Minerals in Afghanistan

The potential for copper

Introduction

There are around 300 documented copper deposits, occurrences and showings in Afghanistan as shown in Figure 1. A variety of styles of copper mineralisation occur in rocks ranging in age from Proterozoic to Neogene. These include sediment-hosted, skarn, porphyry, and vein-hosted, as well as other types. 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 30 km south-south-east of Kabul. Soviet surveys in the 1970s and 1980s indicated resources of 240 Mt at 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 summary of the potential for copper in Afghanistan is shown in Table 1.

Geology of Afghanistan

Afghanistan sits astride the collision zone of the Indo-Pakistan and Asian crustal plates which has given rise to the Himalayas, and as a result has some of the most complex and varied geology in the world. The oldest rocks are Archaean which are succeeded by rocks from the Proterozoic and every Phanerozoic system up to the present day. The country has a long and complicated tectonic history, partly related to its position at the western end of the Himalayas. The tectonic history of the area appears to be the result of successive accretion of fragments of Gondwana to the active margin of Laurasia since the end of the Palaeozoic. Hence, Afghanistan is an assemblage of crustal blocks separated by fault zones, each with a different geological history and mineral prospectivity. This diverse geological foundation has resulted in significant potential for a variety of styles of copper mineralisation, in particular, sediment-hosted, skarn, porphyry and vein-hosted deposits. An introduction to the geology of Afghanistan can be obtained at www.bgs.ac.uk/afghanminerals.

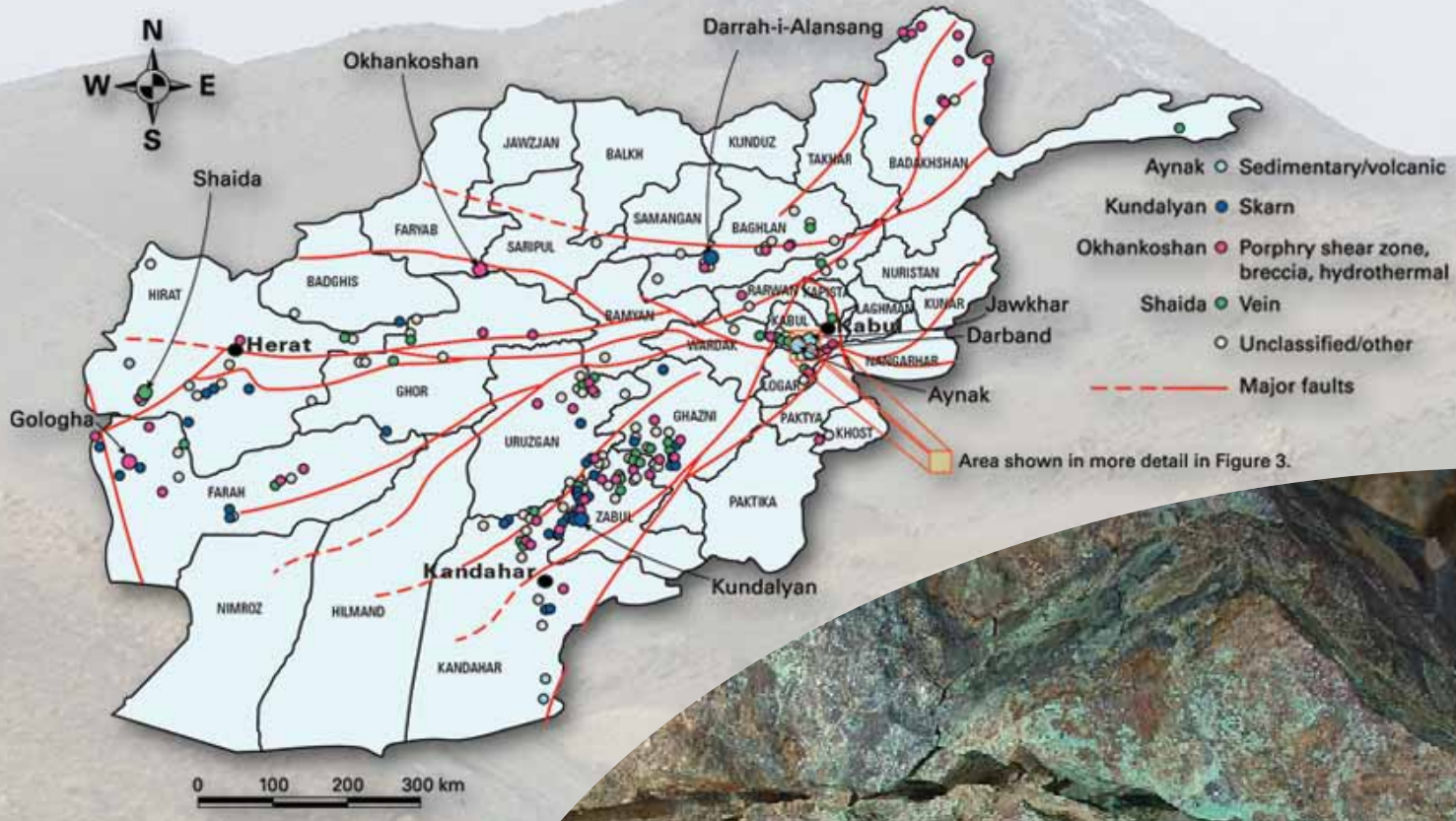


Figure 1. *Copper occurrences in Afghanistan classified by deposit type (based on ESCAP, 1995).*

Copper occurrences in Afghanistan

Sediment-hosted stratiform copper

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. Among the best examples of this type are those of the Zambian Copper Belt which have to date produced in excess of one billion tonnes of copper at an average grade of approximately 2.7 % Cu, as well as significant quantities of cobalt and silver.

The largest and best known copper deposit in Afghanistan is the SHSC type Aynak deposit located in the Kabul Block 30 km south-south-east of Kabul (Deposit Profile 1). The deposit is of Vendian-Lower Cambrian age and is divided into two areas, Central Aynak and Western Aynak. Mineralisation is characterised 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 seawater leaching metals from underlying volcanics as shown in Figure 2.

Deposit Profile 1

Deposit name: Aynak, Logar Province

Deposit style: Stratiform Cu, metasediment-hosted

Host geology: Vendian–Cambrian metamorphosed limestones and volcanics

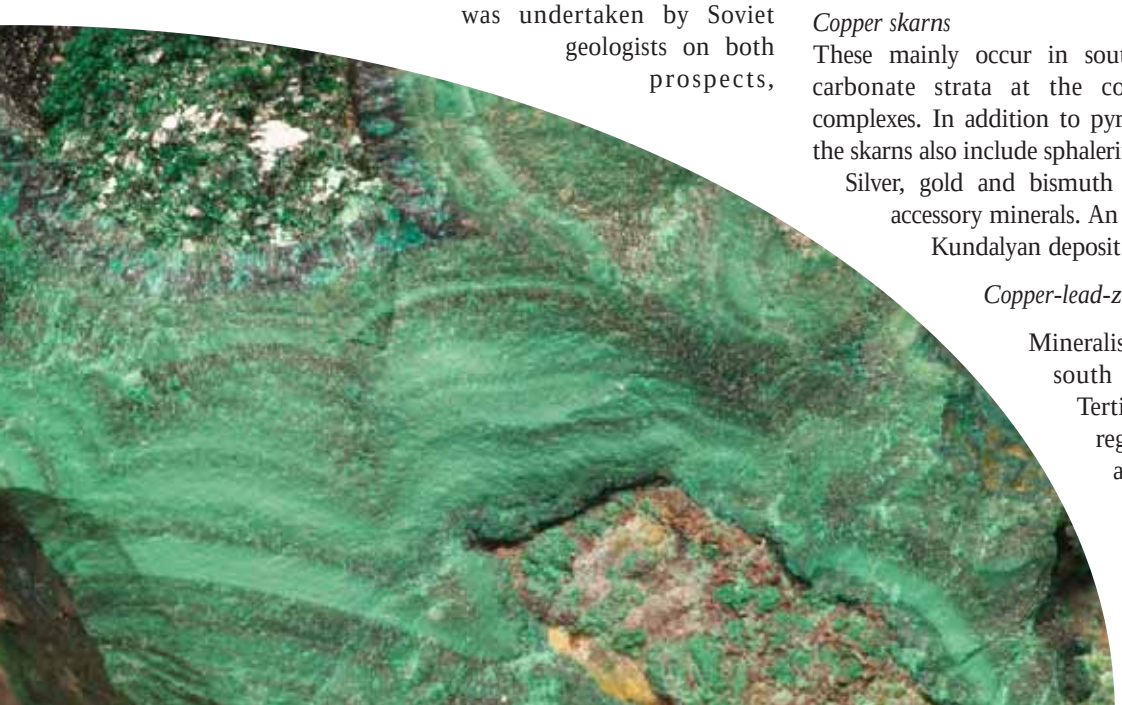
Ore minerals: Bornite, chalcopyrite, chalcocite, native Cu, malachite, covellite, tenorite

Deposit geology: Deposit divided into Central and Western areas. Mineralisation traced for 2 km, up to 1 km wide and 60-210 m thick to max depth of 600 m

Metal content: 'Drill-indicated reserves' est. 240 Mt @ 2.3% Cu, or 175 Mt @ 2.5% Cu

Information source: Abdullah et al. 1980, ESCAP 1995

In addition to Aynak, numerous other SHSC occurrences are found within the region. Notable amongst these are Darband (Deposit Profile 2) and Jawkhar, which are situated a short distance to the north and northeast of Aynak *(Figure 3)*. Considerable exploration was undertaken by Soviet geologists on both prospects, although information on Jawkhar is limited due to the loss of reports during Afghanistan's recent troubled history.



Deposit Profile 2

Deposit name: Darband, Kabul Province

Deposit style: Stratiform Cu, metasediment hosted

Host geology: Proterozoic/Vendian–Cambrian metamorphosed, silicified and micaceous marble

Ore minerals: Chalcopyrite, bornite, pyrite

Deposit geology: Deposit divided into Eastern, Central, Western and Lagernaya areas. Mineralisation occurs in en echelon veinlets and disseminations within silicified, micaceous marble. Mineralised zone traced for 7 km, up to 1 km wide and 18–120 m thick.

Metal content: >80 Mt @ 0.6-2.06% Cu

Information source: Abdullah et al. 1980, ESCAP 1995

Copper and copper-gold skarns

Skarn deposits form by the regional or contact metamorphism of calcareous sedimentary or igneous rock and are found in many environments including adjacent to plutons and along faults and major shear zones. The mineralogy of skarn deposits includes a wide variety of calc-silicate minerals but is usually dominated by garnet and pyroxene. Skarn deposits can yield a variety of metals including copper, tin, tungsten, lead, zinc, molybdenum, silver and gold. The largest copper skarns are associated with porphyry copper granitic intrusions and can contain hundreds of millions of tonnes of combined porphyry and skarn ore, with significant proportions of copper recoverable from the skarn. In Afghanistan, copper skarn mineralisation is widespread, occurring mainly as exocontact concentrations hosted by sedimentary carbonate and calcareous clastic rock associated with intrusions. Fifty-seven copper skarn deposits and occurrences are known in Afghanistan associated with Tertiary intrusions, mainly in southern Afghanistan. They are subdivided into several copper, copper-lead-zinc, and copper-gold skarns. Ore minerals present include chalcopyrite, magnetite, bornite, chalcocite, pyrite, covellite, cassiterite, hematite and native gold in varying proportions.

Copper skarns

These mainly occur in south Afghanistan within Triassic carbonate strata at the contact with various intrusive complexes. In addition to pyrite, chalcopyrite and magnetite, the skarns also include sphalerite, molybdenite and tetrahedrite. Silver, gold and bismuth are also commonly present as accessory minerals. An example of a copper skarn is the Kundalyan deposit (Deposit Profile 3).

Copper-lead-zinc skarns

Mineralisation of this type occurs in south Afghanistan, associated with Tertiary granites, and also in the region of late Hercynian folding at the eastern end of the North Afghan platform associated with Triassic intrusions. Mineralisation consists of

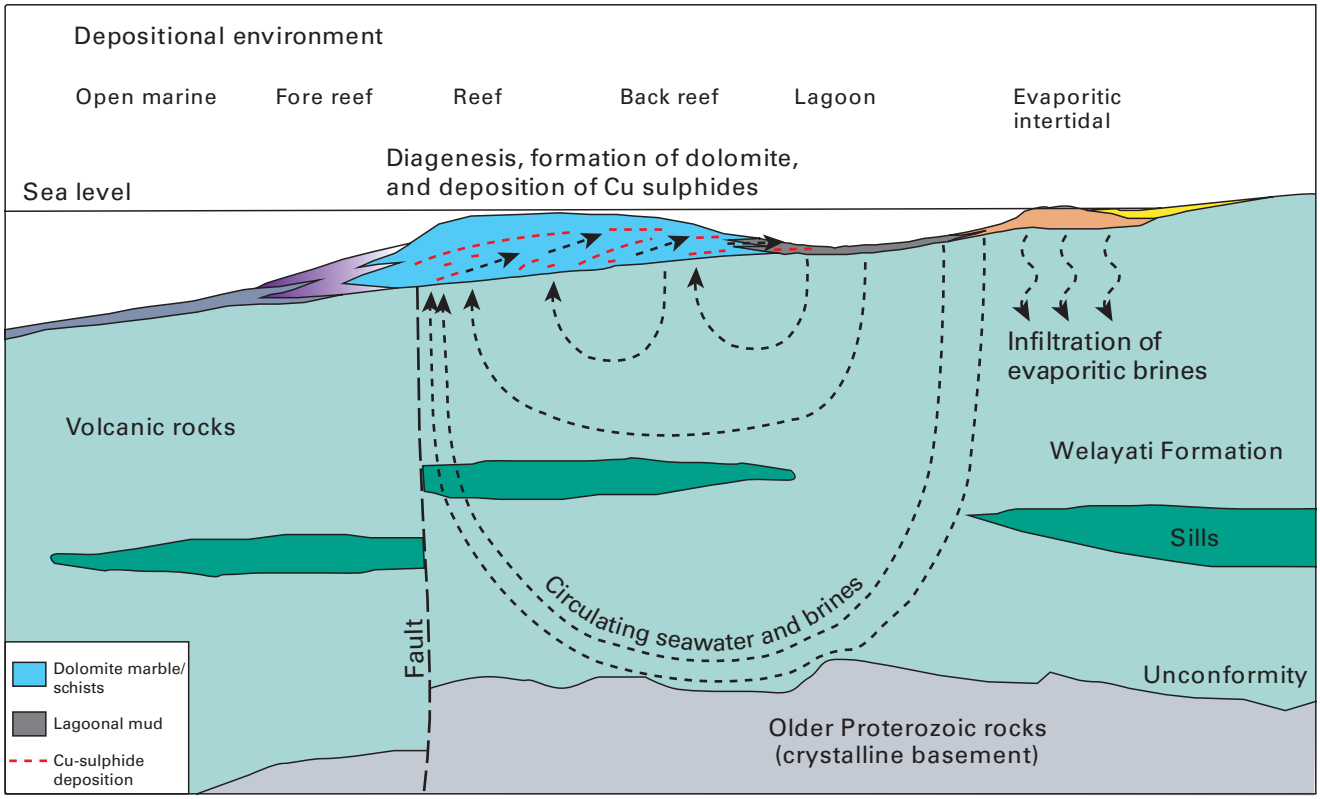


Figure 2. *Metallogenic model showing circulation of brines through underlying volcanic rocks and the formation of the Aynak deposit.*

Deposit Profile 3

Deposit name: Kundalyan, 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 155 m long and 2.59–3.89 m thick. Mineralisation restricted to hematite-kaolin-quartz and meta-carbonates

Metal content: C1+C2 reserves 3700t Cu av. 3.8% Cu; 282.3 kg Au, av. 2.9 g/t Au; 127.3t Mo av. 0.13% Mo

Information source: Abdullah et al. 1980, USGS

Deposit Profile 4

Deposit name: Darrah-i-Alansang, Baghlan Province

Deposit style: Cu-Pb-Zn-Sn-W-Au skarn

Host geology: Late Triassic granite and Middle–Upper Triassic shale

Ore minerals: Pyrrhotite, chalcopyrite, sphalerite, galena, scheelite, cassiterite and ilmenite

Deposit geology: Zone of skarns up to 30 m wide by 200 m long near contact between intrusion and shale

Metal content: 0.01–5% Cu, 0.01–1% Pb, 0.01–3% Zn, up to 0.01% Ag, up to 0.3% Sn

Information source: Abdullah et al. 1980, USGS 2002

chalcopyrite, galena, sphalerite, pyrite and bornite, although other minerals also occur. Skarn rocks occur in lenticular bodies varying from half a metre to tens of metres in thickness and from 10 to 100 m in length. An example of this type is Darrah-i-Alansang in Baghlan Province (Deposit Profile 4).

Copper-gold skarns

Copper-gold skarns occur in south Afghanistan in Triassic dolomites in the exocontact zones of several intrusive complexes. The ore minerals in the skarns include magnetite, chalcopyrite, gold, pyrrhotite, pyrite, bornite and chalcocite with the richest ore associated with phlogopite. At the Zarkashan deposit, which is the largest known gold resource in Afghanistan, mineralisation is irregular along dip and strike, and varies in grade from 0.01-15 % Cu and a trace to 245 g/t Au.

Porphyry copper (+ gold)

Afghanistan has considerable potential for the discovery of copper or copper-gold porphyry deposits in association with younger (Tertiary-age) plutonic rocks of the Tethyan Magmatic Arc. This arc hosts numerous world class porphyry copper-molybdenum-gold deposits elsewhere, including the Sar Chesmeh deposit(>1.2 billion tonnes @ 0.8 % Cu and 0.3 g/t Au) in Iran and the Saindak deposit in Pakistan. Several discoveries of copper in small porphyritic Tertiary intrusions were made in the 1970s, for example the Okhankoshan deposit (Deposit Profile 5).

Further potential occurs in the south-central provinces of Zabul, Ghazni and Kandahar, where a volcanic arc developed during the Cretaceous and Palaeogene. In this area, volcanic sequences are distributed along north-east linear trends,

Deposit Profile 5

Deposit name: Okhankoshan, Faryab Province

Deposit style: Porphyry Cu-Au-Mo

Host geology: Miocene granodiorite-, granite- and dacite porphyries

Deposit geology: Mineralisation controlled by zones of fractures forming linearly elongated stockworks. Zones vary in width from 20–30 to 270 m and extend up to 2.5 km

Alteration: Extensive silicification, pyritisation, sericitisation and kaolinisation

Metal content: 0.1–1.5% Cu, 1–32 g/t Au, 0.01–0.06% Mo, 0.3–2.5% Pb and Zn

Information source: Abdullah et al. 1980

parallel to the structural grain of the region. Copper deposits appear to occur in clusters, suggesting they may be porphyry-related. The occurrence of lead and zinc on the periphery of the copper deposits is another indication that these metals are likely to be zoned around igneous intrusions, and the presence of skarn deposits in the area further highlights the potential for porphyry-style mineralisation. The discovery of Miocene copper porphyry-style mineralisation in Badakhshan on the eastern end of the North Afghan platform also makes this area prospective.

Vein-hosted copper (in shear zones, fractures and breccias)

Copper-bearing vein deposits are widespread throughout Afghanistan in hydrothermal quartz veins associated with fault structures (shear zones) and intrusive masses, sometimes accompanied by other minerals including gold. The USGS Mineral Occurrence Database contains 36 vein-hosted, 43 shear zone-hosted and four breccia-hosted copper occurrences ranging from Archaean to upper Palaeogene in age.

Most copper-bearing veins, breccias and shear-zones are concentrated in an area trending from northern Kandahar Province, through Zabul and into Ghanzi Province. A cluster of copper vein occurrences also occurs in the Kabul and Logar Province area and a few scattered veins are located in the western provinces of Herat (e.g. Shaida, Deposit Profile 6), Farah, (e.g. Gologha, Deposit Profile 7) and Ghowr. Shearzone-hosted copper occurrences also occur in the far northern part of Badakhshan, and in the central province of Oruzgan.

The greatest potential for vein- and shear zone-hosted copper (and gold) mineralisation exists in moderate to gently dipping fault/suture zones along the major transcrustal structural breaks representing remnant terrane collisional boundaries. Potential also exists within dismembered ophiolitic remnants between diverse assemblages of island arcs, subduction complexes and continental-margin clastic wedges. The older Archean volcano-sedimentary greenschist facies rocks occurring within the South Badakhshan Fault Block are favourable hosts for shear zone hosted copper deposits.

References

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Deposit Profile 6

Deposit name: Shaida, Herat Province

Deposit style: Vein hosted Cu

Host geology: Upper Jurassic–Lower Cretaceous volcanics intruded by Oligocene granite plugs

Ore minerals: Pyrite, pyrrhotite, sphalerite, minor chalcopyrite

Deposit geology: Mineralisation consists of six bodies associated with strongly fractured fault zone. Mineralised bodies traced for 150–2400 m long by 2.4–8 m thick

Metal content: C2 reserves are 4.8 Mt @ 1.1% Cu and 1.2% Zn

Information source: Abdullah et al. 1980, ESCAP 1995

Deposit Profile 7

Deposit name: Gologha Deposit, Farah Province

Deposit style: Breccia-hosted copper

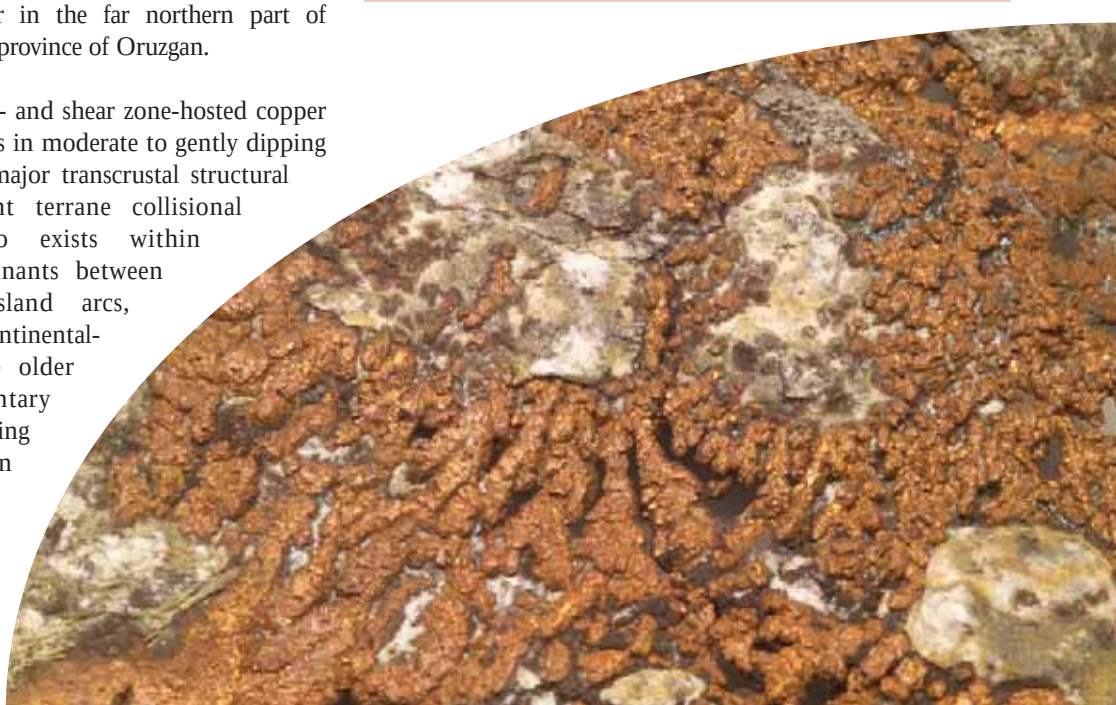
Host geology: Oligocene andesite enclosing zone of brecciated and ferruginous rocks

Ore minerals: Malachite, covellite, chalcocite, pyromorphite

Deposit geology: Brecciated body exposed by an old opening for 40 m. Reported as small producer in 1977.

Metal content: 2.84–6.20% Cu, up to 1% Pb, 0.1–0.7% Zn

Information source: Abdullah et al. 1980, USGS 2002



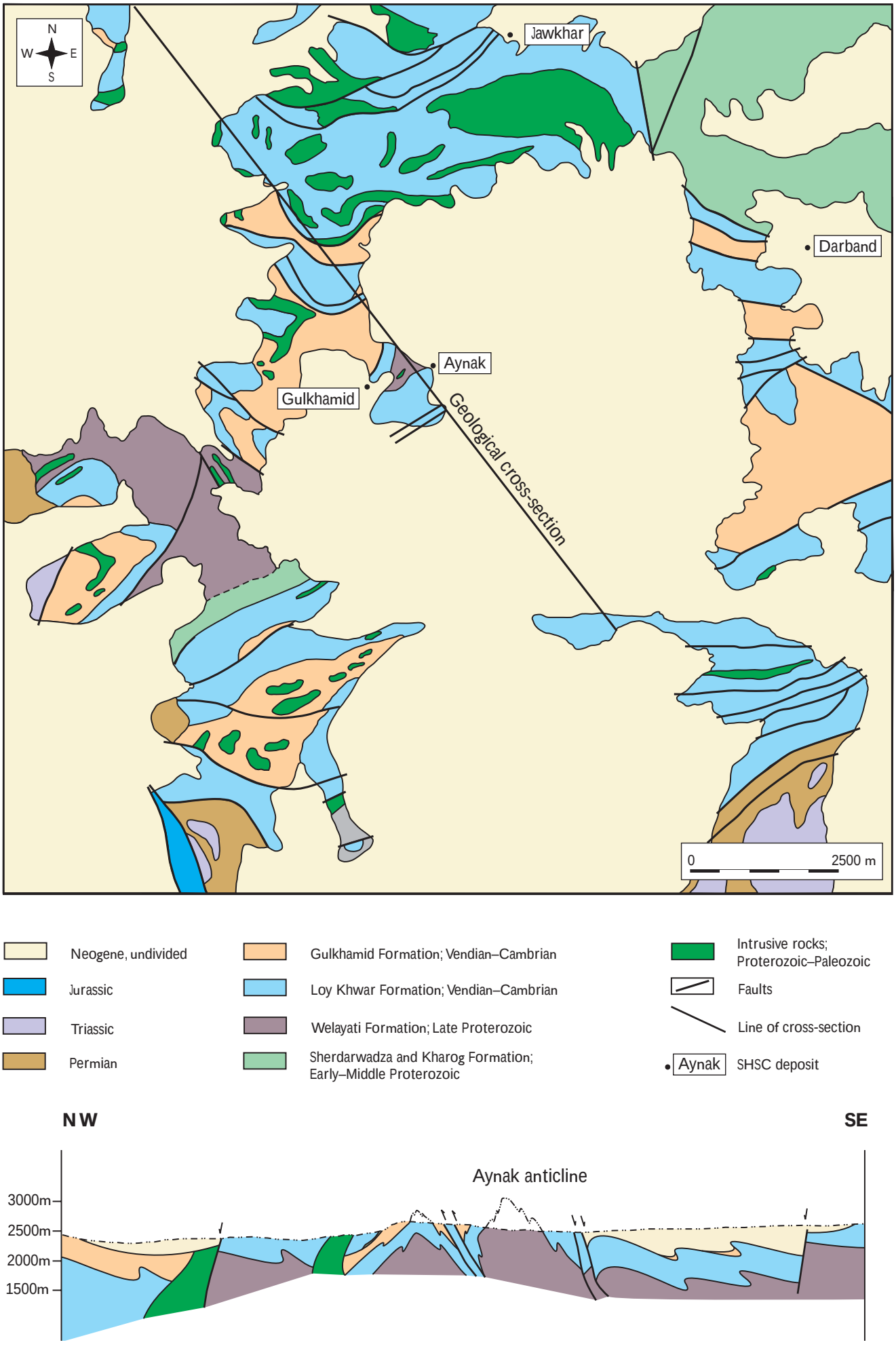


Figure 3. *Simplified geological map and cross-section of the Aynak area.*

Tectonic zone	Geological setting	Mineral deposit type
North Afghanistan Platform (Tadijk Block, Karakum Basin)	Palaeozoic basement intruded by Triassic granitoids. Southern edge cut by an early Mesozoic magmatic arc covered by younger mid-Mesozoic to Neogene sediments	– Shear zone and vein copper – Porphyry Cu-Mo-Au – Sediment-hosted Cu (± Co, Ag, Pb, Zn, PGE, Au, U, V)
Helmand Block (west-central Afghanistan)	Middle Proterozoic high grade metamorphic rocks (2000–5000 m) overlain by greenschist facies Late Proterozoic metasediments (5000–7000 m). Cover rocks are Vendian to Cretaceous formations (1000–8000 m) intruded by Palaeogene acidic to ultrabasic rocks	– Shear zone and vein copper – Granite-related vein, replacement and skarn mineralisation (Cu, Au etc) – Sediment-hosted Cu (± Co, Ag, Pb, Zn, PGE, Au, U, V) – VHMS Cu-Zn-Ag-Mn-Ba-Au deposits in calk-alkaline complexes – Skarn-type, porphyry-related Cu-Pb-Zn-Au mineralisation, related to Cretaceous–Tertiary subduction systems
Farad Block (west and south-west Afghanistan	Unstudied basement. Vendian-Cambrian terrigenous, carbonate and volcanic rocks (420 m), overlain by 9000 m Carboniferous–Jurassic carbonate and volcanic rocks. Infilled by Cretaceous sedimentary rocks. Intruded by Palaeogene granitoids and Miocene diabase swarms, andesite, diorites and porphyry dykes.	– Shear zone and vein copper – Granite-related vein, replacement and skarn mineralisation (Cu, Au etc) – Skarn-type, porphyry-related Cu-Pb-Zn-Au, related to Cretaceous–Tertiary subduction systems – VHMS Cu-Zn-Ag-Mn-Ba-Au deposits in calc-alkaline complexes
Dari-Rod Trough (South Afghanistan)	Middle Proterozoic metamorphosed basement (800 m) overlain by Cretaceous sedimentary-volcanogenic rocks (3300 m). Intruded by Cretaceous and Oligocene (?) ultrabasic and granitoid rocks.	– Shear zone and vein copper – Skarn-type, porphyry-related Cu-Pb-Zn-Au mineralisation, related to Cretaceous–Tertiary subduction systems – VHMS Cu-Zn-Ag-Mn-Ba-Au deposits in calc-alkaline complexes
Nurestan Block (north-east Afghanistan)	Mainly highly metamorphosed Early Proterozoic (10 000 m) basement overlain in parts by Carboniferous-Triassic sedimentary rocks. Intruded by Proterozoic and Cretaceous-Paleogene granitoids and gabbro-diorite intrusions.	– Shear zone and vein copper – Porphyry Cu-Mo-Au
South Badakhshan Block (north-east Afghanistan)	Archean and Proterozoic basement rocks (9000 m). No intrusions.	– Shear zone and vein copper
Kabul Block	Proterozoic basement overlain by Mesozoic sedimentary rocks.	– Sediment-hosted Cu (± Co, Ag, Pb, Zn, PGE, Au, U, V) – Shear zone and vein copper
Katawaz Basin (south-east Afghanistan)	A flexural basin on the western margin of the Indian Plate comprising 10 km of Palaeocene sediments, mostly flysch material, resting on a Palaeozoic and Mesozoic basement.	– Sediment-hosted Cu (± Co, Ag, Pb, Zn, PGE, Au, U, V) – Shear zone and vein copper
Argandab-Tirin Zone (south Afghanistan)	Mesozoic sediments intruded by Zarkashan gabbro, monzonite and syenite intrusive suite, and Argandab granitic massifs.	– Skarn-type, porphyry-related Cu-Pb-Zn-Au mineralisation, related to Cretaceous–Tertiary subduction systems.

Table 1. *Summary of tectonic zones within Afghanistan and associated copper potential.*

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