showing limestone bodies (J23ls) overlained by extensive Quaternary (Q34ac) cover on the eastern end.



Resource Estimation

Table below outlined general parameters used for determining the inferred resource estimation for the limestone bodies at Zandajan.

Specification	Outcrop 2	Outcrop 2	Outcrop 3
Length (m)	1,400	600	630
Width (m)	835	401	535
Area (m²)	1,169,000	240,000	337,050
Depth (m)	155m	155m	155m
Volume (m³)	181,195,000	37,293,000	52,242,750
Bulk density (g/cm³)	2.72	2.72	2.72
Metric tons (T)	492,850,400	101,436,960	142,100,280
Coordinates		N - 34° 19'48.9" E - 61° 56'19.7"	N - 34° 19'59.9" E - 61° 56'10.0"

Conclusion

From a geologic and economic point of view, the area is highly suitable for an investment in building a cement plant with higher production capacity. According to AGS assessment, the Zenda Jan area contains more than one billion tons of cement quality limestone and the resources can be easily upgraded because the limestone and marl units extend further to southwest (*Figure 2*), even under the Quaternary cover.

DIMENSION STONE

Summary
Exotic dimension-stone quality granites which form the Shirbatu Granite Complex (*SGC*) were identified by Afghanistan Geological Survey (*AGS*) geologists during the 2010 field season. The SGC is centered on 67.5590E longitude and 34.8610N latitude, and is located approximately 225km NW from Kabul, the capital city of Afghanistan. The body comprises spectacular porphyritic to equigranular, coarse-medium grained, commonly phenocryts of pinkish orthoclase and microcline feldspars embedded in medium-fine grained feldspars, quartz, and micas. Mapping has delineated extensive outcropping over an area of 164km^2 and exposure of a minimum 200m vertical depth with an inferred resource of 32 billion m^3 based on outcrop dimensions. The outcrops of the Shirbatu Granite Complex (*Figure 1*) are part of a greater "Bamyan Granitoid Complex" in the region, and holds equal potential for exploration, development and exploitation for decorative stone and construction materials. An excellent road network connecting Kabul city is in place with other development options for railway route and energy/power being investigated, to enhance the development of the nearby world-class Hajigak iron ore deposit.

Location and Accessibility
The Bamyan Granite Complex BGC is located approximately 20km west of Bamyan town, the provincial capital of Bamyan Province. The BGC body is further linked by approximately 225 road km NW of Kabul, the capital city of Afghanistan (*Figure 2*).
Additional access from Kabul is via Wardak Province. This road is about 180km long and passes by the Hajigak iron ore deposit. This road is passable but certain portions require major upgrading and reconstruction.
Parts of the outcropping granitic bodies are transected by the new sealed highway between Bamyan and Yawalang.

Figure 1. Part of the Shirbatu Granite Complex showing extensive bodies in the background along the road cut from Bamyan to Yawkalang. The Shirbatu Granite Complex is centered on 67.559°E longitude and 34.861°N latitude.

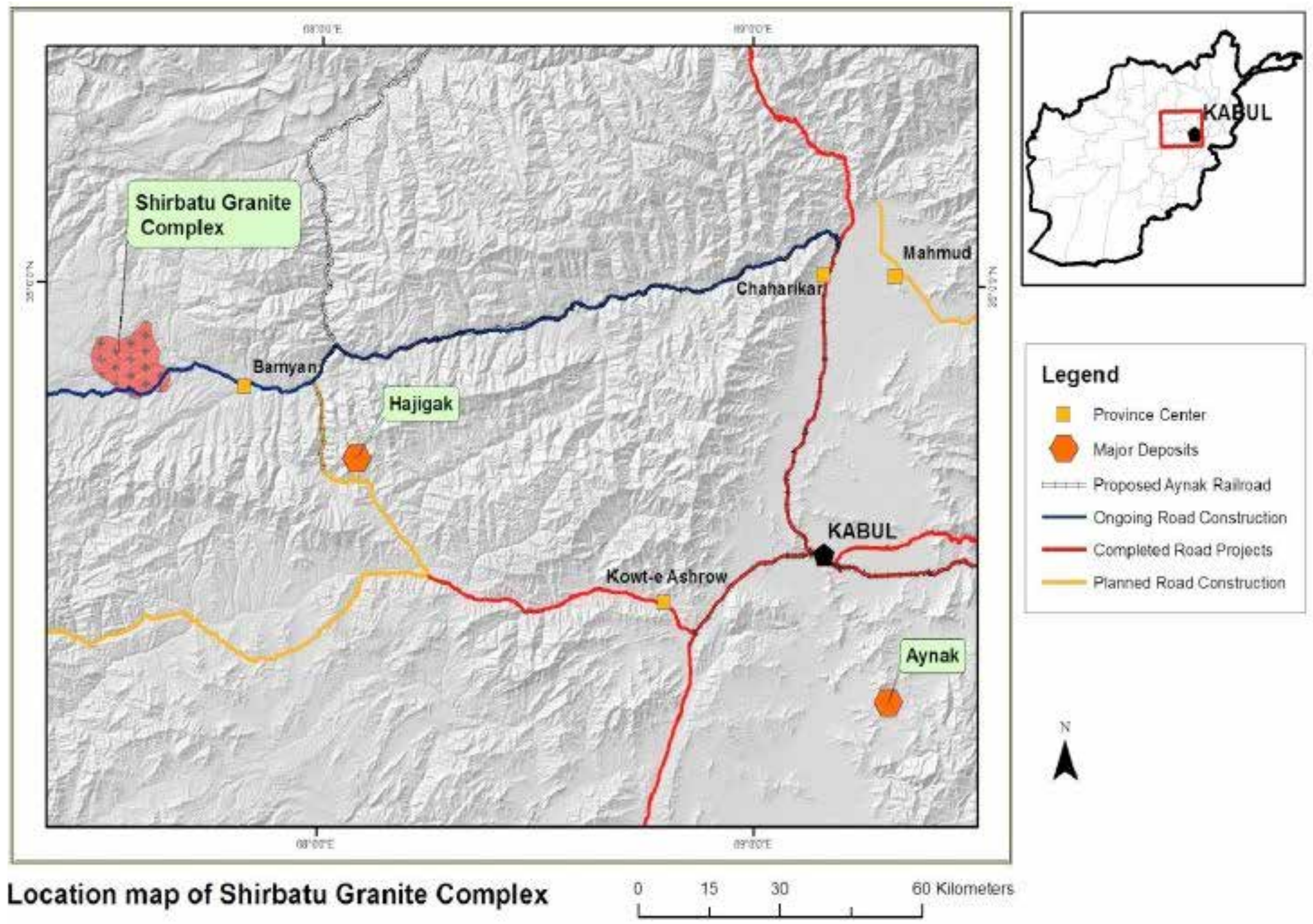
Geology of the Shirbatu Granite Complex

BAMYAN GRANITOID COMPLEX

"Bamyan Granitoid Complex" (*Figure 3*) which extends over thousands of square kilometres from the SW to the NE across Bamyan and Baghlan Provinces. The complex is part of a number of igneous complexes formed during Early to Late Triassic time as a result of subduction of an oceanic crust along the southern margins of the Eurasian plate. The BGC complex intruded Proterozoic and Paleozoic strata and is unconformably overlain by Cretaceous and younger sediments. (*Stazhilo-Alekseev et al. 1976, Abdullah et al. 1978*). Absolute age determinations yielded two distinct ages for the Bamyan Granitoid Complex: 200 to 240ma and 95 to 155ma (*Abdullah et al, 1978*). The age determination therefore indicated two distinct igneous Phases for the Bamyan Granitoid Complex. Phase I (*Early Triassic*) consist of granites and granodiorites, while Phase II (*Late Triassic*) is made of granites, alaskite granites, granosyenites, quartz syenites and granosyenite porphyries.

Phase I granitoid rocks crop out to the NE of the Shirbatu Complex and are represented by coarse-grained granite porphyry and light-grey and grayish-pink granite and granodiorite. They consist of almost equal amounts of plagioclase (*25 to 35%*), microcline (*25 to 30%*) and Quartz (*25 to 32%*) with less biotite (*5 to 8%*), and Accessory apatite, zircon, and other minerals. The texture of the rocks is porphyritic, hypidiomorphic-granular and poikilitic.

Figure 2. Location of Shirbatu granite dimension stone resource, major deposits and infrastructure (planned and existing).



SHIRBATU GRANITE COMPLEX

The Shirbatu Granite Complex (*SGC*) outcrops over a surface area of 164km2 and formed during the Phase II intrusion of granites and granodiorites. There are also some veins and stocks of alaskite granites and granosyenites. At this locality, the complex intruded limestones of Upper Permian age (*Figure 4*).

The contact aureole within the sedimentary rocks is characterized by development of skarn and marbelization of limestones, actinolization and biotization of volcanogenic rocks and serpentinization of dolomites. The presence of migmatized and hornfelsed contact aureoles are up to several hundred metres wide. Several dyke series associated with the complex are represented by pegmatites and, less frequently, diorite porphyry and diabase bodies; measuring a few metres thick and a few dozen meters long, confined mainly to the contact zones of the intrusive.

Phase II granitoid rocks include the ‘Shirbatu Granite Complex’ and are represented by granites, alaskite granite, granosyenite, quartz syenite and syenite porphyry. They are coarse to medium grained, massive light grey and grey-pink rocks with aplitic, graphic and porphyritic textures consisting of varying amounts of:

• microcline (*up to 65%*),
• oligoclase (*10 to 30%*),
• quartz (*15to 30*%),
• biotite (*5 to 7%*) and
• accessory zircon, garnet, apatite, other opaque minerals.

The porphyry granites exhibit the typical granitic texture with elements of pegmatite texture (*Figure 4* and *5*). This type of textures is extremely exotic looking when polished.

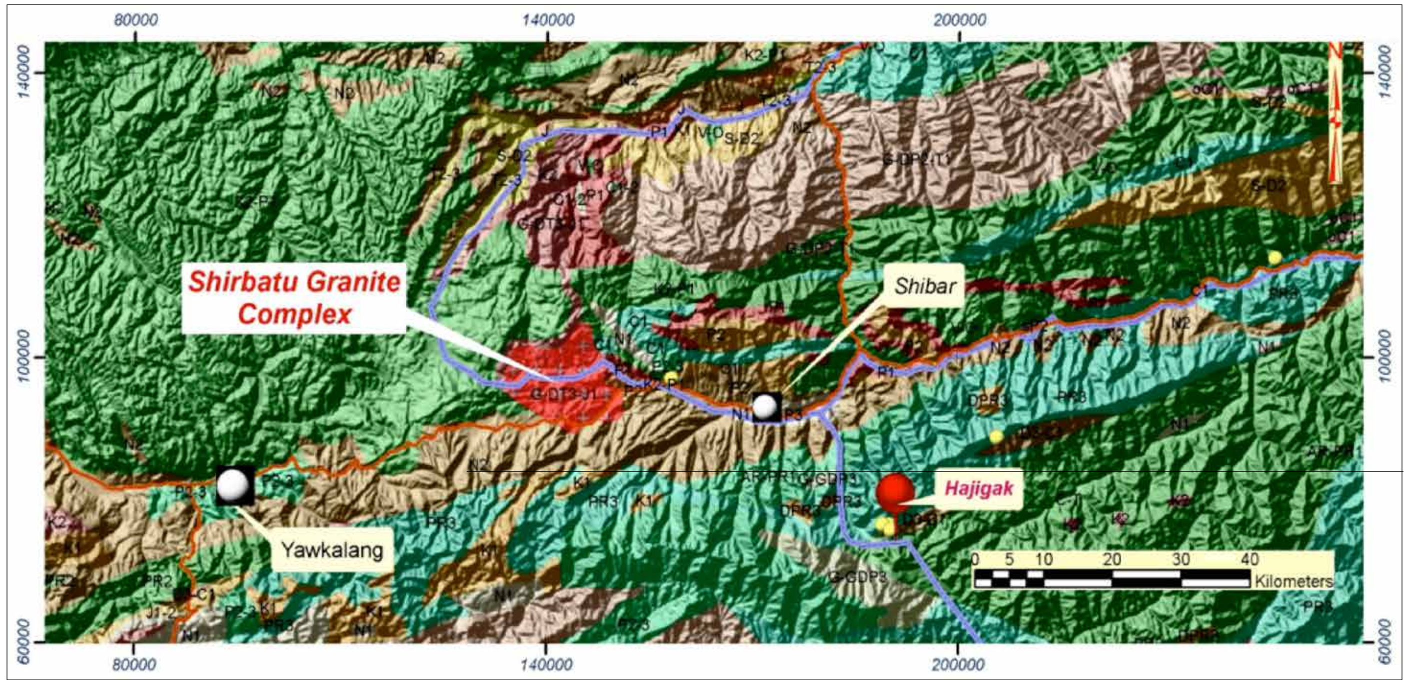


Figure 3. Shirbatu Granite Complex is located some 20km to the west of Bamyan town, along the main road (thick brown line) connecting Bamyan with Band-e-Amir and Yakawlang. G-damartodic and G-DP2-T1 are phase 1 and phase II igneous complexes, respectively. The Shirbatu Granite Complex intruded sedimentary rocks of Upper Permian Limestone and terrigenous sediments, (K2-P1 and C2) which were then unconformably overlain by Neogene (N2) sediments (conglomerates, sandstone and siltstone) (Geology after USGS, compiled from Soviet Union maps, 2007).

Figure 4. A polished slab of coarse grained porphyritic granite. Abundant coarse grained pinkish orthoclase feldspar embedded in relatively medium-fine grain plagioclase feldspar (grey) and quartz (white) and biotite (dark minerals).

Economic Potential

The granites from Shirbatu massif exhibit beautiful textures when polished and can be used as very valuable building stone and decorative tiles, sidewalks, vanities, kitchens tables, and other needs. Texturally, coarse grains of varying amounts of feldspars and quartz are embedded in a finer grained matrix of the same minerals with minor accessories giving a “porphyritic texture” (*Figure 4*) to equigranular and very coarse pegmatitic appearance. Less commonly are medium grained equigranular textures giving the rocks exotic appearance when cut and polished (*Figure 5*). The inferred resource for decorative building stone at The Shirbatu Granite Complex is approximately 32.8 billion m^3. The road infrastructure is being upgraded and access to major markets in the north and to Kabul city will be excellent. With the further railway development, transportation of bulk commodities will be greatly improved.

The production of high quality tiles for decorative purposes and by-products for road aggregates and other usages can be fully established after further exploration and detailed feasibility studies.

Figure 5. A polished slab of medium grained equigranular granite, comprising >60 vol. % of pinkish orthoclase feldspar.

MARBLES

Background
The marble industry is one of the fastest growing sectors of Afghan's economy (*USAID, 2008; Rassin, 2012*). Currently 40 marbles are being quarried, and over a hundred more have been identified and catalogued, and therefore supply is not a major constraint on growth. Current growth is two-pronged; the industry is gaining increased share of the domestic market for low-cost marbles, while expanding exports of high-value marbles that are in demand worldwide.

A wide range of marble is currently being extracted from quarries in Kabul, Logar, Wardak, Badakhshan, Bamyan, Helmand, Herat, Nangarhar, Kandahar, Faryab, Paktia, Parwan, Ghazni and Samangan provinces:

Kabul: Proterozoic marble is quarried in Ghazak, Hazare Baghal, Kariz-Amir, Pul-e-Charkhy, Qalamkar, and Tara Kheel. The Proterozoic *Kariz-Amir Marble* occurs about 40 km north of Kabul and is a granular white, rarely grey-yellow marble. *Ghazak Black* is a popular fine-grained, black marble that occurs 32 km east of Kabul. *Anjirak White Marble* comes from a quarry on Hazare Baghal Mountain and contains small light gray siliceous nodules.

Figure 1. Ornamental marble working in Kabul.

Logar: Proterozoic marble is quarried in Awbazak, Dehnow and Mohammad Agha. *Awbazak Marble* is bioclastic and brown; *Dehnow Marble* is brecciated and brown; *Mohammad Agha Marble* is black and white.

Wardak: Proterozoic *Maydan Marble* occurs near Maydan Shar and consists of grey and dark grey marble 'beds' up to 450 m thick, interbedded with schist. The Maydan Marble Mines are well-known, with five working areas in a 10-12 km outcrop that has worked for 40 years.

Badakhshan: Siluro-Devonian *Bini-Kama Marble* is a medium and coarsely crystalline marble with a resource of about 1,300 million tonnes. Carboniferous *Faizabad Granodiorite* is mined and processed in a new facility.

Bamyan: *Shibartu Granite* is a large untapped dimension stone on the main road between Bamyan city and Yakawlang. This stone is coarse-grained and porphyritic. Large pink orthoclase crystals give it a special appeal.

Herat: Proterozoic *Chesht-i-Sharif Marble* occurs 120 km east of Herat city and consists of a finely crystalline marble ranging in colour from pure white to a subtle light green. The *Chesht Marbles* are currently worked for dimension stone and have been favourably compared to *Carrara Marble*, an Italian marble recognised to be one of the finest in the world.

Nangarhar: Proterozoic *Khogiani Marble* occurs 35 km south-west of Jalalabad and consists of a white marble known as '*Afghan White*'.

Ghazni: The province recently began producing tan coloured *Ghazni Travertine* and *Ghazni White Marble*.

Samangan: Cretaceous to Paleocene *Samangan Marbles* include tan, yellow, and pink colours. Some samples have visible fossils.

ONYX

Onyx is a banded variety of chalcedony, a cryptocrystalline form of quartz. Onyx is highly valued as a high quality marble and the colour of its bands range from white to almost every other colour. Afghan onyx is quarried from several provinces including Bamyan, Helmand and Faryab, with colours including shades of yellow, green or brown. Some of these may in fact be a variety of aragonite (*calcium carbonate*) called travertine, however the traditional name of onyx has remained in place and is still used to this day.

HONEYCOMB ONYX

A new quarry in Chesti-Sharif district of Herat Province produces a honeycomb patterned onyx. Pseudomorphs of gypsum crystals that were replaced by chalcedony are the apparent cause of the honeycomb pattern (*Figure 2*).

Figure 2

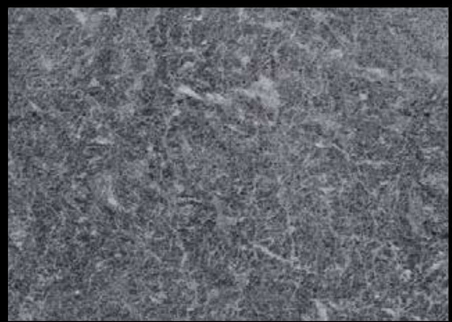
For new projects, contact the Ministry at: invest@momp.gov.af


Kariz-Amir Marble, Kabul


Pul-e-Charkhy, Kabul


Kabul Grey, Kabul


Qalamkar Marble, Kabul


Ghazak Marble, Kabul


Ghazak Black, Kabul


Hazare Baghal, Kabul


Chesht-i-Sharif Marble, Herat


Zurmat Marble, Khost


Mohammad Agha, Logar


Dehnow Marble, Logar


Awbazak Marble, Logar

Mineral Resources in Afghanistan
Marbles


Wardak Grey, Wardak


Wardak White, Wardak


Wardak White, Wardak


Wardak Grey, Wardak


Samangan Brown, Samangan


Samangan Marble, Samangan


Samangan Marble, Samangan


Kaftar Khana, Parwan


Salang Marble, Parwan

Qalatak Marble, Panjshir

Helmand Brown and White Onyx, Helmand

Helmand Brown and White Onyx, Helmand

Helmand Brown Onyx, Helmand

Helmand Green Onyx, Helmand

Yakawlang Onyx, Bamyan

Khogiani Marble (Afghan White), Nangarhar

Almar White Onyx, Faryab

Almar Green Onyx, Faryab

Shah Foladi Geology Park, Bamyan – *Photo Credit*: Dr. Hassan Malestani

TENDERING PROCESS

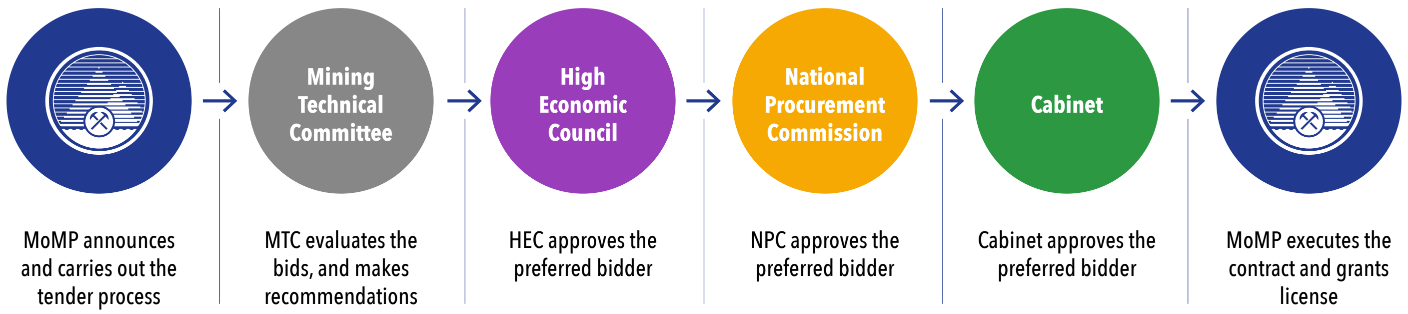
LEGAL FRAMEWORK
MINING SECTOR

The country retains ownership of all mineral resources, and the government grants concessions to private mining companies for exploration and exploitation through a competitive public tender process which is administered by the Ministry of Mines and Petroleum pursuant to the 2018 Minerals Law, with final approval granted by the High Economic Council and the Cabinet.

The 2018 Minerals Law provides for the High Economic Council to approve the mining concession on pre-approved mining areas, with the concessions negotiated through a Mining Technical Committee in the Ministry of Mines and Petroleum. The Ministry is responsible for tendering and management of all large-scale mining projects. It is anticipated that investors will be primarily interested in exploration licenses with priority right for the issue of an exploitation license. The process-map for tendering process for large-scale mining projects is provided below:

ROYALTY RATE

In order to unlock Afghanistan's potential for investment, the new Minerals law has been developed to favor the investors in terms of tendering process and royalty payments. Based on 2018 Minerals Law, the royalty considered for unprocessed, semi-processed and fully processed products are 7.5%, 5% and 2.5% respectively. The government has recognized the importance of fully- processed minerals, which can be a powerful instrument to generate inclusive growth from a sector that otherwise, might be an enclave of isolated activities.




Jegdalek Ruby

The blues lakes of Afghanistan's famous Band-e-Amir National Park located outside Bamyan City
Photo Credit: Graham Crouch/World Bank

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