2.0 Deposits related to mafic igneous rocks

Mineral deposits related to mafic igneous rocks include podiform chromite, ultramafic-hosted talc-magnesite, and serpentine-hosted asbestos. The minerals found in these types of deposits and the deposit types themselves are described and discussed individually, mineral resource tracts and areas of interest are delineated and described, and the undiscovered mineral resources of these mineral deposit types are estimated for the tracts (not for the areas of interest) using the three-part method of quantitative mineral resource assessment (Singer and Ovenshine, 1979; Singer and Cox, 1988; Menzie and Singer, 1990; and Ludington and others, 1992; Singer, 1993). Talc-magnesite deposits associated with metamorphic and metasomatic rocks are discussed separately in section 9.0.

2.1 Podiform Chromite

Contributions by David M. Sutphin, Bruce R. Lipin, Walter J. Bawiec, and Greta J. Orris

2.1.1 Chromite Mineral Occurrences

Most of the chromite deposits occur in a section of Logar Valley in northeastern Afghanistan starting 33 km south of Kabul and extending 15.5 km southward into the valley (Volin, 1950). The Logar River traverses the valley south to north before it joins the Kabul River east of Kabul. The occurrences lie mostly in the hills on the western side of the valley and occur in two groups about 9 km apart. The northern group is on or near Kuh-e-Mohammad Agha; the southern one is on Kohe Saymahmude Ghazi west of the Logar River. Chromite is also found in small quantities at locations in Kandahar, Paktia, and Parwan Provinces. Most of the names of geographic features are from Google Earth.

2.1.2 Description of Podiform Chromite Deposit Models

Podiform chromite deposits are pod-like masses of massive coarse-grained to finely disseminated chromitite in ultramafic parts of ophiolite complexes (Albers, 1986; Singer and Page, 1986). They form in the lower part of the oceanic lithosphere as magmatic cumulates occurring in elongate magmatic pockets along spreading plate margins. The cumulates are subsequently exposed in accreted terranes as part of ophiolite assemblages. The host rock types are highly deformed dunite and harzburgite of ophiolite complexes that are commonly serpentinized. These deposits are commonly restricted to tectonized dunite and harzburgite or in the lower parts of ultramafic cumulates. Chromite is the major ore mineral with ferrichromite, magnetite, ruthenium-osmium-iridium alloys, and laurite as possible accessory minerals. Podiform chromite deposits are highly resistant to weathering and oxidation.

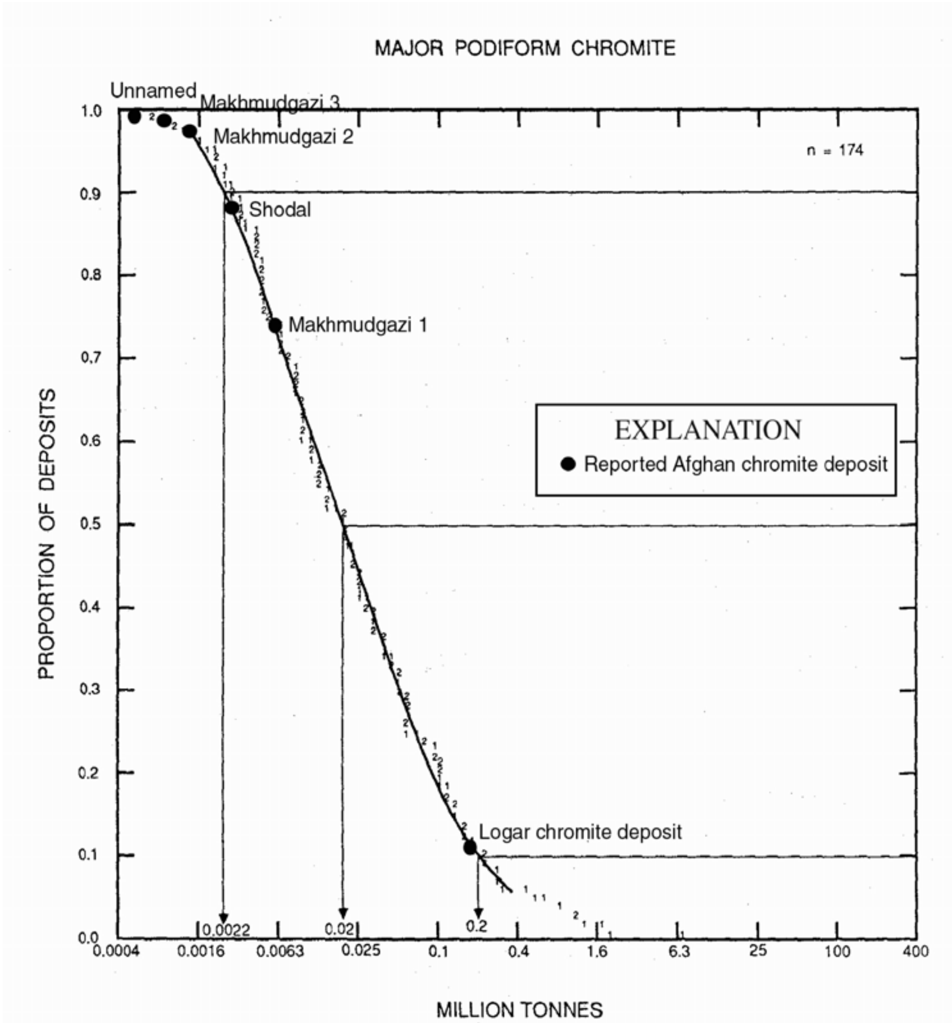


Figure 2.1-1. Graph showing estimated tonnages of Afghan podiform chromite occurrences plotted on the major podiform chromite tonnage curve (after Singer and others, 1986).

Two podiform chromite grade and tonnage models have been produced. The major podiform chromite deposit model was built using data from 174 deposits from around the world (Singer and others, 1986). Major podiform chromite deposits have a mean tonnage of 20,000 metric tons with 80 percent of the deposits ranging from 2,200 to 200,000 metric tons; 80 percent of the grades range from 33 percent to 52 wt. percent chromite; the mean is 46 wt. percent (Singer and others, 1986). Figure 2.1-1 shows the major podiform tonnage model with the estimated tonnages of six known Afghanistan chromite deposits superimposed (Volin, 1950). Because these deposits are not significantly different from the major podiform chromite model, it was not necessary to consider the minor podiform chromite model (Singer and Page, 1986) based on the small deposits found in the western United States.

Previous Investigations

The known area of chromite mineralization in Logar Valley occupies a 45 km section along the west flank of the valley, with the northernmost deposit about 14 km south of Kabul (fig. 2.1-2). The main source of information concerning the chromite deposits in the Logar Valley is Volin (1950). He and his crew carried out mapping, drilling, channel sampling, and chemical analyses on the chromite deposits in the region.

The ultramafic-mafic rocks that host these deposits in Afghanistan are part of a series of ophiolites that were emplaced during the Eocene and extend from Afghanistan and western Pakistan through the Arabian Peninsula (Gnos and others, 1997).

Volin (1950) identified eleven areas that contain chromite deposits and these are summarized below. Four of the areas (1, 2, 3, and 5) contain 27 diamond-drill holes totaling 975.7 meters. The other areas were sampled by a combination of jack-hammer holes, channel sampling, and trenching. Details of the results of the work may be found in Volin (1950). The major rock types are serpentinized harzburgite and dunite with minor noritic dikes in the southernmost areas. These rock types were noted but not mapped by Volin. The chromite deposits are all found in envelopes of dunite surrounded by harzburgite, typical of chromite occurrences in ophiolites. The drilling investigation at the three largest deposits (1, 2, and 5), which are collectively referred to by Abdullah and others (1977) as the Logar chromite deposit, and projection of the smaller deposits to a depth of eight meters, an arbitrary but reasonable estimate, yielded a resource estimate of 181,200 tons containing 35.8 to 57.5 wt. percent Cr_2O_3. These three largest deposits (the Logar chromite deposit) comprise 92 percent of the total. Maps of some of the known podiform chromite deposits in Logar Valley are included in figures 2.1-2-2.1-12.

Logar Province

The Logar deposit (figure 2.1-2) is located about 8 km west of the Logar River on the south flank of Qatarsang occurs as two parallel lenticular chromite zones. The zones strike NW, are 10 to 100 m long and 1 to 10 m thick, and consist dominantly of chromite in the middle of a large Eocene ultra mafic intrusive. Ore reserves are approximately 181,200 t of 42.4 wt. percent Cr_2O_3 with a Cr/Fe ratio of 2.8 to 1. The ore material requires dressing (Volin, 1950).

The Werek chromite occurrence is located on the curving east flank of Tor Wersek Ghar. The occurrence assays 37.3 wt. percent Cr_2O_3 and occurs as a 29 m by 3 m thick body in an Eocene ultra mafic plug (Shcherbina and others, 1975). No estimate of resources is known.

The Makhmudgazi 1 occurrence (fig. 2.1-2), located on the north slope of Kohe Saydmahmude Ghazi about 2 km west of the Logar River, is composed of two massive chromite occurrences 5 m by 40 m and 3 m by 50 m in size and a number of small lenses in Eocene ultra mafic rocks. Volin (1950) estimated reserves to be 5,600 t assaying 43.4 wt. percent Cr_2O_3.

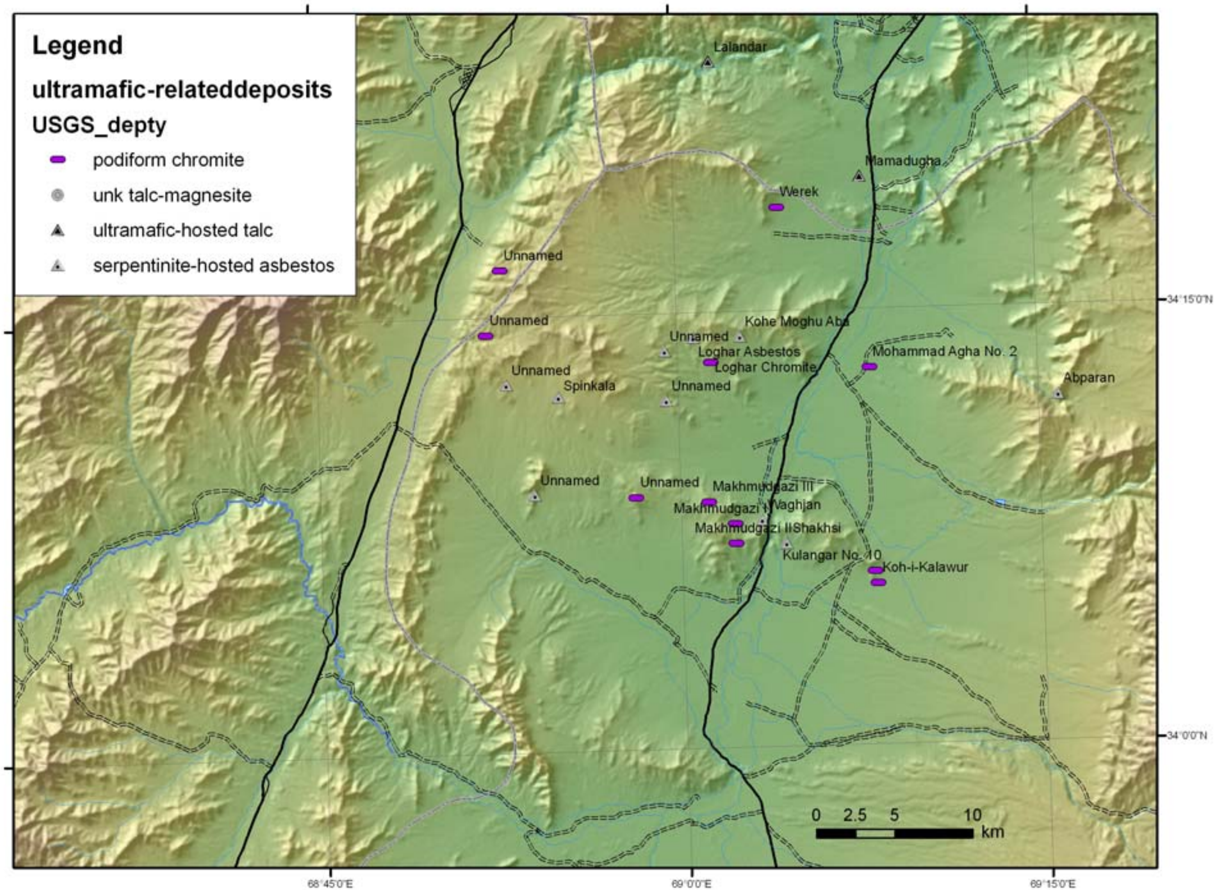


Figure 2.1-2. Locations of known podiform chromite and other mineral occurrences in Logar Valley south of Kabul.

The Makhmudgazi 2 occurrence (fig. 2.1-1) is situated about 1 km south of Makhmudgazi 1 in an Eocene peridotite. This occurrence has a number of chromite lenses ranging from 1 m by 5 m to 2 m by 51 m in size. Volin (1950) reports the reserves to total 1,300 t of 43.4 wt. percent Cr_2O_3.

Makhmudgazi 3 occurs on the north slope of Kohe Saydmahmude Ghazi about 3 km west of the Logar River. Two massive chromite occurrences, each between 30 and 40 m long and 0.3 and 0.5 m thick occur in Eocene ultra mafic rocks (fig. 2.1-2). Reserves were estimated in 1950 to be 840 t assaying 42.3 wt. percent Cr_2O_3 (Volin, 1950).

At Koh-i-Kalawur, along the southeast foot of Kohe Saymahmude Ghazi east of the Logar River, seven chromite lenses as much as 4.5 by 27 m in size are hosted in an Eocene ultra mafic plug (fig. 2.1-2). Reserves were estimated to be 4,300 t assaying 42.8 wt. percent Cr_2O_3 (Volin, 1950). This occurrence may be, or is located near, the Kulangar No. 10 chromite occurrence reported by Bowersox and Chamberlin (1995.)

Volin (1950) reports an unnamed chromite showing at 34° 16'20"N, 68° 53'10"E. At this location, on the west flank of Sro Ghar, south of the merger of the Kabul River and a river from the northwest, chromite float is seen in eluvial talus covering an area of 30 m by 20 m derived from an Eocene peridotite (Volin, 1950). No estimate of resources was reported.

An unnamed chromite showing is also reported at 34° 14'10"N, 68° 52'20"E by Volin (1950). On the west flank of the mountains between Sro Ghar and Tor Ghar, are several chromite lenses up to 6 to 20 m long and as much as 10 m thick in Eocene ultra mafic intrusive rocks (Volin, 1950). No estimate of resources was made by Volin.

A third unnamed chromite showing can be found at 34° 08'50"N, 68° 58'05"E. A chromite lens about 10 m long and 2 m thick occurs in Eocene ultra mafic intrusive rocks at this site (Volin, 1950). Reserves are estimated at 200 t assaying 44.1 percent Cr_2O_3.

2.1.3 Description of Mineral Resource Tracts and Areas of Interest

Two tracts (umf01A and B) were delineated as being permissive for the occurrence of mineral deposit types related to ultramafic rocks. They were selected based on the presence of ultramafic rocks of Eocene age and the presence of known podiform chromite, ultramafic-hosted talc-magnesite, and serpentine-hosted asbestos deposits (often in clusters). For two of the tracts, umf01A and B, estimates were made of the numbers of undiscovered podiform chromite, ultramafic-hosted talc-magnesite, and serpentine-hosted asbestos deposits.

Five additional areas of interest were delineated based of the presence of ultramafic rocks. Two of the areas were based on the presence of ultramafic rocks of Eocene age (umf01C and D). The other three areas of interest were based on ultramafic rocks of specific geologic eras, Proterozoic, Paleozoic, and Mesozoic (umf02, 03, and 04, respectively). Areas of interest are permissive for the occurrence of ultramafic-hosted mineral deposits; however few if any occurrences have been identified in them. Estimates of undiscovered mineral deposits were not made for areas of interest. The two tracts and five areas of interest are described below.

Tract ID: umf01A—Eocene Ultramafic Rocks of Logar Valley

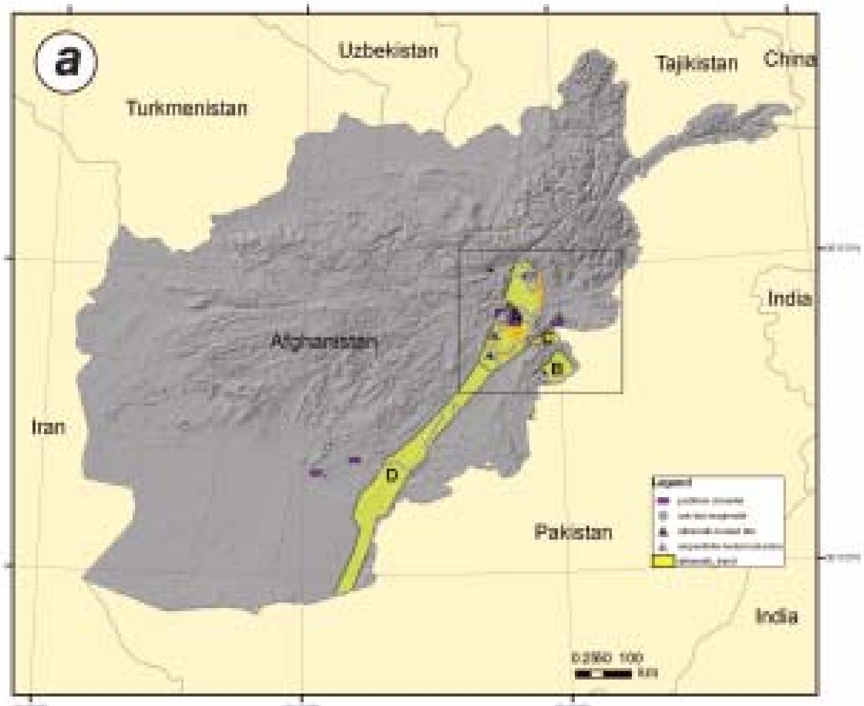
Deposit type—Major podiform chromite

Age of mineralization—Pre-Eocene, emplacement took place in the Early Eocene.

Examples of deposit type— In tract umf01A: Logar deposit, Werek occurrence, Makhmudgazi 1, 2, and 3 occurrences. Worldwide: Troodos in Cyprus, Semail in Oman, Acoje in the Philippines, Kempersai in Kazakhstan.

Exploration history— Volin (1950), Shcherbina and others (1975).

Tract boundary criteria— The tract is defined by the mapped boundary of the ultramafic rocks in the area (figure 2.1-3). The north, east, and west sides of the tract are fault bounded. The tract roughly follows the outline of the valley between Gazni and Gardez in the south, past Logar Valley, Kabul, and Bagram north to Carikar and Mahmud-e Raqi. Tract umf01A contains a fault-bounded ovoid area identified on the Russian structural map as an area of Early Alpian folding. All the known ultramafic-hosted mineral occurrences within the tract are located in the area of folding.



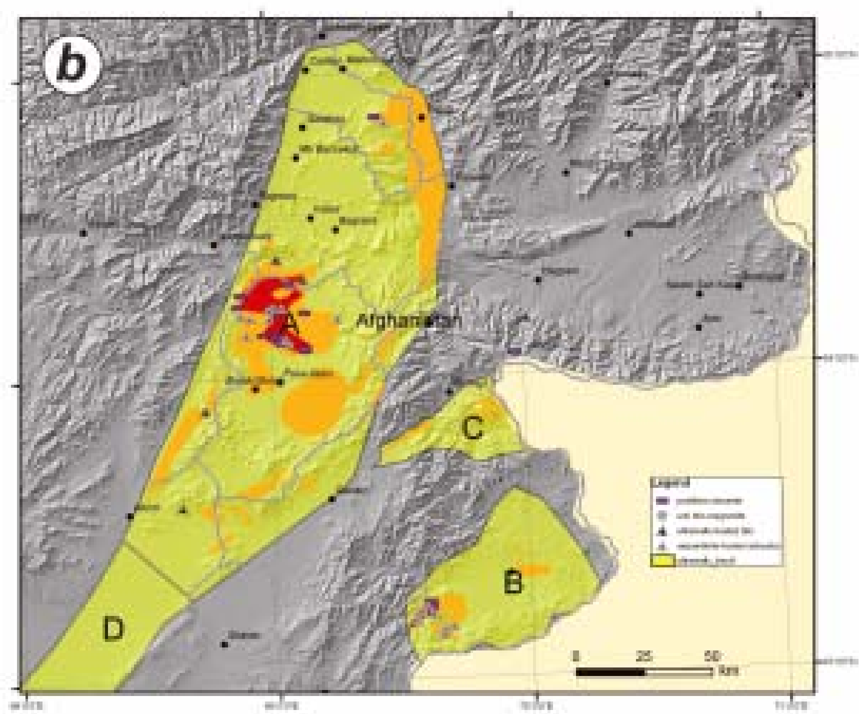


Figure 2.1-3. Maps showing locations of tracts, areas of interest, and ultramafic-related deposits in Afghanistan. (a) Total tracts for Eocene ophiolite sequence. (b) Inset from (a) showing tracts umf01A, B, C, and D.

Important data sources— Volin, 1950; Shcherbina and others, 1975; geologic map, (Doebrich and Wahl, 2006); mineral deposit database (Abdullah and others, 1977).

Needs to improve assessment— The assessment can be improved by the following;

1. Processed gravity and magnetic geophysical data to estimate the subsurface extent of the ultramafic rocks extend below the surface.
2. Careful mapping of the boundaries between dunite and harzburgite in the ultramafic rocks, because the probability of substantial chromite deposits is higher in dunite than it is in harzburgite.

Optimistic factor— The fact that more than 181,000 tons of chromite oxide has been found at the surface is encouraging.

Pessimistic factors—

1. Other ophiolites in Pakistan and south through the Arabian Peninsula that were emplaced during the same convergent event have not been particularly productive with respect to chromite.
2. The ophiolite here has been dismembered by tectonic forces. Thus, the most productive stratigraphic section for chromite which is about a 2-4 km section containing the transition from depleted harzburgite to cumulate dunite and wehrlite may be missing.

Quantitative assessment—Estimates of undiscovered podiform chromite deposits in tract umf01A were made (table 2.1-1). Better mapping and geophysics would make for a better assessment,

Table 2.1-1. Probability estimates of undiscovered podiform chromite deposits in tract umf01A.

			Probability			
Estimator	**90 percent**	**50 percent**	**10 percent**	**5 percent**	**1 percent**	**Total**
1	5	10	100	-	-	35.165
2	5	8	12	20	50	9.465
3	10	20	50	-	-	25.330
4	7	14	21	-	-	13.531
5	3	8	25	-	-	11.399
Consensus	6	11	30	-	-	14.798

The figures in table 2.1-1 show that the geoscientists' estimates varied from about 9 deposits to more than 35 deposits, a factor of about 3.7. For the Eocene Ultramafic Rocks of Logar Valley tract (umf01A), the assessment team found that there is a 90 percent chance of 6 or more undiscovered major podiform chromite deposits, a 50 percent chance of 11 or more, and a 10 percent chance of 30 or more. Consensus estimates were not made at the 5 percent or 1 percent probability levels. The estimate is subjective and is based on expert opinion and analogy with geologically similar well-explored areas in other parts of the world. This estimate results in a mean estimate of 14.798 undiscovered deposits. These estimates were used to generate probabilistic estimates of the amounts of chromite and platinum-group elements contained in the undiscovered deposits using Monte Carlo simulation (see section 1.1). The results are tabulated in table 2.1-2 and shown graphically in figure 2.1-14 and 2.1-15).

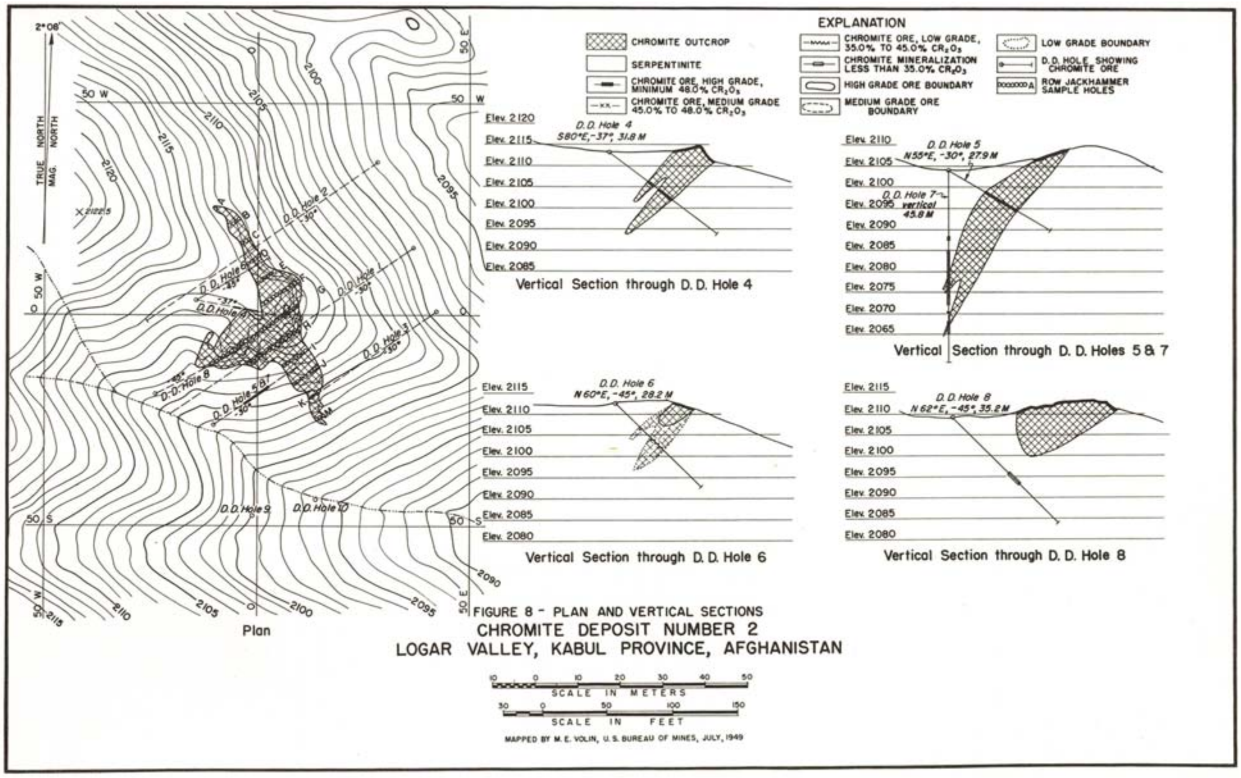


Figure 2.1-4. Map view and cross sections of one deposit in Logar Valley, Afghanistan (Volin, 1950).

With the known occurrence of numerous podiform chromite occurrences in Logar Valley, the team believes that there are about 15 locales where podiform chromite deposits might exist, based on the occurrence of ultramafic rocks, extensive strike-slip faults, and prominent aeromagnetic anomalies. Past drilling by Volin (1950) defined the details of the known bodies, but undiscovered pods of chromite deposits may be identified with further modern exploration.

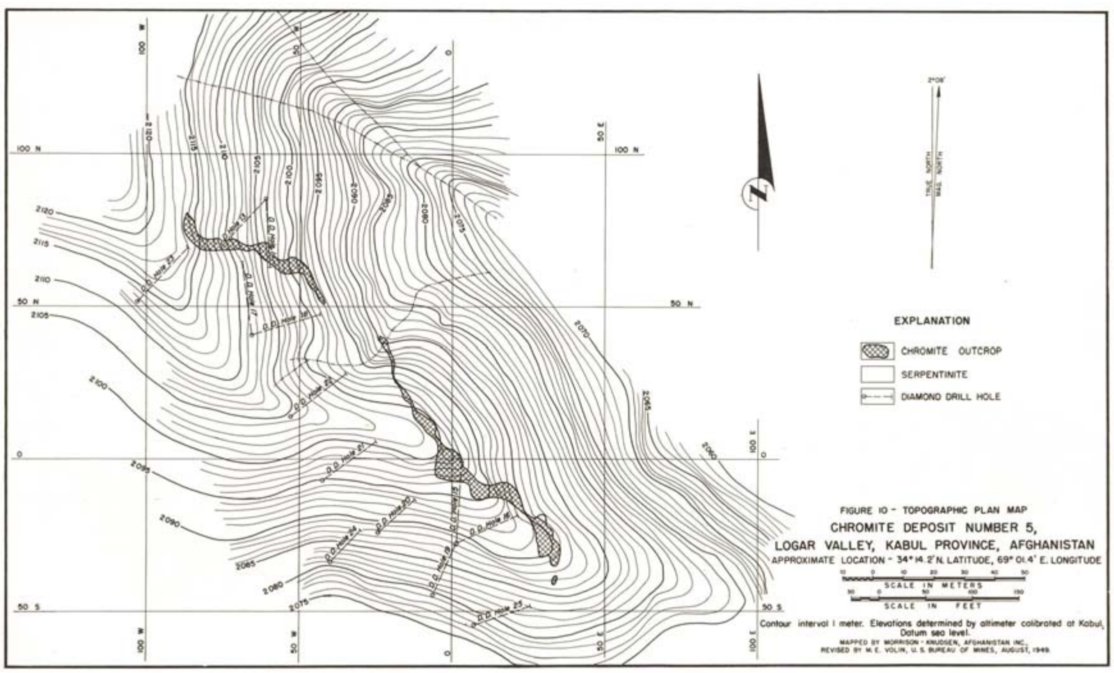


Figure 2.1-5. Location of a known chromite deposit in the Logar Valley, Afghanistan (Volin, 1950).

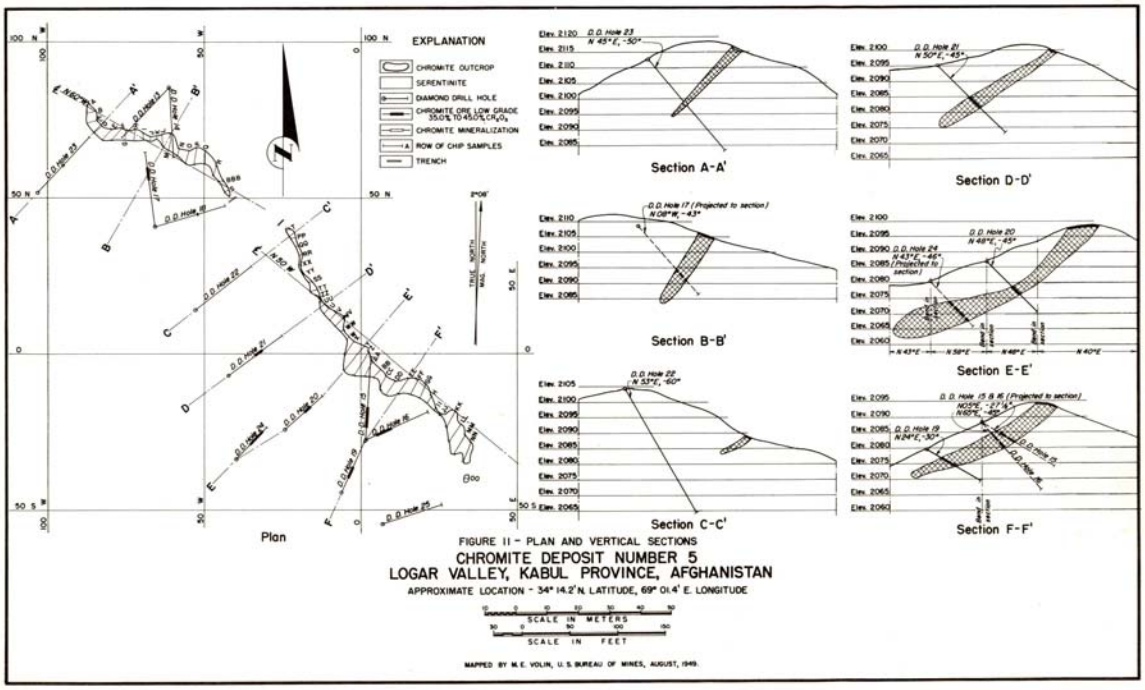


Figure 2.1-6. Location of a known chromite deposit in Logar Valley, Afghanistan (Volin, 1950).

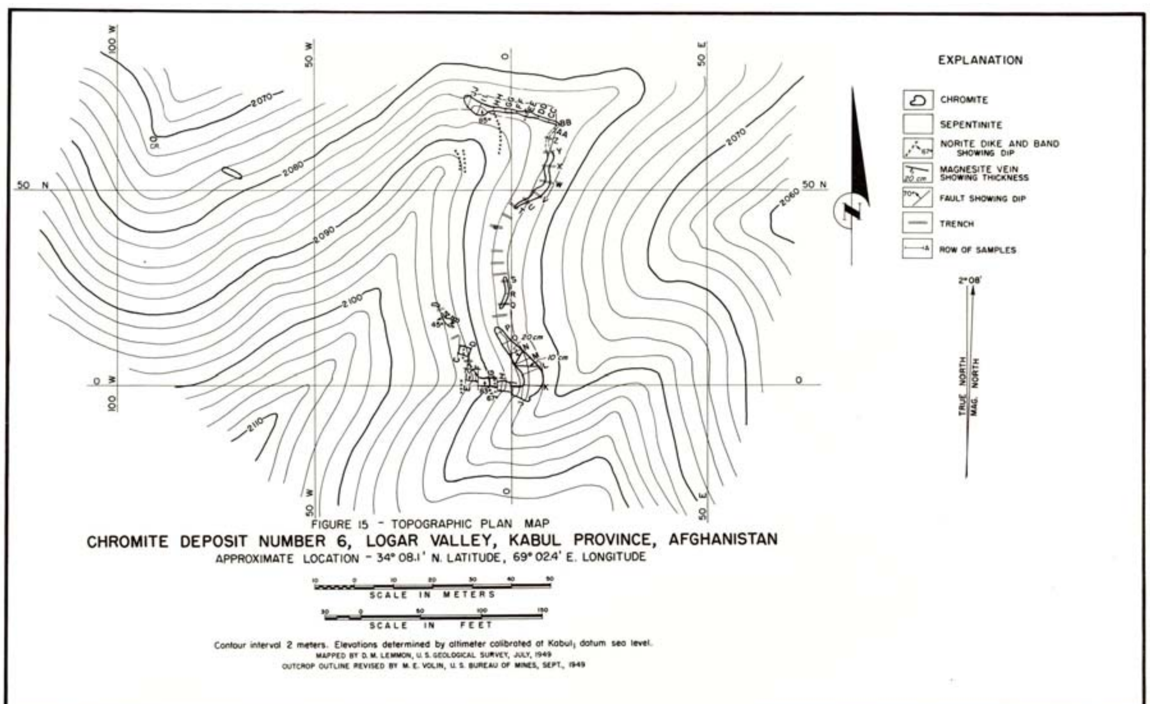


Figure 2.1-7. Map of a known chromite deposit in Logar Valley, Afghanistan (Volin, 1950).

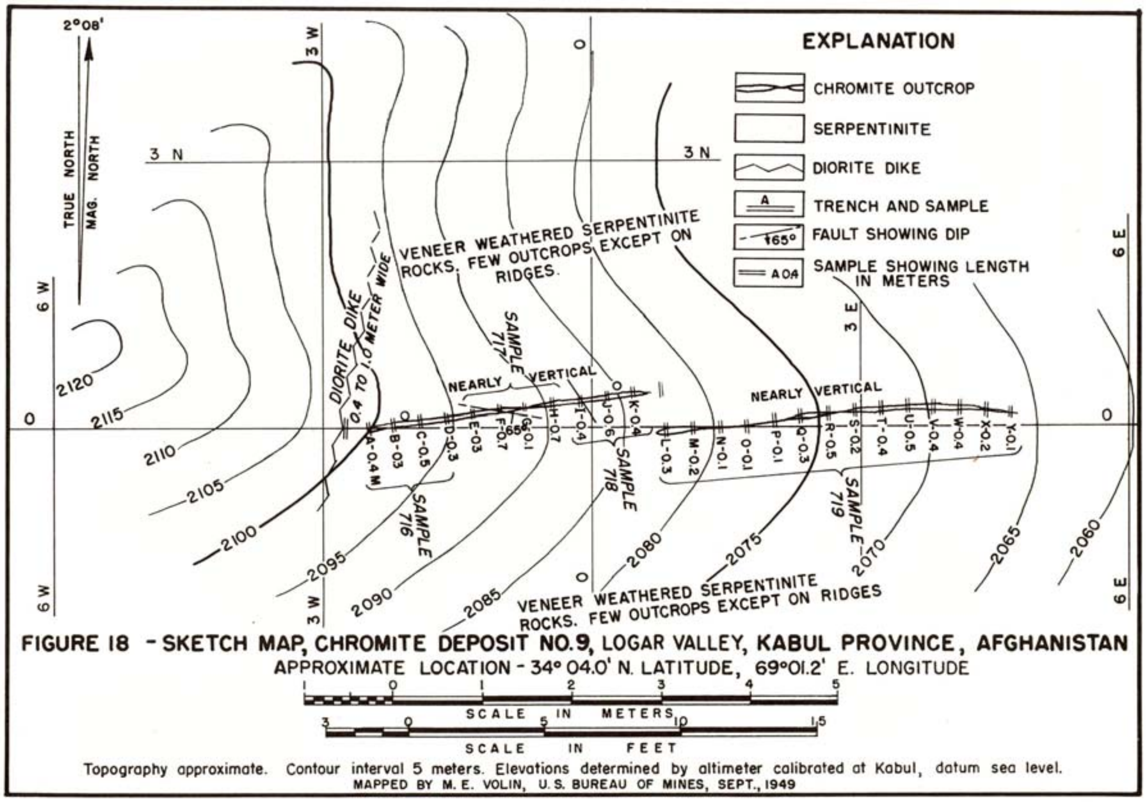


FIGURE 18 - SKETCH MAP, CHROMITE DEPOSIT NO.9, LOGAR VALLEY, KABUL PROVINCE, AFGHANISTAN
APPROXIMATE LOCATION - 34° 04.0' N. LATITUDE, 69°01.2' E. LONGITUDE
Topography approximate. Contour interval 5 meters. Elevations determined by altimeter calibrated at Kabul, datum sea level.
MAPPED BY M. E. VOLIN, U. S. BUREAU OF MINES, SEPT., 1949

Figure 2.1-8. Map of a known chromite deposit in Logar Valley, Afghanistan (Volin, 1950).

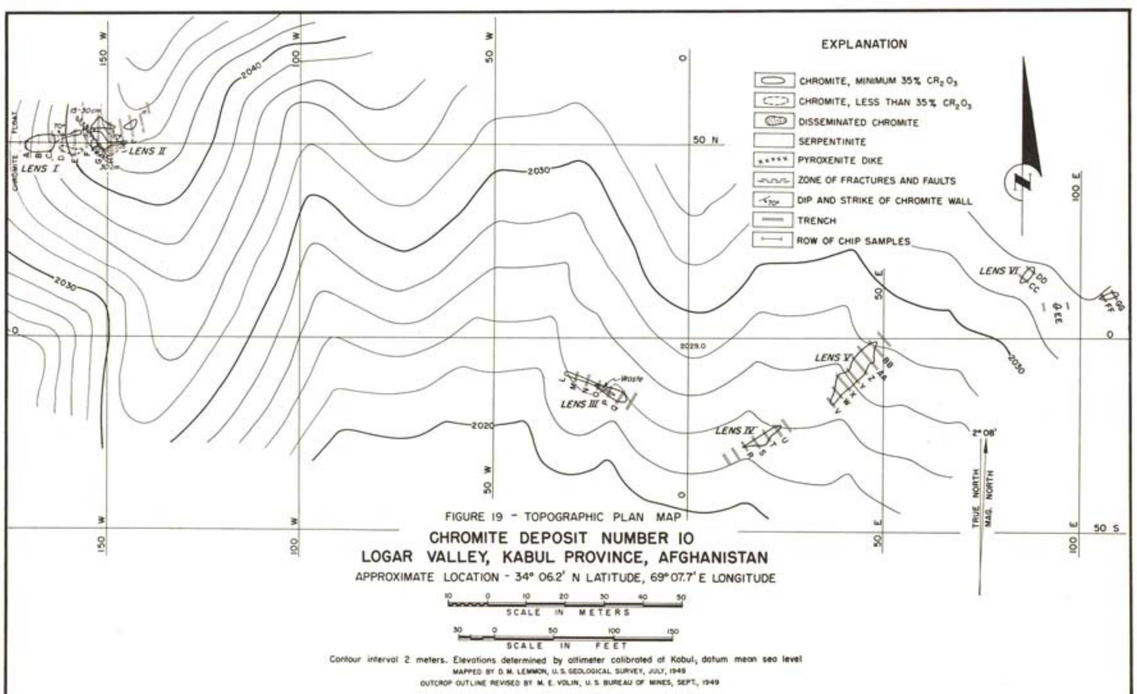


FIGURE 19 - TOPOGRAPHIC PLAN MAP
CHROMITE DEPOSIT NUMBER 10
LOGAR VALLEY, KABUL PROVINCE, AFGHANISTAN
APPROXIMATE LOCATION - 34° 06.2' N LATITUDE, 69° 07.7' E LONGITUDE
Contour interval 2 meters. Elevations determined by altimeter calibrated at Kabul, datum mean sea level
MAPPED BY D. M. LEMMON, U. S. GEOLOGICAL SURVEY, JULY, 1949
OUTCROP OUTLINE REVISED BY M. E. VOLIN, U. S. BUREAU OF MINES, SEPT., 1949

Figure 2.1-9. Location of a known chromite deposit in Logar Valley, Afghanistan (Volin, 1950).

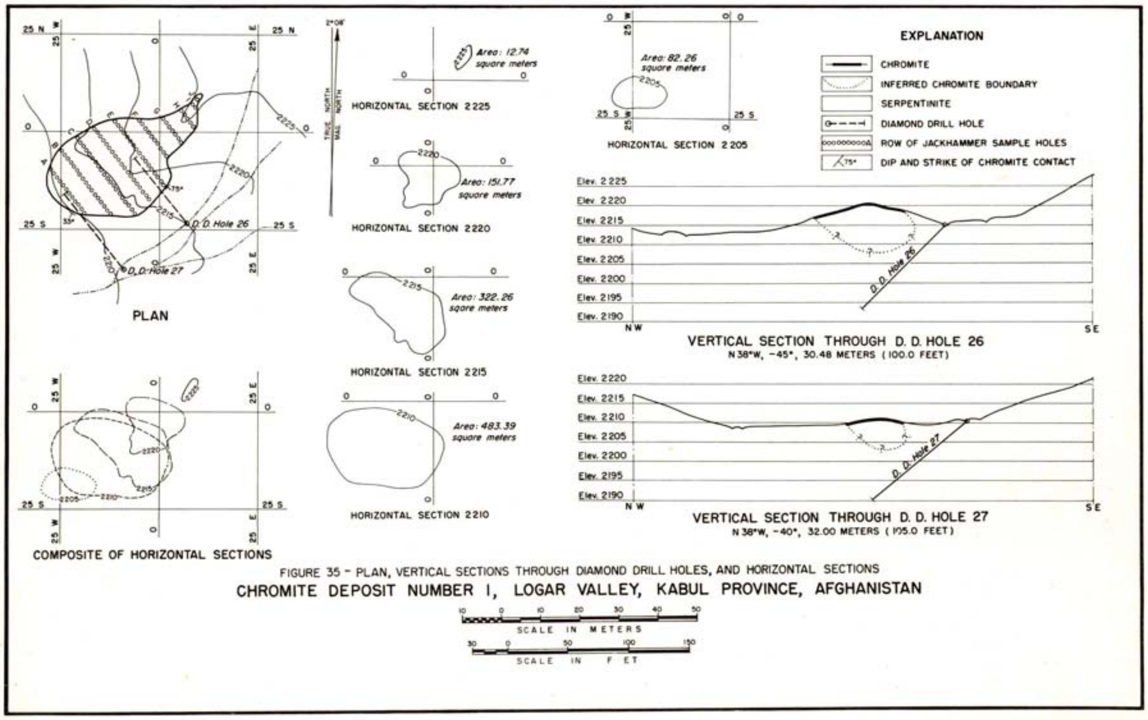


Figure 2.1-10. Vertical cross section of a known chromite deposit in Logar Valley, Afghanistan (Volin, 1950).

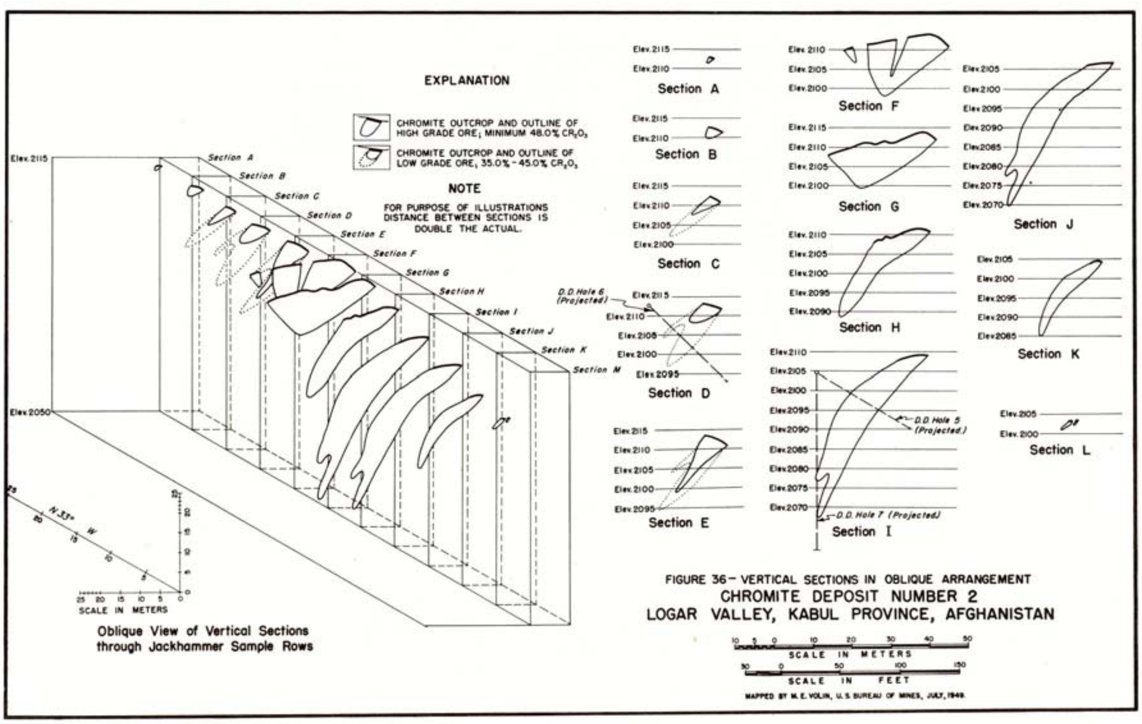


Figure 2.1-11. Vertical cross sections and three dimensional view of a known chromite deposit in Logar Valley, Afghanistan (Volin, 1950).

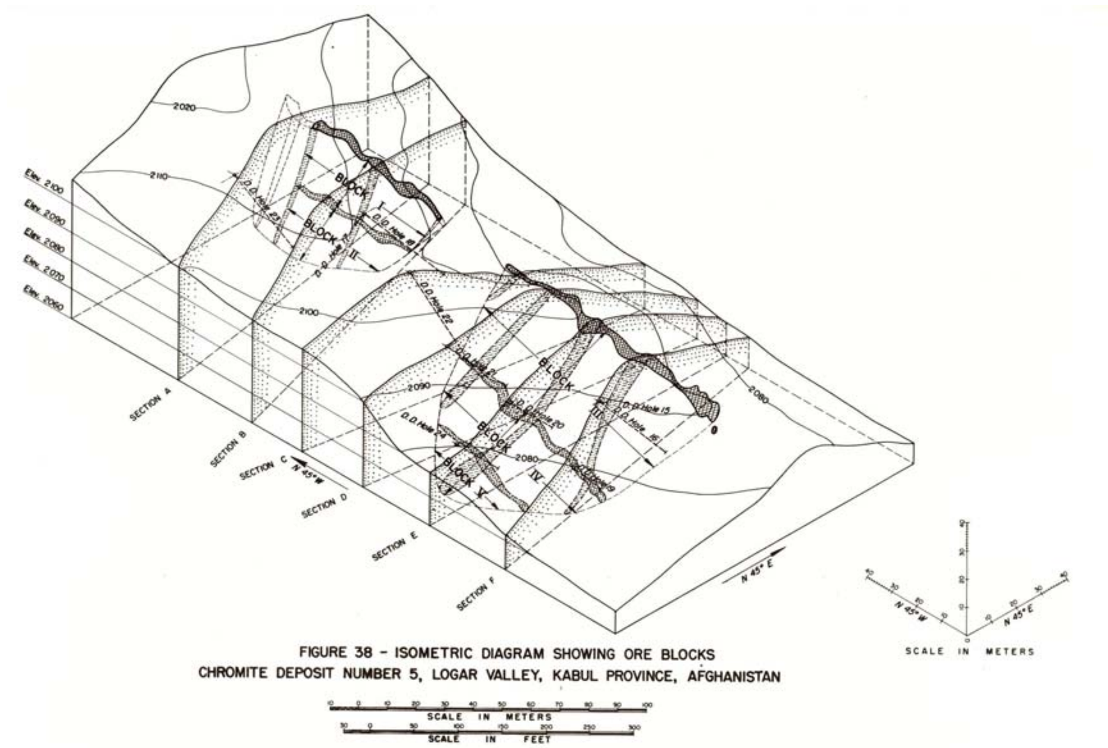


Figure 2.1-12. Three dimensional representation of ore blocks in a known chromite deposit in Logar Valley, Afghanistan (Volin, 1950).

Parwan Province

The Jurati chromite occurrence (fig. 2.1-13) is located about 45 km north-northeast of Kabul near the peak of Sarpokhi Ghar. The mineralization is 20 m by 30 m in size and found in the western part of an Eocene peridotite (Denikaev and others, 1971).

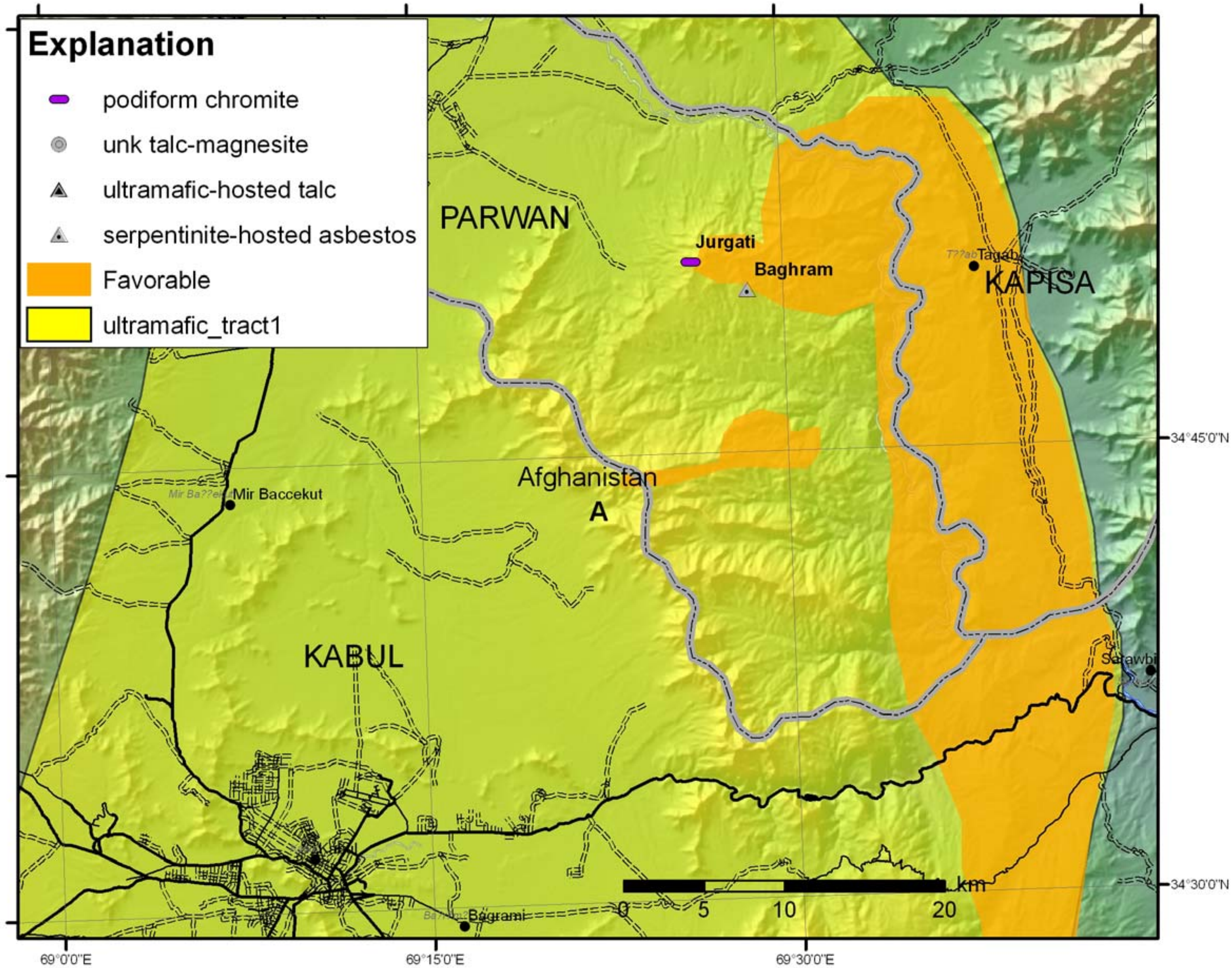


Figure 2.1-13. Location of the Jurgati chromite occurrence, Parwan Province, Afghanistan

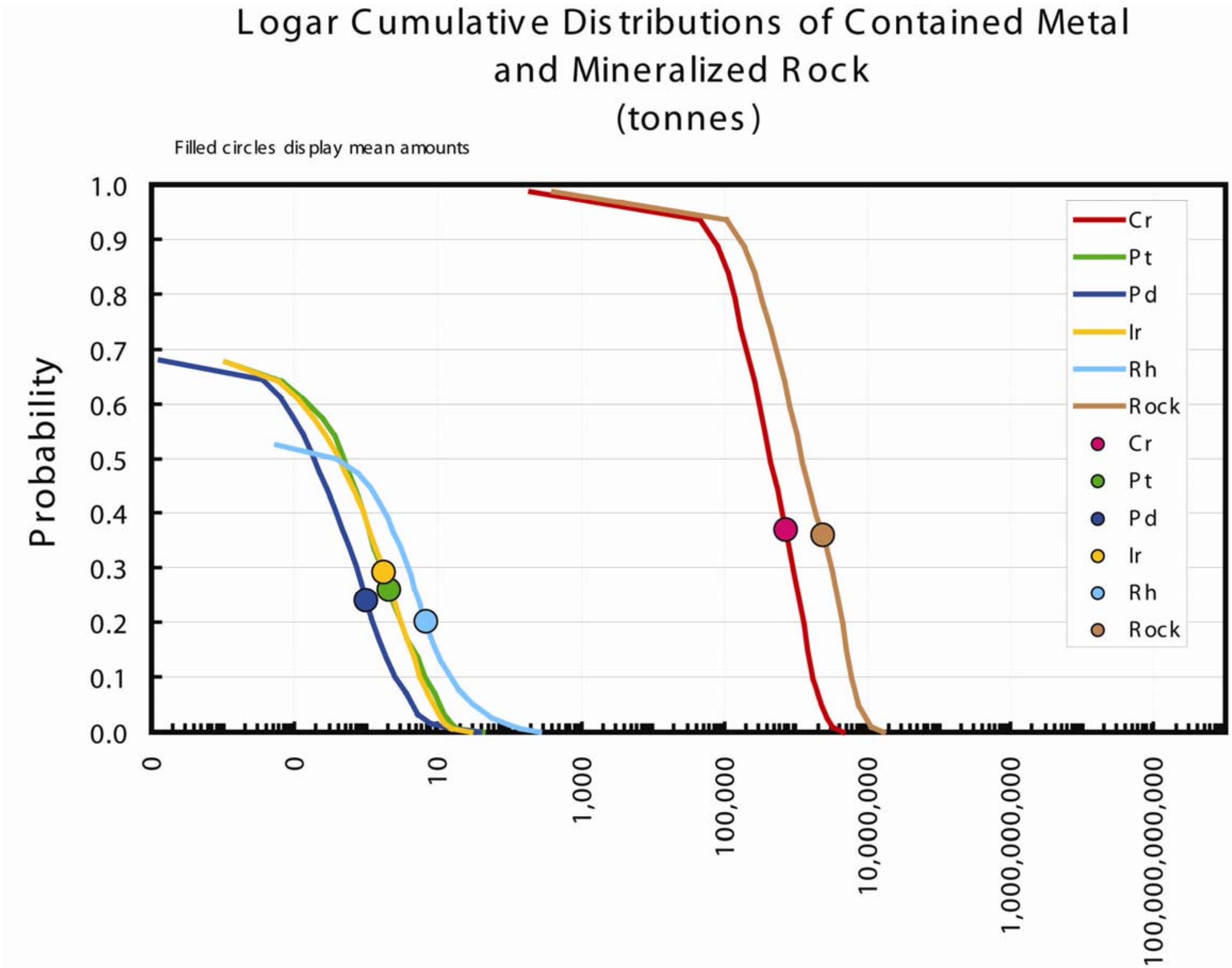


Figure 2.1-14. Cumulative distributions for chromite, platinum-group elements, and rocks for the probabilistic estimates ofumf01A, the Eocene Ultramafic Rocks of Logar Valley permissive tract

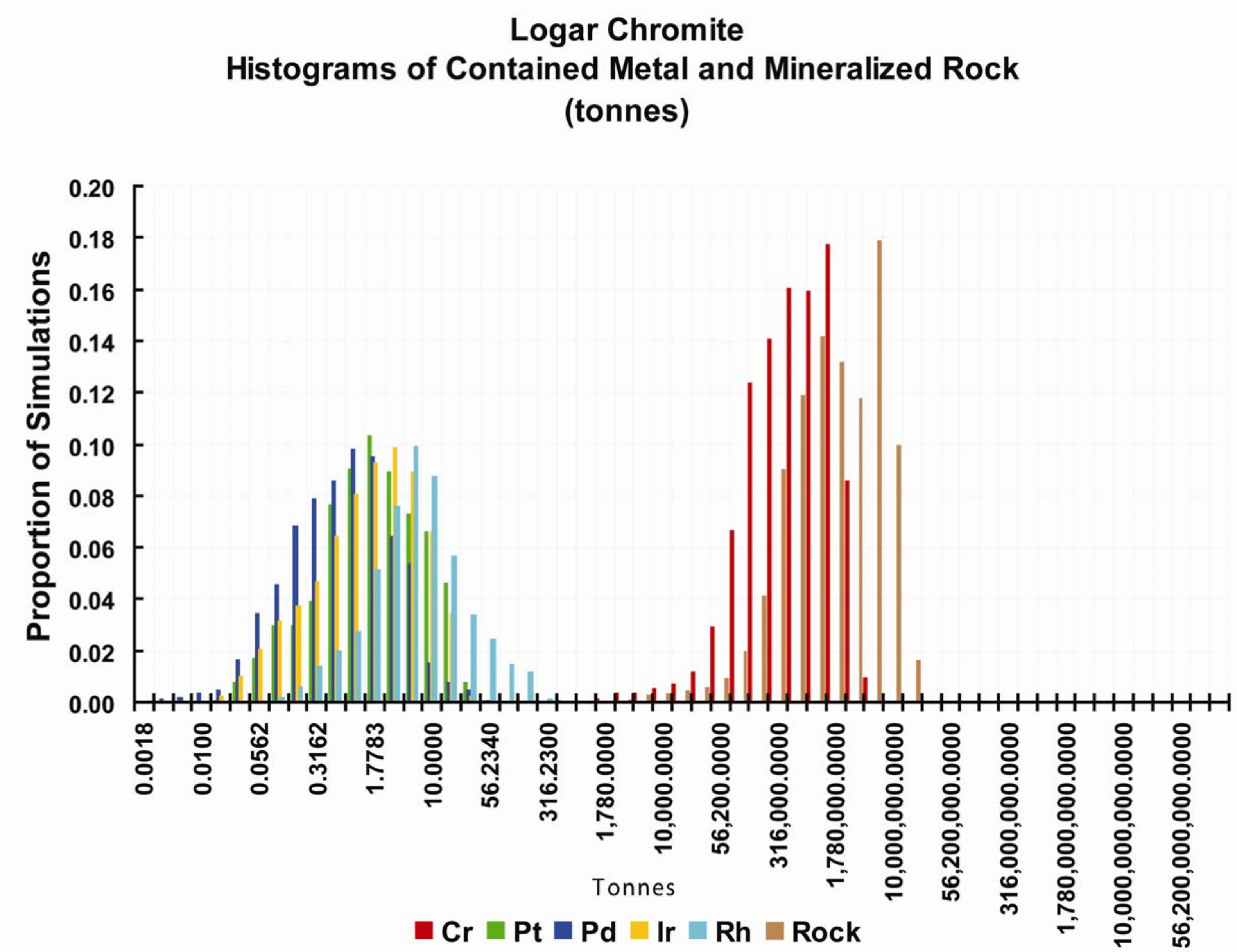


Figure 2.1-15. Histograms of estimated contained chromite, palladium, iridium, and mineralized rock for undiscovered podiform deposits for the probabilistic estimate for umf01A, the Eocene Ultramafic Rocks of Logar Valley permissive tract.

Table 2.1-2. Table showing probabilistic distribution of estimated contained metal and mineralized rock for undiscovered podiform chromite deposits for the probabilistic estimates for umf01A, the Eocene Ultramafic Rocks of Logar Valley permissive tract.

There is a 90 percent or greater chance of 6 or more deposits.
There is a 50 percent or greater chance of 11 or more deposits.
There is a 10 percent or greater chance of 30 or more deposits.

Quantile	Cr (tonnes)	Pt (tonnes)	Pd (tonnes)	Ir (tonnes)	Rh (tonnes)	Ru (tonnes)	Rock (tonnes)
0.95	34,000	0	0	0	0	0	79,000
0.90	71,000	0	0	0	0	0	170,000
0.50	440,000	1	0	0	0	0	1,200,000
0.10	1,700,000	7	3	6	15	37	6,000,000
0.05	2,300,000	10	4	9	33	87	7,700,000
mean	720,000	2	1	2	7	15	2,400,000
Probability of mean	0.37	0.26	0.24	0.29	0.20	0.21	0.36
Probability of zero	0.01	0.32	0.32	0.32	0.48	0.48	0.01

Tract ID: umf01B—Eocene Ultramafic Rocks Near Khost

Deposit type—Major podiform chromite

Age of mineralization—Pre-Eocene, emplacement took place in the early Eocene.

Examples of deposit type— In tract umf01B: Sperkaw and Shodal occurrences. Worldwide: Troodos in Cyprus, Semail in Oman, Acoje in the Philippines, and Kempersai in Kazakhstan.

Paktia Province

At the Sperkaw chromite occurrence just west of Teragharay near the border with Khost Province, ten massive chromite bodies are found in Eocene peridotite. The bodies are as much as 110 m long and 1 to 10 m thick. They assay from 43.11 to 53.48 percent Cr_2O_3 and from 5.57 to 7.23 Fe. Associated with the chromite bodies is chrysotile asbestos mineralization in two sericite-carbonate shear zones. The areas of asbestos mineralization are 20 to 60 m thick and 3 km to 4 km along strike. The asbestos fibers in the veinlets are as much as 10 to 12 cm long (Sborshchikov and others, 1974).

The Shodal occurrence is located southwest of Teragharay and about 1 km south of Sperkaw. There are 34 known chromite-bearing lenses ranging from 3 m to 40 m long and 0.2 to 0.4 m thick and thin veinlets with disseminated chromite; all occur in Eocene peridotite. The massive chromite lenses have minor olivine grains and assay 44.36 wt. percent Cr_2O_3. Nitikin and others (1973) speculate that reserves are 4,002 t.

Exploration history—Denikaev and others (1971)

Tract boundary criteria—This tract is delineated by the mapped boundary of the ultramafic rocks in the area and aeromagnetic highs associated with those rocks (fig. 2.1-16). Small areas of dunite, peridotite, and serpentinite occur east and west of Khost. The ultramafic rocks west of Khost contain ultramafic-hosted deposits, the presence of which were important in determining the tract boundary.

Important data sources —Denikaev and others (1971); geologic map, (Doebrich and Wahl, 2006; mineral deposit database (Orris and Bliss, 2002; and Abdullah and others, 1977).

Needs to improve assessment—

1. Processed gravity and magnetic geophysical data to estimate the subsurface extent of the ultramafic rocks.
2. Careful mapping of the boundaries between dunite and harzburgite, because the probability of substantial chromite deposits is higher in dunite than it is in harzburgite.

Optimistic factors—The presence of mafic and ultramafic rocks permissive for podiform chromite deposits in the eastern and western parts of the areas are positive, as are the two known podiform chromite occurrences and the cluster of serpentine-hosted asbestos occurrences.

Pessimistic factors—

1. Other ophiolites in Pakistan and South through the Arabian Peninsula that were emplaced during the same convergent event have not been particularly productive with respect to chromite.
2. The ophiolite here has been dismembered by tectonic forces. Thus, the most productive stratigraphic section for chromite, which is a 2-4 km section containing the transition from depleted harzburgite to cumulate dunite and wehrlite may be missing.
3. The amount of chromite at the surface is quite small.

Quantitative assessment—The assessment team recognized that better mapping and geophysics would make for a better assessment. Rather than estimating the number of deposits individually, the geoscientists provided a consensus estimate of 5.466 undiscovered podiform chromite deposits in tract umf01B (table 2.1-3).

Table 2.1-3 Consensus probability estimates of undiscovered major podiform chromite deposits in tract umf01B.

Estimator	Probability					Total
	90 percent	50 percent	10 percent	5 percent	1 percent	
Consensus	2	5	10	---	---	5.466

For the Eocene Ultramafic Rocks Near Khost tract (umf01B), the assessment team found that there is a 90 percent chance of 2 or more undiscovered major podiform chromite deposits, a 50 percent chance of 5 or more, and a 10 percent chance of 10 or more (table 2.1-3). Consensus estimates were not made at the 5 percent or 1 percent probability levels. The estimate is subjective and is based on expert opinion and analogy with geologically similar well-explored areas in other parts of the world. This estimate results in a mean estimate of 5.466 undiscovered deposits. These estimates were used to generate probabilistic estimates of the amounts of chromite and platinum-group elements contained in the undiscovered deposits using Monte Carlo simulation (see section 1.1). The results are tabulated in table 2.1-4 and shown graphically in figures 2.1-17 and 2.1-18.

With the known presence of numerous podiform chromite occurrences west of Khost, the team believes that there are five locales where podiform chromite deposits are most likely to exist. This belief is based on the occurrence of ultramafic rocks, extensive strike-slip faults, and prominent aeromagnetic anomalies. The team also believes that the Khost tract has not been sufficiently explored and that additional areas containing undiscovered pods of chromite deposits may be identified with further modern exploration.

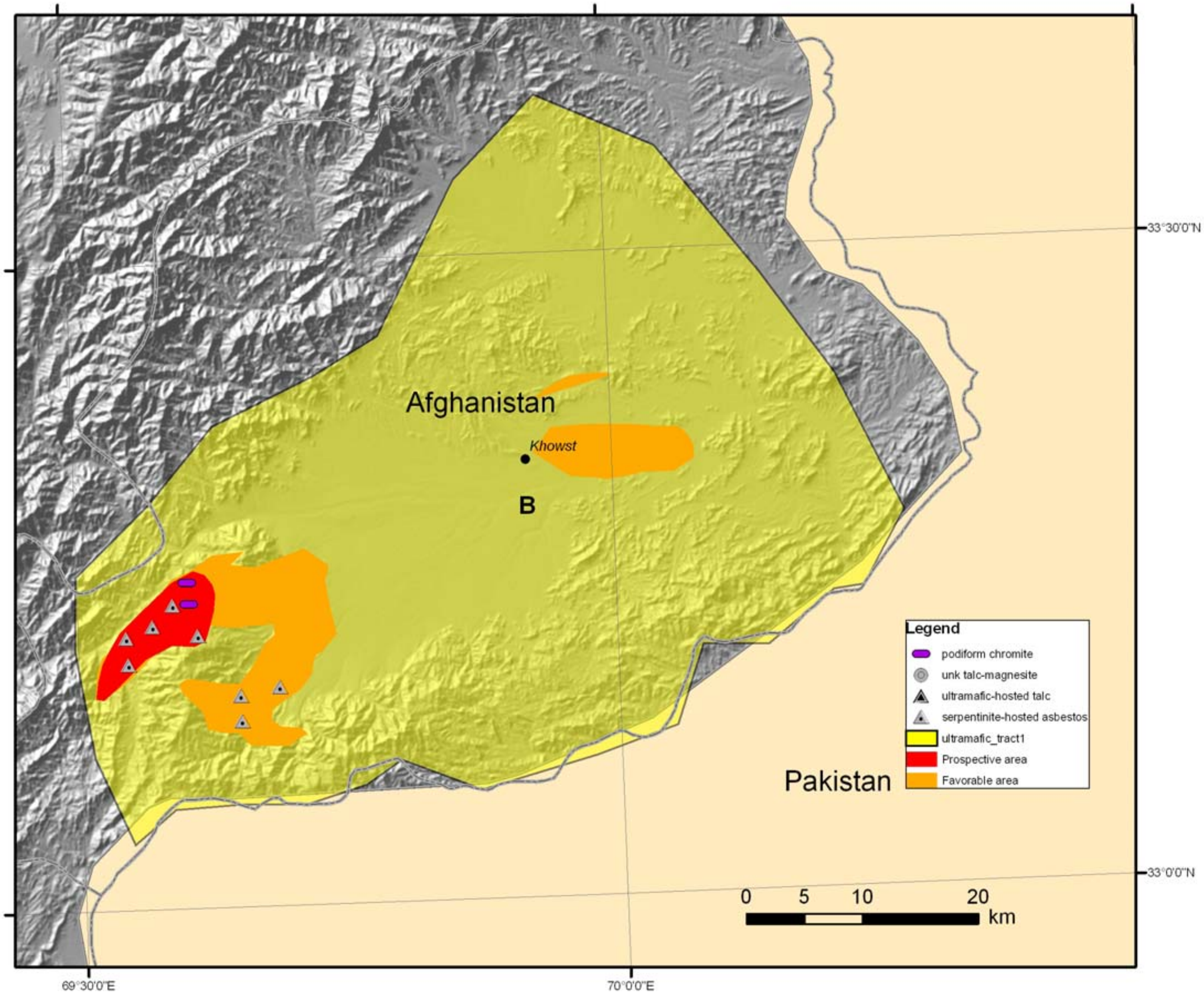


Figure 2.1-16. Location of the Sperkaw and Shodal chromite occurrences in tract umf01B and areas favorable and prospective for the occurrence of podiform chromite deposits in Paktia Province, Afghanistan.

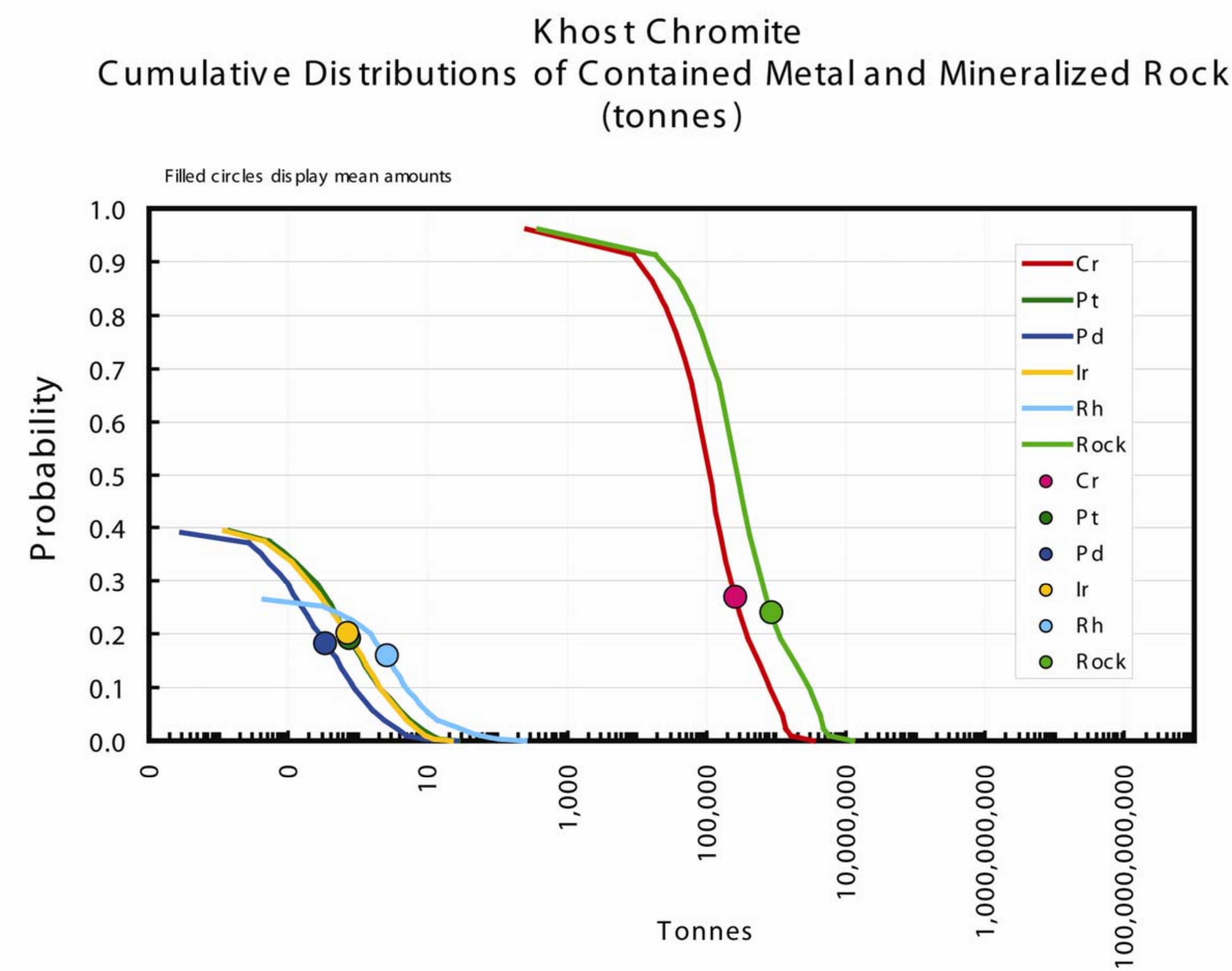


Figure 2.1-17. Cumulative distributions for chromite, platinum-group elements, and rocks for the probabilistic estimates of tract umf01B the Eocene Ultramafic Rocks near Khost permissive tract.

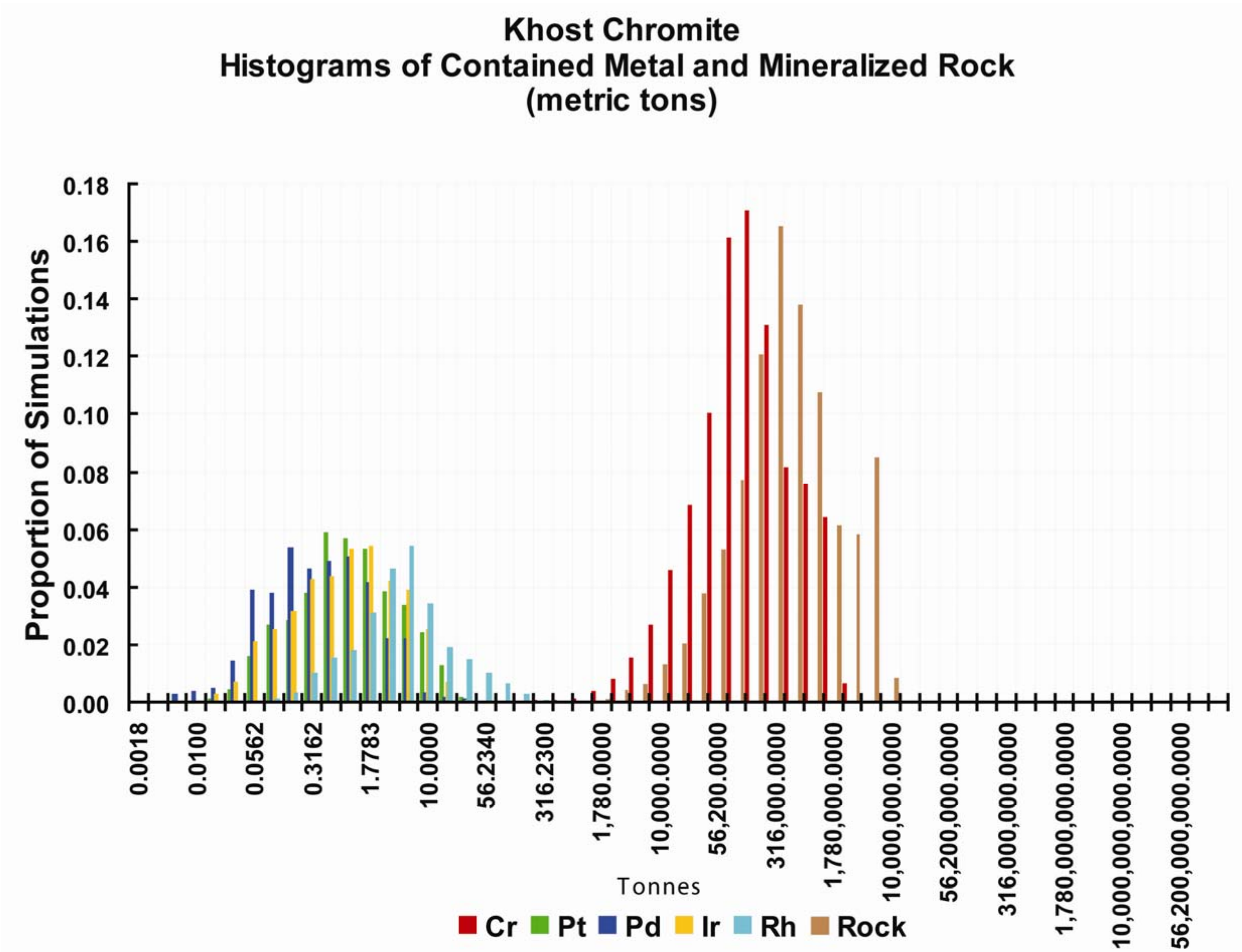


Figure 2.1-18. Histograms of estimated contained chromite, palladium, iridium, and mineralized rock for undiscovered podiform deposits for the probabilistic estimate for tract umf01B the Eocene Ultramafic Rocks near Khost permissive tract.

Table 2.1-4 Table showing probabilistic distribution of estimated contained metal and mineralized rock for undiscovered podiform chromite deposits for the probabilistic estimates of tract umf01B the Eocene Ultramafic Rocks near Khost permissive tract.

There is a 90 percent or greater chance of 2 or more deposits.
There is a 50 percent or greater chance of 5 or more deposits.
There is a 10 percent or greater chance of 10 or more deposits.

Quantile	Cr (tonnes)	Pt (tonnes)	Pd (tonnes)	Ir (tonnes)	Rh (tonnes)	Ru (tonnes)	Rock (tonnes)
0.95	2,400	0	0	0	0	0	4,800
0.90	11,000	0	0	0	0	0	23,000
0.50	110,000	0	0	0	0	0	270,000
0.10	820,000	2	1	2	5	11	3,000,000
0.05	1,200,000	4	2	4	11	22	4,300,000
mean	260,000	1	0	1	3	6	860,000
Probability of mean	0.27	0.19	0.18	0.20	0.16	0.17	0.24
Probability of zero	0.04	0.61	0.61	0.61	0.73	0.73	0.04

Area ID: umf01C—Eocene Ultramafic Rocks of Paktia, Province, North of Khost, Area of Interest

Deposit type—Podiform chromite

Age of mineralization—Pre-Eocene, emplacement took place in the early Eocene.

Examples of deposit type— In tract umf01C: None. Worldwide: Troodos in Cyprus, Semail in Oman, Acoje in the Philippines, and Kempersai in Kazakhstan.

Exploration history—Sborshchikov and others (1974), Nitikin and others (1973).

Tract boundary criteria—The tract is delineated by the presence of mafic and ultramafic rocks of Eocene age outside of Logar Valley (fig. 2.1-19). The northern boundary of Area umf01C runs roughly along faults striking to the southwest south of Ali Hayl. One mapped ultramafic rock unit consisting of dunite, peridotite, and serpentinite in the northwest part of the area is bounded by the fault. Area umf01C contains magnetic highs associated with the ultramafic rocks.

Important data sources—Sborshchikov and others (1974), Nitikin and others (1973); geologic map, (Doebrich and Wahl, 2006; mineral deposit database (Orris and Bliss, 2002; and Abdullah and others, 1977).

Needs to improve assessment—

1. Processed gravity and magnetic geophysical data to estimate the subsurface extent of the ultramafic rocks.
2. Careful mapping of the boundaries between dunite and harzburgite in the ultramafic rocks, because the probability of substantial chromite deposits is higher in dunite than it is in harzburgite.

Optimistic factors—The presence of mafic and ultramafic rocks similar to those containing podiform chromite deposits in Logar Valley is a positive factor.

Pessimistic factors—

1. Ophiolites in Pakistan and south through the Arabian Peninsula that were emplaced during the same convergent event have not been particularly productive with respect to chromite.
2. The ophiolite here has been dismembered by tectonic forces. Thus, the most productive stratigraphic section for chromite, which is about a 2-4 km section containing the transition from depleted harzburgite to cumulate dunite and wehrlite, may be missing.
3. The amount of chromite at the surface is quite small.

***Quantitative assessment*—**Not advisable without better mapping and geophysics. No estimates of undiscovered podiform chromite deposits were made.

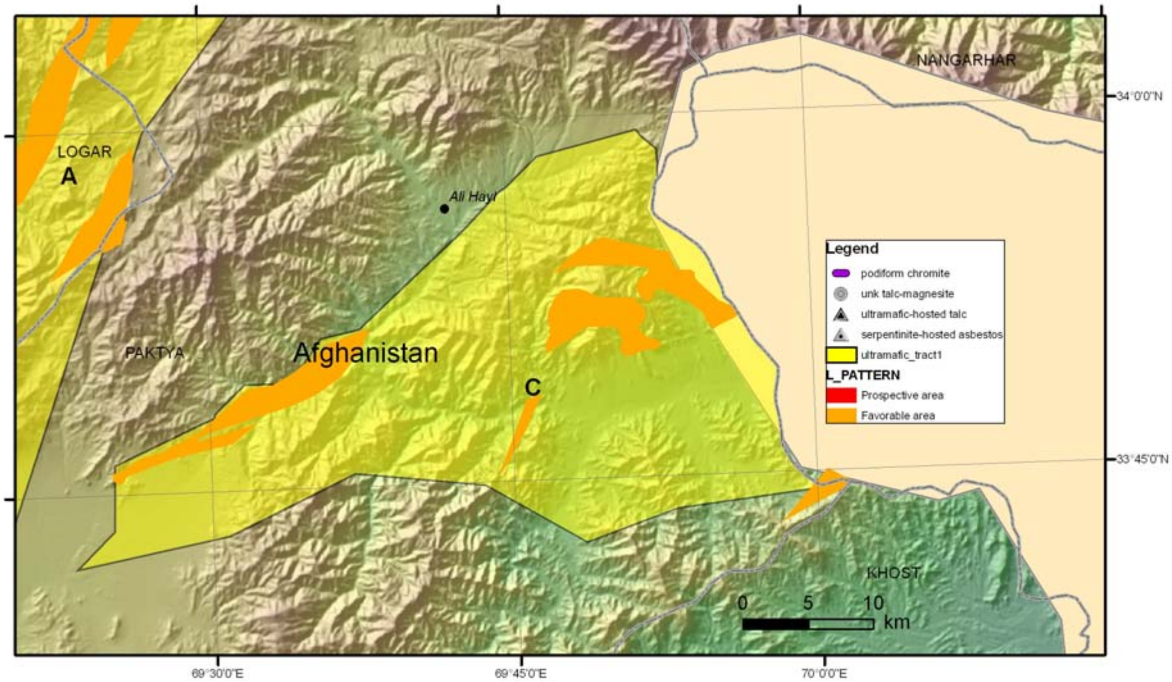


Figure 2.1-19 Location of tract umf01C and favorable areas in Paktia Province, Afghanistan. No estimate of undiscovered ultramafic-related deposits was made.

Area ID: umf01D—Ghazni to Kandahar Valley Area of Interest

***Deposit type*—**Podiform chromite

***Age of mineralization*—**Unknown, but emplacement took place in the early Eocene.

***Examples of deposit type*—** In tract umf01D: None. Worldwide: Troodos in Cyprus, Semail in Oman, Acoje in the Philippines, and Kempersai in Kazakhstan.

***Exploration history*—**Dovgal and others, 1971

***Tract boundary criteria*—**The tract was delineated using the presence of mapped extensive strike-slip faults and aeromagnetic anomalies trending along the tectonic zone stretching from Kabul through the Logar Valley, south of Ghazni, Qalat-e Gilzay, and Kandahar, and south-southwestward to the Pakistan border (fig. 2.1-20). The aeromagnetic highs are speculated to show pieces of Eocene age ophiolite separated by strike-slip faulting from the larger ophiolite in Logar Valley and strung out along the tract to the southwest toward Kandahar and beyond. The northern boundary closely follows the tectonic contact between an area of early Alpian folding to the north and an area of late Alpian folding.

***Important data sources*—**Dovgal and others, 1971; geologic map, (Doebrich and Wahl, 2006; mineral deposit database (Orris and Bliss, 2002; and Abdullah and others, 1977).

***Needs to improve assessment*—**The assessment can be improved by the following;

1. Processed gravity and magnetic geophysical data to estimate the subsurface extent of the ultramafic rocks.

2. Careful mapping of the boundaries between dunite and harzburgite in the ultramafic rocks, because the probability of substantial chromite deposits is higher in dunite than it is in harzburgite.

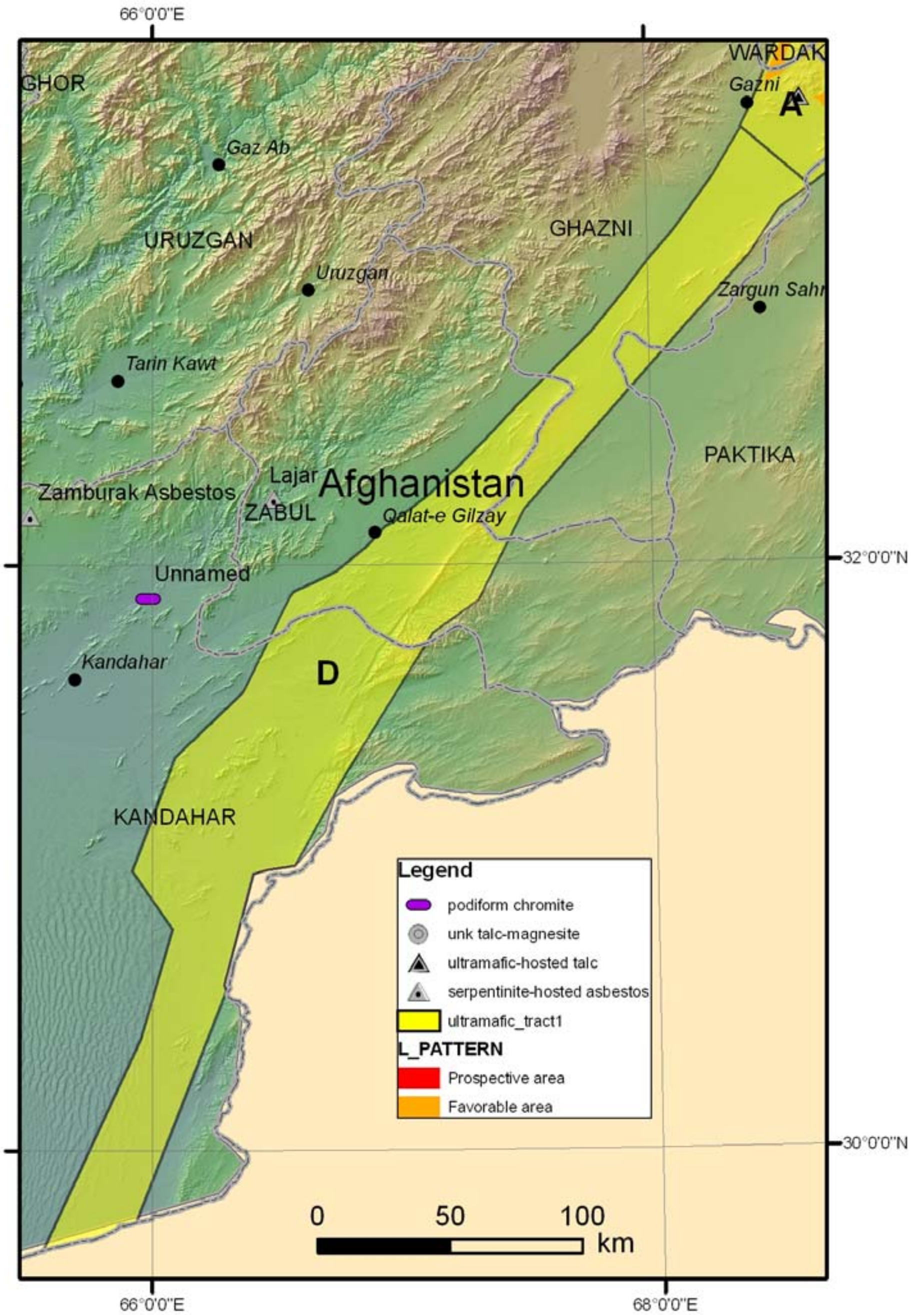


Figure 2.1-20. Location of tract umf01D in southern Afghanistan.

Optimistic factors—Aeromagnetic highs may indicate hidden parts of ophiolite permissive for ultramafic-hosted mineral deposit types.

Pessimistic factors—

1. Other ophiolites in Pakistan and south through the Arabian Peninsula during the same convergent event have not been particularly productive with respect to chromite.

2. The ophiolite here has been dismembered by tectonic forces. Thus, the most productive stratigraphic section for chromite, which is about a 2– to 4–km-long section containing the transition from depleted harzburgite to cumulate dunite and wehrlite, may be missing.
3. The amount of chromite at the surface is quite small.

Quantitative assessment—Not advisable without better mapping and geophysics. No estimates were made of undiscovered podiform chromite deposits in the Ghazni to Kandahar Valley Area of Interest (umf01D).

Additional Areas of Interest of Ultramafic-Hosted Mineral Deposits

The following areas of interest were delineated for their permissiveness for undiscovered ultramafic-hosted mineral deposits types such as podiform chromite, serpentine-hosted asbestos, and ultramafic-hosted talc-magnesite. No estimates were made of numbers of undiscovered mineral deposits for any of these areas, but the areas of interest are identified and described to indicate that they are permissive for those types of deposits.

Area ID: umf02—Proterozoic Ultramafic Rock Area of Interest

Deposit type—Podiform chromite, ultramafic-hosted talc-magnesite, or serpentine-hosted asbestos

Age of mineralization—Proterozoic? Host rocks are of Proterozoic age.

Examples of deposit type— In tract umf02: None. Worldwide: Troodos in Cyprus, Semail in Oman, Acoje in the Philippines, and Kempersai in Kazakhstan.

Exploration history—Sborshchikov and others (1974), Nitikin and others (1973).

Tract boundary criteria— The permissive area includes all Proterozoic mafic and ultramafic intrusive rocks in the country. The polygons in figure 2.1-21 have a 1-km buffer to make them visible at the scale of the map.

Important data sources—Dovgal and others, 1971; geologic map, (Doebrich and Wahl, 2006; mineral deposit database (Orris and Bliss, 2002; and Abdullah and others, 1977).

Needs to improve assessment—Processed gravity and magnetic geophysical data to estimate the subsurface extent of the ultramafic rocks.

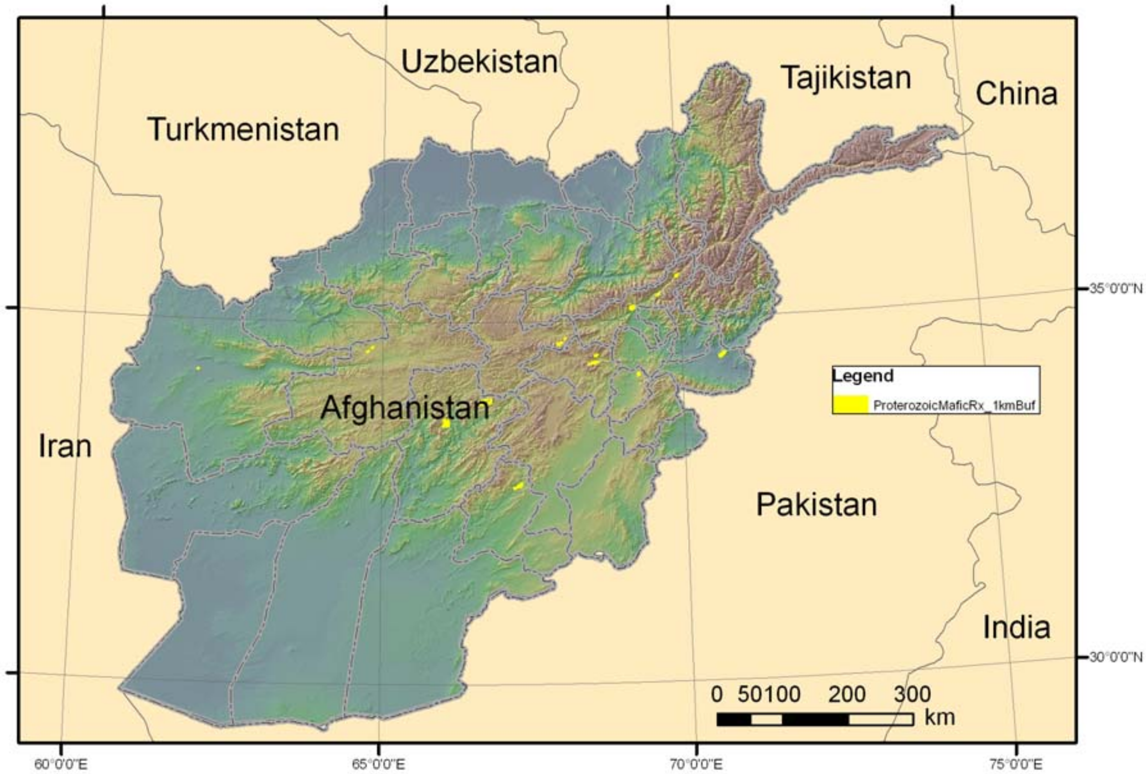


Figure 2.1-21. Location of umf02, the Proterozoic Ultramafic Rock Area of Interest for ultramafic-hosted mineral deposits, is based upon the occurrence of Proterozoic age mafic and ultramafic rocks

Optimistic factors—The presence of ultramafic host rocks and an apparent lack of modern geological and geophysical exploration.

Pessimistic factors—Over time, the ophiolite here has been dismembered by tectonic forces. There are no reported ultramafic-hosted minerals occurrences in Proterozoic age ultramafic rocks.

Quantitative assessment—Not advisable without better mapping and geophysics. No estimates of undiscovered podiform chromite, ultramafic-hosted talc-magnesite, or serpentine-hosted asbestos deposits were made.

Area ID: umf03—Paleozoic Ultramafic Rocks Area of Interest

Deposit type—Podiform chromite, ultramafic-hosted talc-magnesite, or serpentine-hosted asbestos

Age of mineralization—Paleozoic? Host rocks are of Mississippian (Early Carboniferous) age

Examples of deposit type— In tract umf03: None. Worldwide: Troodos in Cyprus, Semail in Oman, Acoje in the Philippines, and Kempersai in Kazakhstan.

Exploration history—Sborshchikov and others (1974), Nitikin and others (1973).

Tract boundary criteria— This area consists of Mississippian age mafic and ultramafic rocks mapped as diorite, dunite, gabbro, peridotite and serpentinite (fig. 2.1-22). The polygons are drawn with a wide outline to make them visible at the scale of the map.

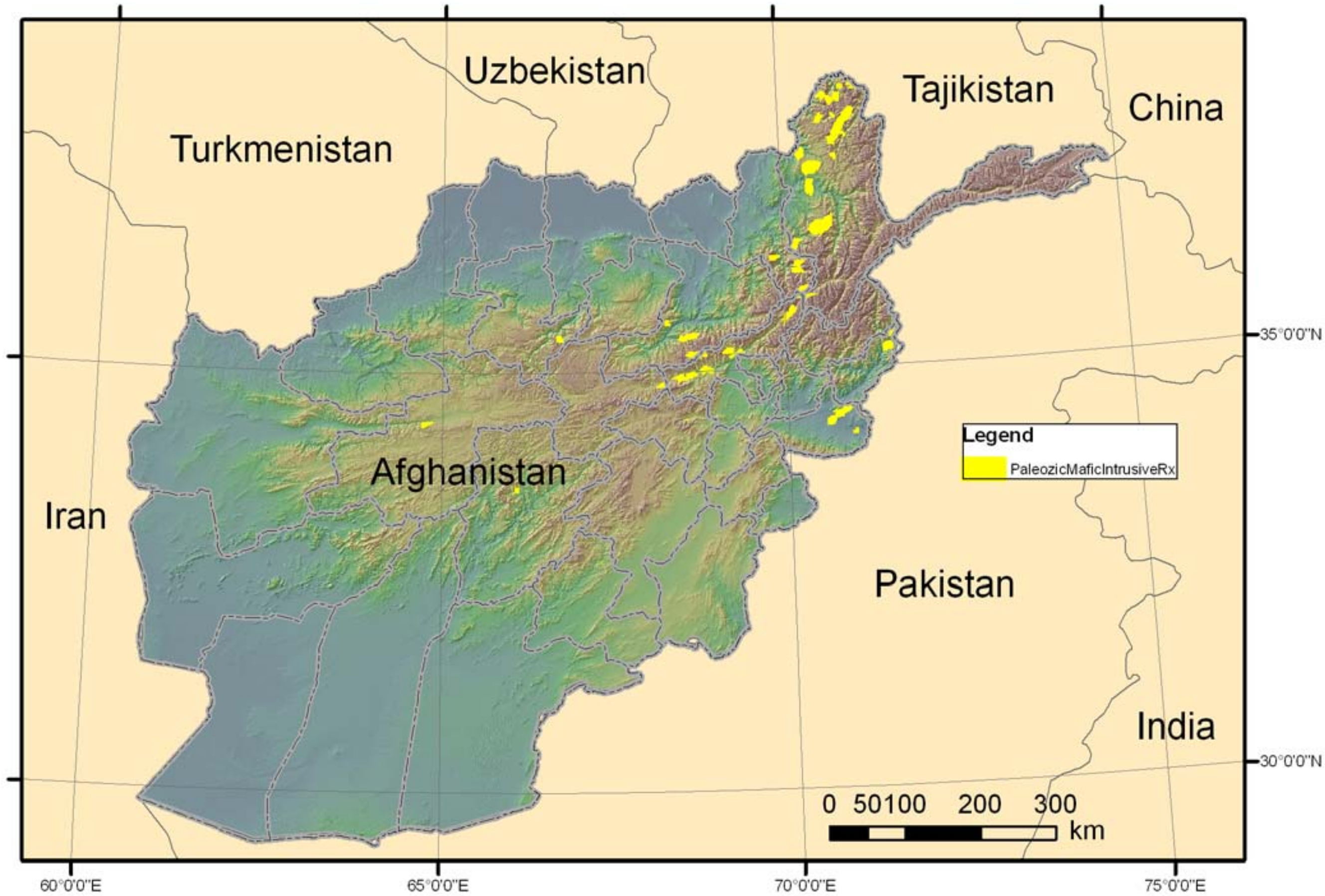


Figure 2.1-22. Area of interest umf03, the Paleozoic Ultramafic Rocks Area of Interest based on the presence of Paleozoic age ultramafic rocks

Important data sources**—**Dovgal and others, 1971; geologic map, (Doebrich and Wahl, 2006; mineral deposit database (Orris and Bliss, 2002; and Abdullah and others, 1977).

Needs to improve assessment**—** Processed gravity and magnetic geophysical data to estimate the subsurface extent of the ultramafic rocks.

Optimistic factors**—**Many of these rocks are in very remote and rugged locations that have not faced modern exploration.

Pessimistic factors**—**The ophiolite here has been dismembered by tectonic forces. Only a few of the known ultramafic-hosted talc and serpentinite-hosted asbestos mineral occurrences are located in or near these rocks.

Quantitative assessment**—**Not advisable without better mapping and geophysics. No estimates of undiscovered podiform chromite, ultramafic-hosted talc-magnesite, or serpentine-hosted asbestos deposits were made.

Area ID: umf04—Mesozoic Ultramafic Rocks Area of Interest

Deposit type**—**Podiform chromite, ultramafic-hosted talc-magnesite, or serpentine-hosted asbestos

Age of mineralization**—**Probably Early Cretaceous

Examples of deposit type—There are two known podiform chromite and four serpentine-hosted asbestos occurrences north of Kandahar in this area of interest. The occurrences are in an area of small scattered Early Cretaceous mafic and ultramafic intrusions within an area approximately 155 km by 42 km in size in the foothills.

Kandahar Province

There is an unnamed chromite showing at 31° 53'14"N, 65° 59'29"E. Numerous chromite fragments 0.15 to 0.20 m in diameter have been found at Cakyan south of the river in eluvial deposits overlying Cretaceous peridotite intrusives over an area of 20 to 30 m^2. The fragments assayed 1 percent Fe, 0.1 percent Cu, and 0.5 g/t Au (Dovgal and others, 1971). No estimate of resources is known.

There is also an unnamed chromite showing at 31° 41'30"N, 65°14'40"E. At this showing near De Keskenakhud Ghar, small chromite lenses were identified in Lower Cretaceous ultra mafic rocks over an area of 30 m by 150 m (Dovgal and others, 1971). No estimate of resources is known.

Exploration history—Sborshchikov and others (1974), Nitikin and others (1973).

Tract boundary criteria— This area consists of Early Cretaceous age ultramafic rocks mapped as dunite, peridotite, and serpentinite. The polygons (fig. 2.1-23) have a 1-km buffer and are drawn with a wide outline to make them visible at the scale of the map.

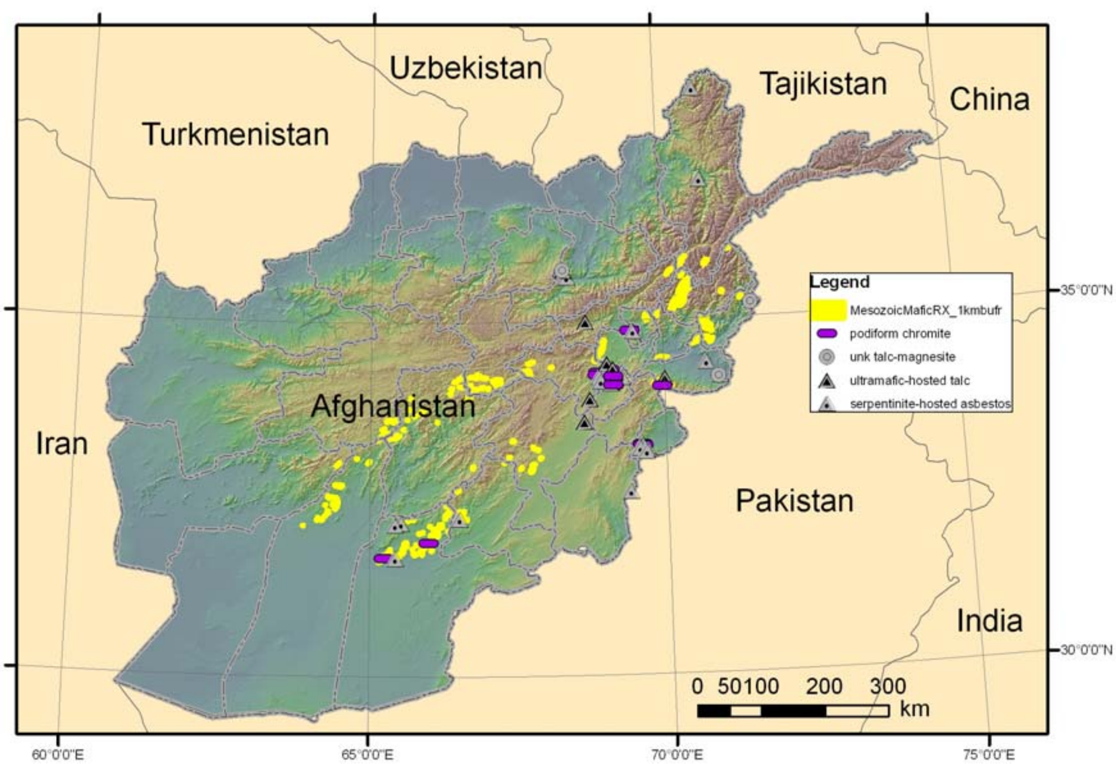


Figure 2.1-23. Area of interest umf04 where Mesozoic age mafic and ultramafic rocks are permissive to host deposits that occur in those types of rocks.

Important data sources —Geologic map, (Doebrich and Wahl, 2006; mineral deposit database (Orris and Bliss, 2002; and Abdullah and others, 1977).

Needs to improve assessment—Processed gravity and magnetic geophysical data to estimate the subsurface extent of the ultramafic rocks.

Optimistic factors—Many of these rocks are in very remote and rugged locations that lack modern exploration. North of Kandahar, are two known podiform chromite deposits and four serpentine-hosted asbestos occurrences located in or near these rocks.

Pessimistic factors—The ophiolite here has been dismembered by tectonic forces.

Quantitative assessment—Not advisable without better mapping and geophysics. No estimates of undiscovered podiform chromite, ultramafic-hosted talc-magnesite, or serpentine-hosted asbestos deposits were made for area of interest umf04.

References

Abdullah, S., Chmyriov, V.M., Stazhilo–Alekseyev, K.F., Dronov, V.I., Gannan, P.J., Rossovskiy, L.N., Kafarskiy, A.Kh., and Malyarov, E.P., 1977, Mineral resources of Afghanistan (2d ed.): Kabul, Afghanistan, Republic of Afghanistan Geological and Mineral Survey, 419 p.

Albers, J.P., 1986, Descriptive model of podiform chromite, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 34.

Denikaev, Sh.Sh., Feoktistov, V.P., Pyzhyanov, I.V., Adjruddin, A., Narbaev, Sh.N., and Konev, Yu.M., 1971, The geology and minerals of the southern part of Eastern Afghanistan (an intermediate report by the Kabul crew on the work of 1970: Kabul, Department of Geological and Mineral Survey, unpub. data.

Doebrich, J.L., and Wahl, R.R., compilers, 2006, Geologic and mineral resource map of Afghanistan: U.S. Geological Survey Open–File Report 2006–1038, scale 1:850,000, [http://pubs.usgs.gov/of/2006/1038/].

Doebrich, J.L., Wahl, R.R., Ludington, S.D., Chirico, P.G., Wandrey, C.J., Bohannon, R.G., Orris, G.J., Bliss, J.D., 2006, Geologic and mineral resources map of Afghanistan: U.S. Geological Survey Open–File Report 2005–1038, scale 1:850,000, available on web at *http://pubs.er.usgs.gov/usgspubs/ofr/ofr20061038.*

Dovgal, Yu.M., Chalyan, M.A., Nagalev, V.S., Demin, A.N., Vaulin, V.A., Belich, A.I., Sonin, I.I., Kononykhin, E.T., Zharikhin, K.G., Maksimov, N.P., Skvortsov, N.S., and Kharitonov, A.P., 1971, The geology and minerals of the southeastern part of Central Afghanistan: Kabul, Department of Geological and Mineral Survey, scale 1:200,000, unpub. data.

Gnos, E., Immenhauser, A., and Peters, T., 1997, Late Cretaceous/Early Tertiary convergence between the Indian and African plates recorded in ophiolites and related sediments: Tectonophysics, v. 253, p. 53–64.

Ludington, Steve, Orris, G.J., and Cox, D.P., 1992, Methods of resource assessment, *in* U.S. Geological Survey and Servico Geologico de Bolivia, Geology and mineral resources of the Altiplano and Cordillera Occidental, Bolivia: U.S. Geological Survey Bulletin 1975, p. 218–219.

Menzie, W.D., and Singer, D.A., 1990, A course on mineral resource assessment: Proceedings of International Symposium on Mineral Exploration: The Use of Artificial Intelligence, 1990, Tokyo and Tsukuba, Japan, p. 177–188.

Nikitin, O.A., Kononykhin, E.T., Korol, A.N., and Fakir, A., 1973, Report on the results of prospecting within the Spira lead–and–zinc occurrence: Kabul, Department of Geological and Mineral Survey, unpub. data.

Orris, G.J., and Bliss, J.D., 2002, Mines and mineral occurrences of Afghanistan: U.S. Geological Survey Open–File Report 2002–110, 95 p., available on web at *http://geopubs.wr.usgs.gov/open–file/of02–110/*.

Papp, J.F., 1994, Chromite, *in* Carr, D.D., Sr. ed., Industrial Minerals and Rocks, 6th ed.: Littleton, Colorado, Society for Mining, Metallurgy, and Exploration, Inc., p. 209–228.

Sborshchikov, I.M., Drannikov, V.S., and Bilan, I.K., 1974, The geology and minerals of southern and southeastern Afghanistan: Kabul, Department of Geological and Mineral Survey, unpub. data.

Shcherbina, Yu. I., Petrov, S.E., and Silkin, V.G., 1975, The geology and minerals of the central part of the Kabul median mass: Kabul, Department of Geological and Mineral Survey, unpub. data.

Singer, D.A., 1993, Basic concepts in three-part quantitative assessments of undiscovered mineral resources: Nonrenewable Resources, v. 2, no.1-2, p. 69–81.

Singer, D.A., and Cox, D.P., 1988, Applications of mineral deposit models to resource assessments: U.S. Geological Survey Yearbook, Fiscal Year 1987, p. 55–57.

Singer, D.A., and Ovenshine, A.T., 1979, Assessing metallic resources in Alaska: American Scientist, v. 67, no. 5, p. 582–589.

Singer, D.A., and Page, N. J, 1986, Grade and tonnage model of minor podiform chromite, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, 379 p., available online at *http://pubs.usgs.gov/bul/b1693/html/bullfrms.htm*.

Singer, D.A., Page, N. J, and Lipin, B.R., 1986, Grade and tonnage model of major podiform chromite, in Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, 379 p. available on web at *http://pubs.usgs.gov/bul/b1693/html/bullfrms.htm*.

Volin, M.E., 1950, Chromite deposits in Logar Valley, Kabul Province, Afghanistan: Washington, D.C., U.S. Bureau of Mines Report, 58 p.

2.2 Ultramafic-Hosted Talc-Magnesite

Contributions by David M. Sutphin, Greta J. Orris, and James D. Bliss.

Talc and magnesite are two magnesium-rich minerals that may occur in the same or spatially associated deposits; this includes deposits hosted by ultramafic rocks. The term “talc” is a mineral name, but it is also commonly used to describe rocks that contain the mineral in variable amounts. Massive talcose rock is called steatite, and an impure massive variety is known as soapstone (Virta, 2005). The mineral talc is extremely soft with a Mohs hardness of 1 (as compared to diamond with a hardness of 10.) Talc, which is most familiar to people as talcum powder, but has many other uses, is a hydrous silicate mineral with the chemical formula $Mg_3Si_4O_{10}(OH)_2$. Although talc is commonly relatively pure in composition, small amounts of aluminum, iron, manganese, and titanium may be present as impurities. Talc can be translucent white, apple green, dark green, or brown, depending on the composition of these impurities. Structurally, talc is composed of microscopic platelets. The bonds holding these platelets together are very weak, which enable the platelets to slide by one another and result in the greasy feel of talc (U.S. Geological Survey, 2000).

Magnesite ($MgCO_3$) is the dominant industrial mineral source for magnesia (MgO). Magnesia is characterized by its inertness and high melting point and is commonly used to produce high-temperature refractories, chemicals and fertilizer, and magnesium—the lightest of the structural metals (Harben and Kužvart, 1996a; Bodenlos and Thayer, 1973; Kramer, 2001). Most magnesite and magnesia extracted from brines and seawater are processed into dead-burned magnesia (calcined at a temperature exceeding 1,450 °C) or caustic-calcined magnesia (calcined at a lower temperature that leaves a small amount of CO_2 in the resulting compound). Dead-burned magnesia is used dominantly for refractories, while caustic-calcined magnesia is the preferred starting material for chemicals, cement, filler, fertilizers, and many other uses (Harben and Kuzvart, 1996a.) This assessment of Afghanistan's undiscovered magnesite resources is limited to magnesite in non-sedimentary, non-brine deposits. Talc-magnesite deposits associated with metamorphic and metasomatic rocks are discussed separately in section 9.0.

Concerns have been expressed about the association of asbestos with talc. The alteration of serpentinite by Si-rich fluids may produce chrysotile asbestos as well as talc. In addition, tremolite amphibole (which can be asbestiform) may be an intermediate product of carbonation of serpentinite. Chrysotile forms at a lower temperature than talc and differs in some other formational conditions, so while chrysotile is chemically similar to talc, it is unlikely that it will be present within the portion of a talc deposit that has a grade suitable for mining. Overall, most talc is asbestos free (http://www.emporia.edu). The general public is in contact with talc in powders and its potential for inhalation has drawn the attention of health researchers (*www.ima-eu.org*). In mining and processing talc, miners and factory workers may be at a greater risk because of prolonged exposure to fine particles of talc. When talc is being mined and processed, large amounts of dust particles may be in the air and workers could inhale it into their lungs. When massive concentrations are inhaled, long-term accumulation may occur in the lungs. Inhalation of too much talc dust may cause lung disease and other health problems. Talc has not been proven to cause human lung cancer, even in mine and factory workers. Research shows talc miners have the same mortality rate as non-talc miners with regard to lung cancer (http://www.emporia.edu).

2.2.1 Talc-Magnesite Deposit Models

There have been numerous attempts to model ultramafic-hosted magnesite, talc, and talc-magnesite mineral deposits (Page 1998a and b; Paradis, and Simandl, 1996, Simandl and Ogden, 1999). Talc and magnesite are commonly found together, but also separately as replacements for serpentinite. Asbestos deposits, magnesite deposits, and podiform chromite deposits are commonly associated deposit as are “verde antique” dimension stone deposits (Simandl and Ogden, 1999; Page, 1998a, b). The following description draws from the previously referenced deposit models, as well as other sources.

Magnesite, talc, and mixed talc-magnesite deposits occur in serpentinized zones within ultramafic rocks in tectonically transported rocks and greenstone belts, which may or may not have an ophiolite affiliation (Simandl and Ogden, 1999). Deposits are commonly associated with large faults or shear zones. Serpentinites that contain these deposits have undergone additional carbonation and alteration by hydrothermal fluids containing a significant amount of CO_2 (Pohl, 1990, McCarthy and others, 2006). Whether talc and (or) magnesite forms from this process is a function of the CO_2 and Mg content of the altering hydrothermal fluids, the original Mg content of the host rock, the completeness of the alteration process, and the spatial relationship of the alteration to regional faults and siliceous country rocks (Koons, 1981; Harben and Kužvart, 1996a, b; Simandl and Ogden, 1999). In progressive carbonation of serpentinite, talc-magnesite mineralization will be followed by quartz-magnesite and magnesite. Talc content may also result or be enhanced from steatization of talc-carbonate rock by subsequent Si-rich fluids or from the metamorphic reaction of serpentinite and talc-carbonate rock with siliceous country rock (Harben and Kužvart, 1996b; McCarthy and others, 2006).

Ultramafic magnesite deposits are commonly small compared to other deposits of magnesite, although the size range of the deposits is quite variable. Deposits are composed of cryptocrystalline magnesite in the form of veins, nodules, stockworks, and lenses in altered serpentinite (Kramer, 2006; Page, 1998b). Deposits related to regional fault systems cutting ultramafic rocks are commonly magnesite rich (Simandl and Ogden, 1999).

Ultramafic talc deposits are the most abundant type of talc deposits, although the majority of world production of talc is from metasedimentary deposits (McCarthy and others, 2006). In place of magnesium within its crystal lattice, talc from serpentinite-hosted deposits may contain significant levels of iron, nickel, and (or) chromium that affect the color of the talc and cannot be removed. Talc grades are commonly higher near the periphery of the ore bodies where steatization may have been more pronounced (Harben and Kužvart, 1996b; McCarthy and others, 2006).

It can be extremely difficult to impossible to predict whether a deposit will contain talc or magnesite or some unknown combination of the two, especially in the absence of detailed geologic information. There are no studies of the Afghanistan ultramafic rocks and their serpentinization that would allow us to predict whether talc or magnesite should be the dominant Mg mineral. Ultramafic talc and magnesite deposits may be spatially associated with chrysotile asbestos, podiform chromite, nickel laterite, and “verde antique” dimension stone deposits in related rocks (Simandl and Ogden, 1999; Page, 1998a, b). Known occurrences in Afghanistan (fig. 2.2-1, table 2.2-1) indicate that only talc with associated asbestos has been definitively identified in the ultramafic rocks; the known magnesite dominated deposits are believed to be a different deposit type. Grade and tonnage modeling indicates that there is a continuum between talc-only and magnesite-only deposits within serpentinized ultramafic rocks, but grade and tonnage models were constructed separately for talc and magnesite, as many deposits contain only one of the commodities in significant amounts (G.J. Orris, pers. commun., 2007). Because of the limited exploration in these areas and the lack of detailed geology, we cannot eliminate the possibility that magnesite may occur with or without talc in the ultramafic rocks. Therefore the tracts should be considered permissive for both talc and magnesite, although known occurrences do not contain magnesite and, in the absence of better information, would suggest that magnesite is unlikely to occur in significant amounts in these rocks.

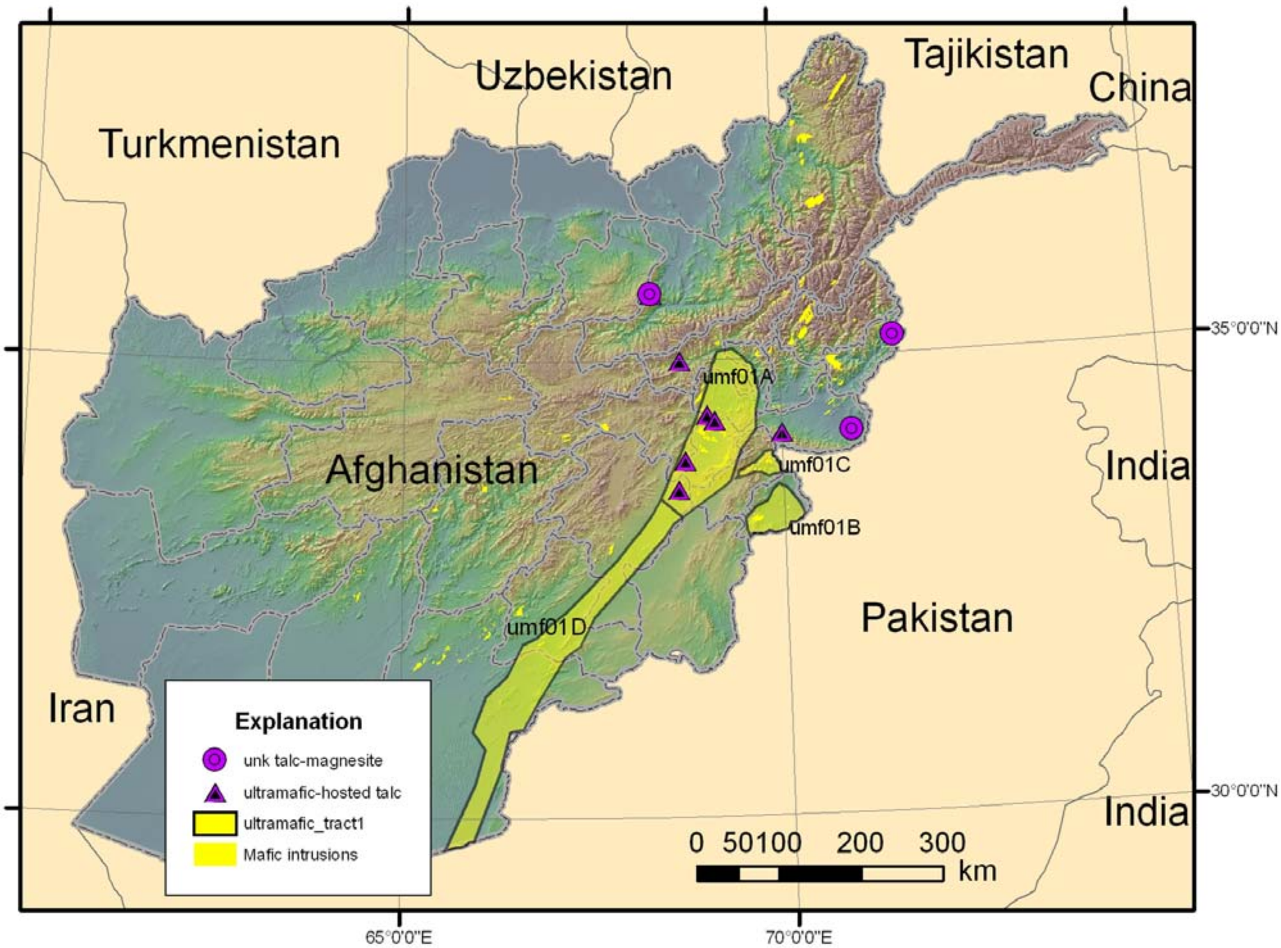


Figure 2.2-1. Known talc-magnesite occurrences in Afghanistan and tracts and areas of interest permissive for their presence

Exploration guides—Ultramafic-hosted talc-magnesite deposits commonly correspond to aeromagnetic lows; unserpentinized parts of ultramafic host rocks present strong magnetic anomalies (Simandl and Ogden, 1999). Deposits are commonly found near contacts with country rocks and in, or near, faults and fractures, as well as spatially associated with podiform chromite and serpentine-hosted asbestos deposits (Page, 1998a, b). Deposits may be relatively resistant to weathering and may accumulate as residue above and near buried talc bodies (Blount and others, 1995; Page, 1998b) or form topographic lows that can be covered by lakes and swamps (Simandl and Ogden, 1999).

Examples of deposit type—Worldwide, deposits that belong to this deposit type include the Deloro magnesite-talc deposit in Ontario, Canada; the Lhanaslampi talc deposit, Norway; and the Cobb magnesite deposit, New Zealand.

Known occurrences—There are six ultramafic-hosted talc or talc-magnesite occurrences in the Afghanistan mineral database (table 2.2-1). The largest known talc-magnesite deposits in Afghanistan, Achin and Ghunday, are not believed to belong to the ultramafic-hosted deposit type. Figure 2.2-2 shows that the known occurrences occur in eastern Afghanistan.

Baghlan Province

The Danay Ghury occurrence, NNW of Kabul, is located in Middle-Upper Carboniferous calcareous slate where a small ultramafic plug occurs with a 1,000 m^2 talc-bearing zone at the contact with the plug (Mikhailov, 1967). The deposit type for Daray Ghury is unknown.

Kabul Province

The Lalandar occurrence is located close to the contact between small Eocene ultramafic bodies and interbedded slate and marbled limestone of Late Permian age. The occurrence consists of four pervasive talc-bearing zones 100 to 800 m long with 20 by 30 m nests and lenses of talc. The occurrences have been exploited by local residents (Shcherbina and others, 1975). These occurrences may or may not be of the ultramafic type.

Table 2.2-1. Ultramafic talc and magnesite occurrences in Afghanistan and talc-magnesite of uncertain affiliation (indicated by "*").

Name	Province	Commodity	Short Description	Reference
Danay Ghury*	Baghlan	talc	Talc at endocontact of ultramafic plug with sediments.	Abdullah and others, 1977.
Farenjal	Parvan	asbestos, talc	Asbestos and talc in serpentinite.	Abdullah and others, 1977.
Lalandar	Kabul	talc	Talc in Eocene ultramafic rocks.	Abdullah and others, 1977.
Loe-Dakka (Los –Dakka)	Nangarhar	talc, asbestos	---	Bowersox and Chamberlin, 1995.
Narzi*	Konar	talc	---	Bowersox and Chamberlin, 1995.
Unnamed	Maydan	talc	At 33°54'N., 68°44'W.	Abdullah and others, 1977.

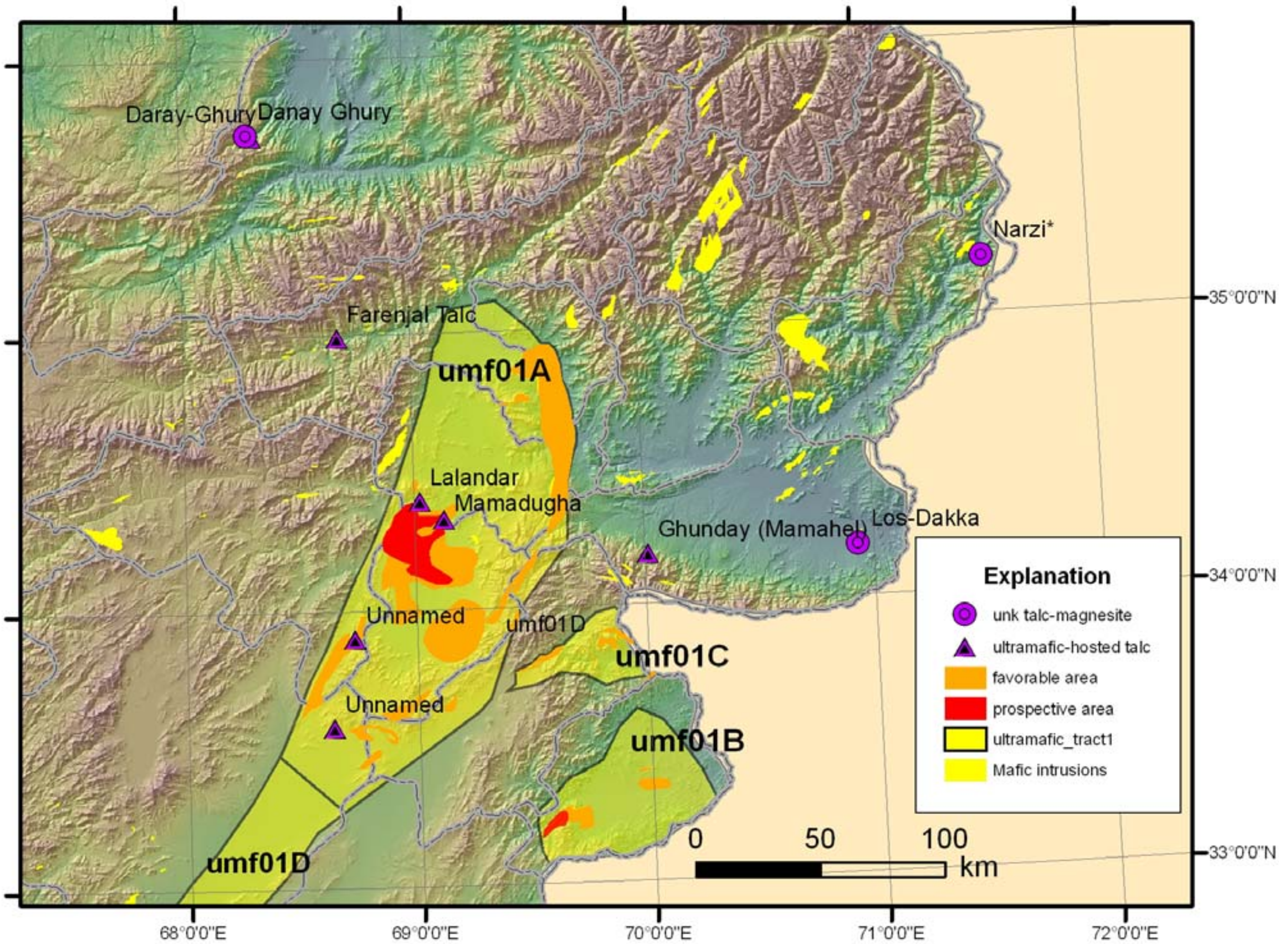


Figure 2.2-2. Locations of ultramafic-hosted talc-magnesite occurrences and ultramafic mineral resource tracts and areas of interest in southeast Afghanistan.

Konar Province

An occurrence near Narzi along the Pakistani border has no other information reported. The deposit type of Narzi is unknown.

Maydan Province

An unnamed talc showing consists of small talc lenses 3 to 5 m long and 0.1 to 0.5 m thick in Eocene age serpentinized and schistose ultramafic rocks (Denikaev and others, 1971).

Parvan Province

Farenjal talc occurrence is situated at the contact between a small serpentinite plug and Lower Carboniferous schist, and consists of a narrow, talc-bearing zone about 10 m wide containing greasy white lamellar talc. The serpentinite has cross-fiber asbestos veinlets 15 to 20 cm thick (Kazak and others, 1965).

Nangarhar Province

Los-Dakka is said to be a talc-magnesite occurrence in the province, but little information is reported. The deposit type for Los-Dakka is not known.

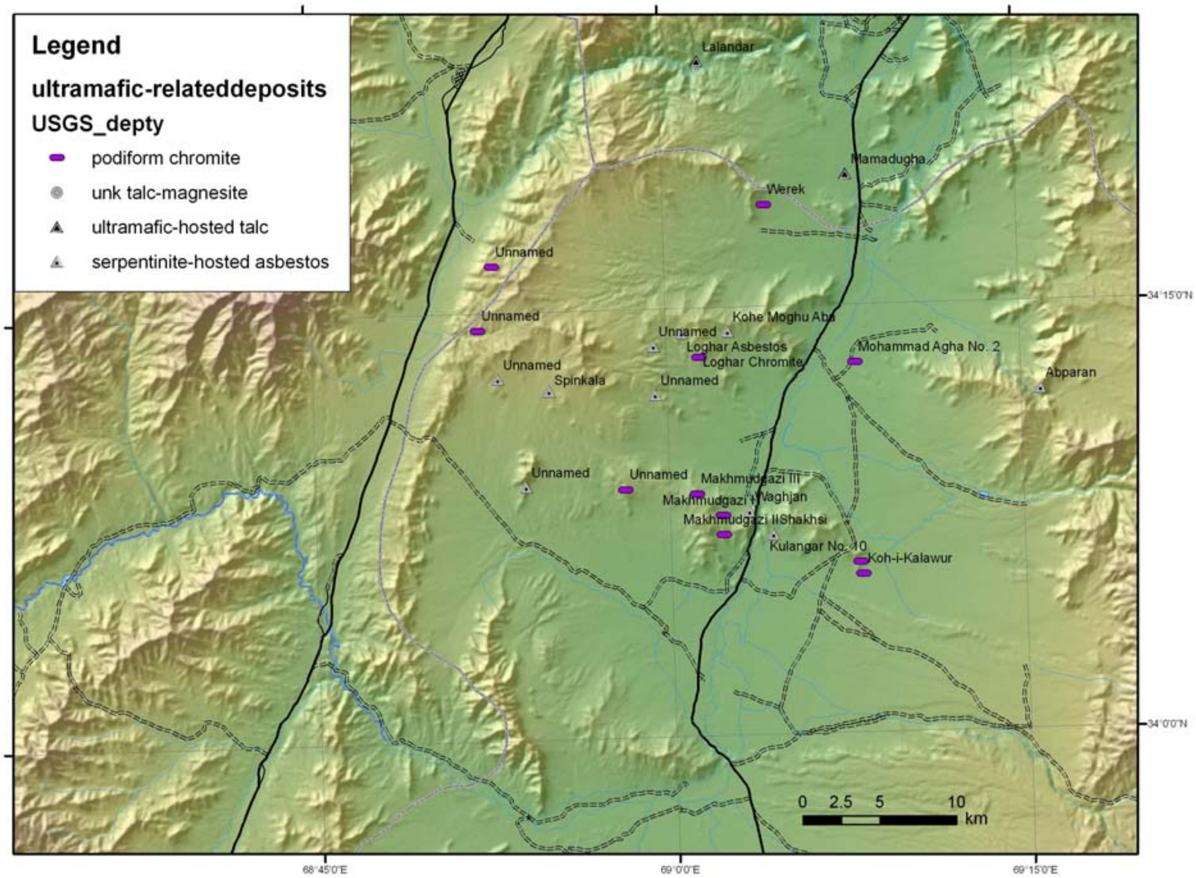


Figure 2.2-3. Location of talc-magnesite and other ultramafic-hosted occurrences in Logar Valley south of Kabul.

Mineral Resource Tracts

Because they form in the same types of rocks, the same tracts and areas of interest were delineated for ultramafic-hosted talc-magnesite deposits as for podiform chromite deposits. Two tracts (umf01A and B) were delineated as being permissive for the occurrence of mineral deposit types related to mafic and ultramafic rocks. They were selected based on the presence of those rock types and the presence of known podiform chromite, ultramafic-hosted talc—(magnesite?), and serpentine-hosted asbestos deposits (that tend to be spatially clustered) and the genetic relationship between these deposit types. See the podiform chromite section for details of the tracts and areas of interest.

For tracts umf01A and B estimates of the numbers of undiscovered mineral deposits for podiform chromite, ultramafic-hosted talc-magnesite, and serpentine-hosted asbestos were made. Such estimates were not made for areas of interest umf01C and D. For tracts umf01A, B, and area C, favorable and (or) prospective areas have been delineated, but no separate estimates were made for undiscovered deposits in favorable or prospective areas.

Tract ID: umf01A—Eocene Age Ultramafic Rocks of Logar Valley

For information on tract umf01A, see section 2.1.

Quantitative assessment—Ultramafic talc deposits, Tract A, Afghanistan. Estimates of undiscovered talc deposits in tract umf01A are shown in table 2.2-2 and figures 2.2-4 and 2.2-5. The USGS-AGS Assessment Team agreed to a consensus value of 1.140 undiscovered ultramafic-hosted talc-magnesite deposits in tract umf01A. For tract umf01A, the assessment team found that there is a 90 percent chance of

0 or more undiscovered ultramafic-hosted talc-magnesite deposits, a 50 percent chance of 0 or more, a 10 percent chance of 3 or more, a 5 percent of 5 or more, and a 1 percent chance of 8 or more. The estimate is subjective and is based on expert opinion and analogy with geologically similar well-explored areas in other parts of the world. The expected mean number of undiscovered ultramafic talc deposits results in a mean value of 15 million metric tons of talc and tabulated below. The assessment team recognized that better mapping and geophysics would improve their estimates of undiscovered talc-magnesite deposits.

Table 2.2-2. Probability estimates of undiscovered ultramafic-hosted talc-magnesite deposits in tract umf01A.

	Probability					
Estimator	**90 percent**	**50 percent**	**10 percent**	**5 percent**	**1 percent**	**Total**
1	0	1	4	8	10	1.960
2	0	0	5	10	-	1.875
3	0	0	2	4	6	0.810
4	0	1	2	3	5	1.135
5	0	0	1	3	5	0.510
Consensus	0	0	3	5	8	1.140

Table 2.2-2 shows that the estimates varied from about one half of one deposit to almost 2 deposits, a factor of about 4.

Probability assignment for Monte Carlo Simulation (MCS)

Number of deposits	Probability of selection during MCS
0	0.567
1	0.133
2	0.133
3	0.079
4	0.025
5	0.019
6	0.013
7	0.013
8	0.017

Summary of the amount of mineralized rock and talc (in million tons) in undiscovered ultramafic talc deposits in Tract A, Afghanistan [p(mean)—probability of mean; p(0)—probability of zero or no ultramafic talc resources]

Material	90% of at least	50% of at least	10% of at least	Mean (10^6 t)	p(mean)	P(0)
Rock	0.0	0.0	120.	34.	0.25	0.58
Talc	0.0	0.0	54.	15.	0.25	0.58

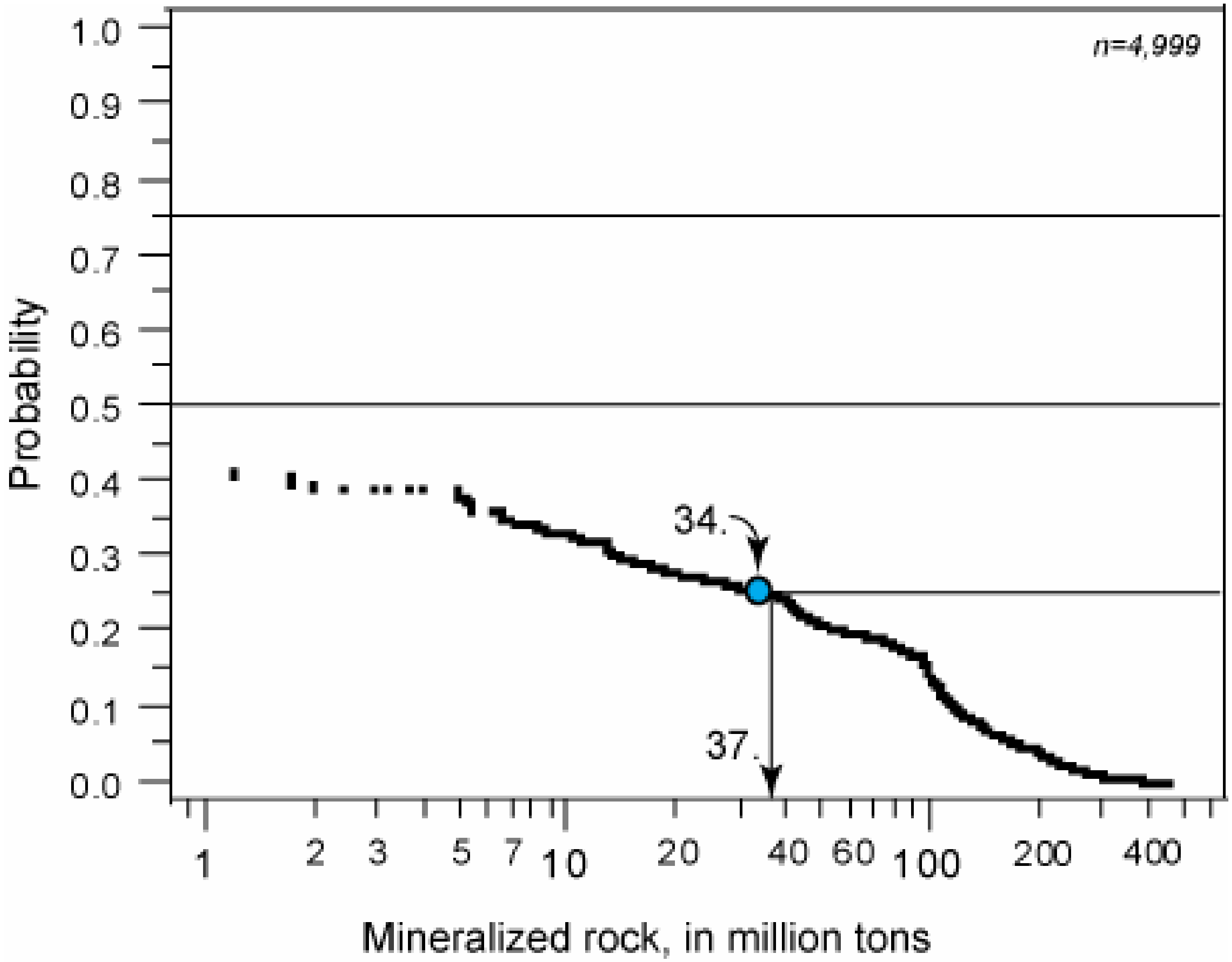


Figure 2.2-4. Output of Monte Carlo simulation for mineralized rock in undiscovered ultramafic talc deposits of Tract A, Afghanistan. Values of the 75th, 50th, and 25th percentiles are given along the bottom axis when available. Blue point on curve is for the average amount of mineralized rock (34 million t) for those iterations not zero and has a probability of 0.25.

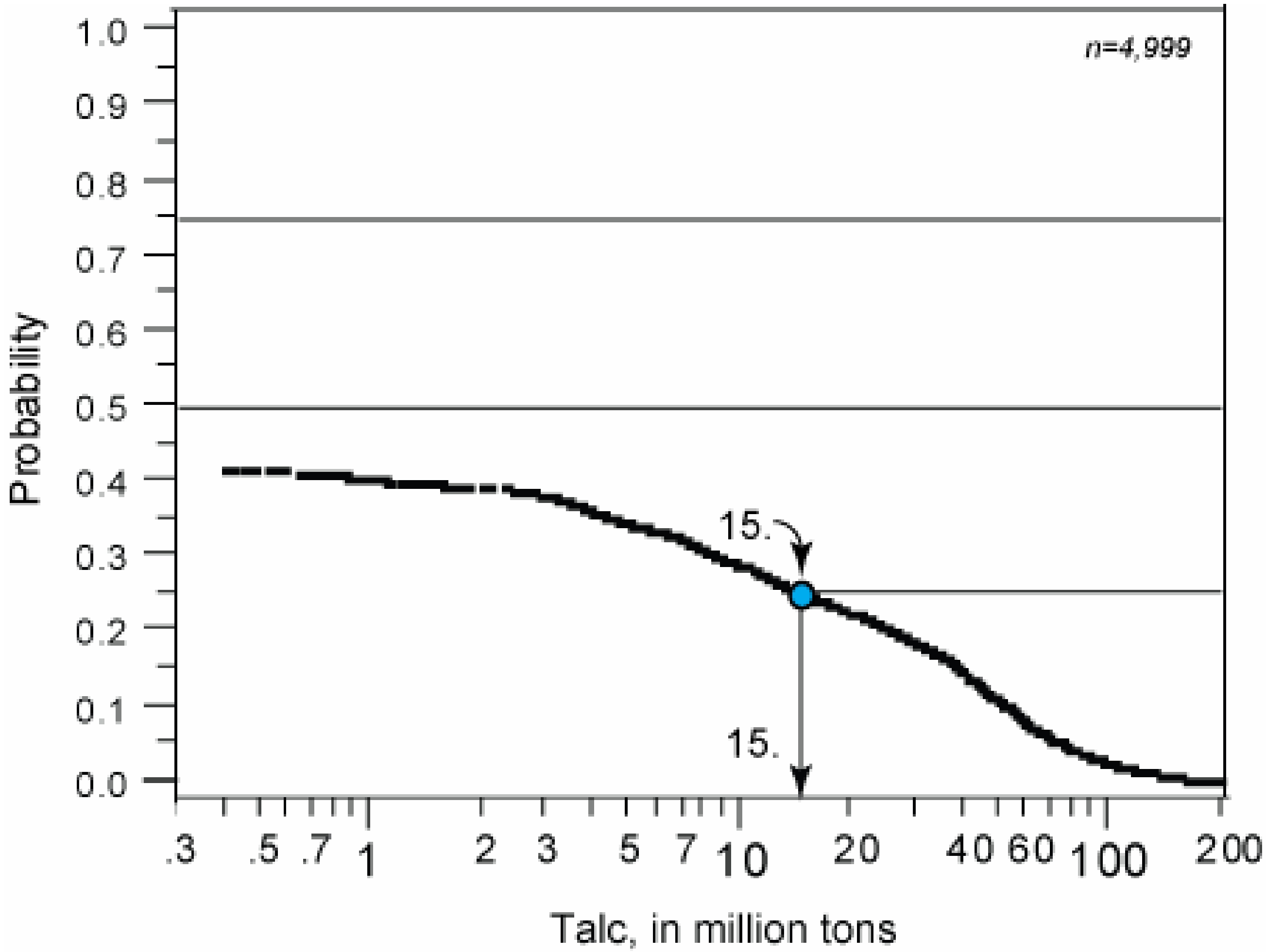


Figure 2.2-5. Output of Monte Carlo simulation for talc in undiscovered ultramafic talc deposits of Tract A, Afghanistan. Values of the 75th, 50th, and 25th percentiles are given along the bottom axis when available. Blue point on curve is for the average amount of resources (15 million t) for those iterations not zero and has a probability of 0.25.

With the known existence of numerous ultramafic-hosted talc-magnesite occurrences in Logar Valley, the team believes that there is more than 1 locale where serpentine-hosted talc-magnesite deposits might exist. This is based on the presence of ultramafic rocks, extensive strike-slip faults, and prominent aeromagnetic anomalies. Prospecting for undiscovered ultramafic-hosted talc-magnesite deposits using modern geochemical and geophysical techniques may be rewarded.

Tract ID: umf01B—Eocene Age Mafic and Ultramafic Rocks of the Khost Area

For information on tract umf01B, see section 2.1.

Quantitative assessment— For tract umf01B, the assessment team found that there is a 90 percent chance of 0 or more undiscovered major podiform chromite deposits, a 50 percent chance of 0 or more, and a 10 percent chance of 1 or more. No estimates were made at the 5 percent or 1 percent probability levels. The estimate is subjective and is based on expert opinion and analogy with geologically similar well-explored areas in other parts of the world. These estimates result in a mean of 0.3 undiscovered deposits. The consensus estimate of 0.300 deposits (table 2.2-3, figures 2.2-6 and 2.2-7), which results in a mean value of 4 million metric tons of talc and tabulated below. This assessment for tract umf01B shows that the assessment team judged tract umf01B to have considerably less probability for undiscovered serpentine-hosted talc deposits than tract umf01A. With the known existence of numerous serpentine-hosted asbestos and podiform chromite occurrences in the tract west of Khost, the team believes that there is less than 1 locale where serpentine-hosted talc-magnesite deposits might exist, based on the presence of ultramafic rocks, extensive strike-slip faults, and prominent aeromagnetic anomalies. Prospecting for undiscovered serpentine-hosted talc-magnesite deposits using modern geochemical and geophysical techniques may identify additional targets. The USGS-AGS Assessment Team recognized that better mapping and geophysics would improve their estimates of undiscovered talc-magnesite deposits. Because of this lack of information, they made only a consensus estimate of undiscovered talc-magnesite deposits in tract umf01B (table 2.2-3).

Table 2.2-3. Probability estimate of undiscovered ultramafic-hosted talc-magnesite deposits in tract umf01B.

	Probability					
Estimator	90 percent	50 percent	10 percent	5 percent	1 percent	Total
Consensus	0	0	1	---	---	0.300

Probability assignment for Monte Carlo Simulation (MCS)

Number of deposits	Probability of selection during MCS
0	0.7
1	0.4

Summary of the amount of mineralized rock and talc (in million tons) in undiscovered ultramafic talc deposits in Tract B, Afghanistan [p(mean)—probability of mean; p(0)—probability of zero or no ultramafic talc resources]

Material	90% of at least	50% of at least	10% of at least	Mean (10^6 t)	p(mean)	P(0)
Rock	0.0	0.0	30.	9.1	0.16	0.71
Talc	0.0	0.0	14.	4.0	0.12	0.71

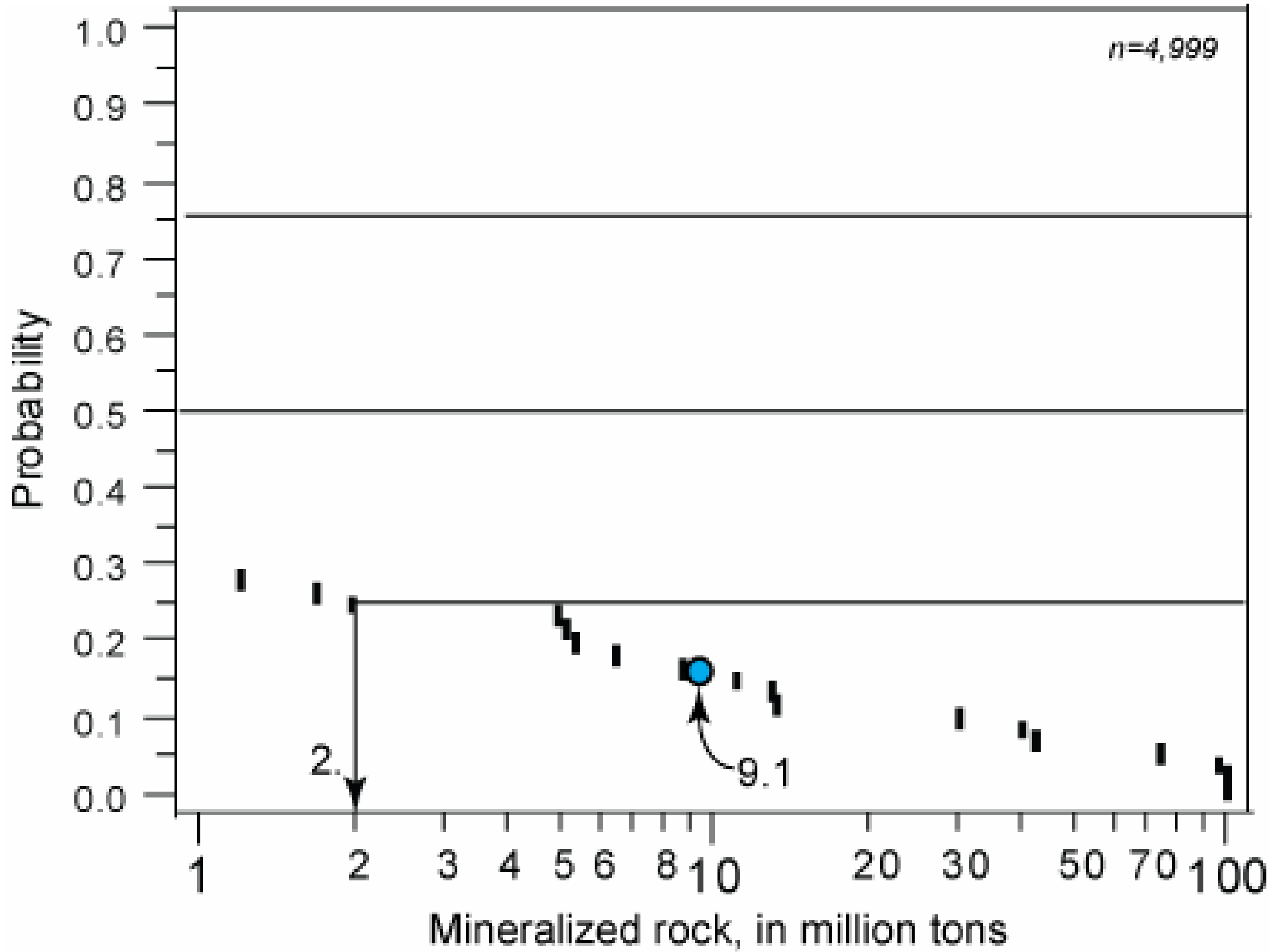


Figure 2.2-6. Output of Monte Carlo simulation for mineralized rock in undiscovered ultramafic talc deposits of Tract B, Afghanistan. Values of the 75th, 50th, and 25th percentiles are given along the bottom axis when available. Blue point on curve is for the average amount of mineralized rock (9.1 million t) for those iterations not zero and has a probability of 0.16.

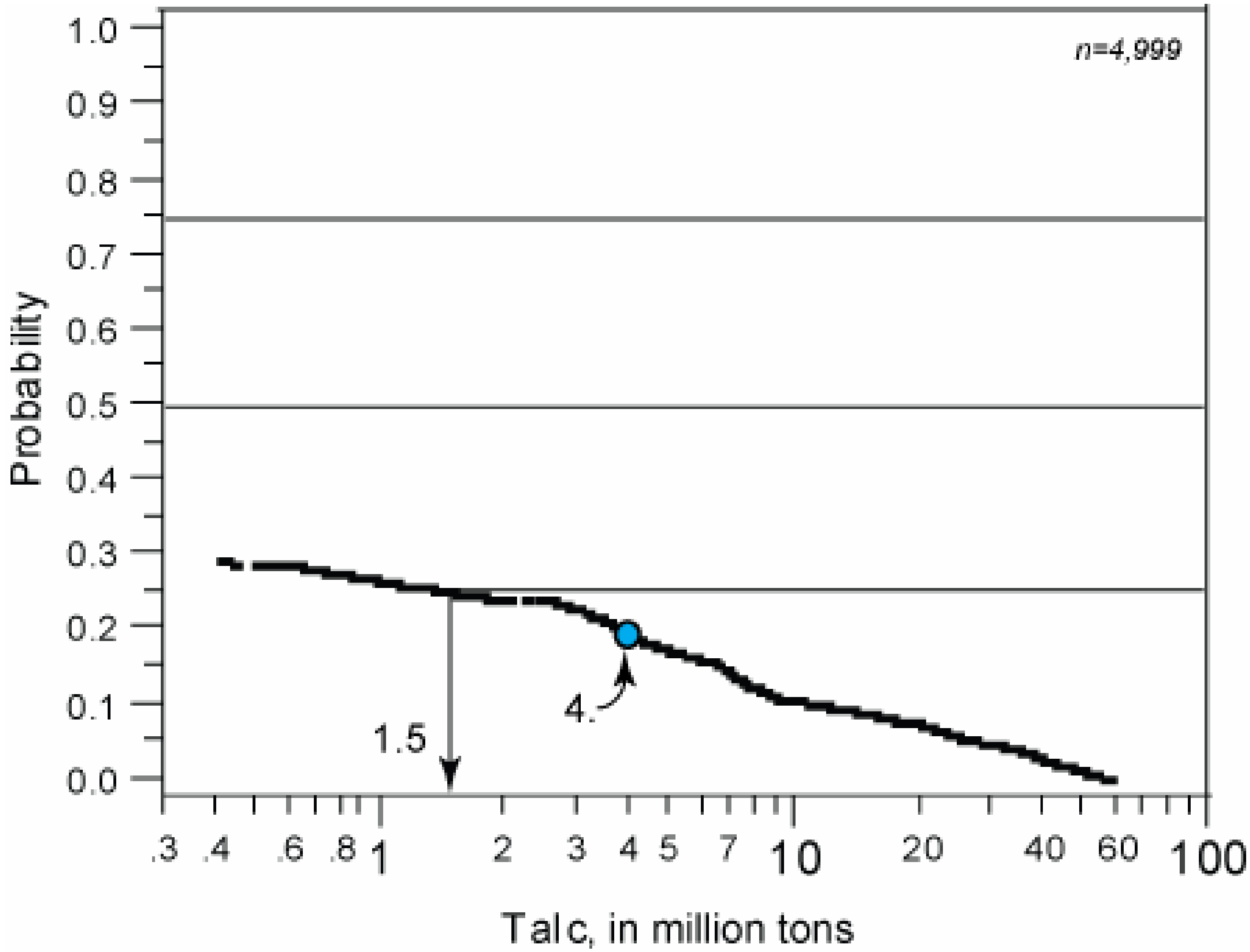


Figure 2.2-7. Output of Monte Carlo simulation for talc in undiscovered ultramafic talc deposits of Tract B, Afghanistan. Values of the 75th, 50th, and 25th percentiles are given along the bottom axis when available. Blue point on curve is for the average amount of resources (4 million t) for those iterations not zero and has a probability of 0.12

References

Abdullah, S., Chmyriov, V.M., Stazhilo–Alekseyev, K.F., Dronov, V.I., Gannan, P.J., Rossovskiy, L.N., Kafarskiy, A.Kh., and Malyarov, E.P., 1977, Mineral resources of Afghanistan (2d ed.): Kabul, Afghanistan, Republic of Afghanistan Geological and Mineral Survey, 419 p.

Blount, A.M., Lathrop, R.G., and Parkinson, G.A., 1995, Application of X-ray diffraction and visible-near infrared spectroscopy in talc exploration, *in* Simard, C.M., compiler, and Walker, B.J., ed., Proceedings, 28th forum on the Geology of Industrial Minerals: West Virginia Geological and Economic Survey and U.S. Bureau of Mines, Circular C–46, p. 50–55.

Bodenlos, A.J., and Thayer, T.P., 1973, Magnesian refractories, *in* Brobst, D.A. and Pratt, W.P., United States Mineral Resources: U.S. Geological Survey Professional Paper 820, p. 379–384.

Bowersox, G.W., and Chamberlin, B.E., 1995, Gemstones of Afghanistan: Tucson, Arizona, Geoscience Press, 220 p.

Denikaev, Sh.Sh., Pyzhyanov, I.V., Feoktistov, V.P., Adjruddin, A., Narbaev, Sh.N., and Konev, Yu.M., 1971, unknown/incomplete, scale 1:500,000, unknown/incomplete, scale 1:500,000, unpub. data.

Doebrich, J.L., and Wahl, R.R., compilers, 2006, Geologic and mineral resource map of Afghanistan: U.S. Geological Survey Open–File Report 2006–1038, scale 1:850,000, available on web at *http://pubs.usgs.gov/of/2006/1038/*.

Harben, P.W., and Kuzvart, Milos, 1996a, Magnesite and magnesia, *in* Industrial minerals: A global geology: London, Industrial Minerals Information Ltd., p. 232–246.

Harben, P.W., and Kuzvart, Milos, 1996b, Talc and soapstone, *in* Industrial minerals—A global geology: London, Industrial Minerals Information Ltd., p. 407–417.

Kazak, Yu.M., Lapke, F.F., Galstukhin, E.A., and Koretskiy, M.S., 1965, Report on the geological exploration at the Farenjal barite deposit in 1963–64 and prospecting–exploration investigations at the Tangi–Murch celestite deposit in 19 V. 1–3: Department of Geological and Mineral Survey, Kabul, unpub. data.

Koons, P.O., 1981, A study of natural and experimental metasomatic assemblages in an ultramafic-quartzofeldspathic metasomatic system from the Haast Schist, South Island, New Zealand: Contributions to Mineralogy and Petrology, v. 78, p. 189-195.

Kramer, D.A., 2001, Magnesium, its alloys and compounds: U.S. Geological Survey Open-File Report 01-341, version 1.0, available on web at *http://pubs.usgs.gov/of/2001/of01-341/*.

McCarthy, E.F., Genco, N.A., and Reade, E.H., Jr., 2006, Talc, *in* Kogel, J.E., Trivedi, N.C., Barker, J.M., and Krukowski, S.T., eds., Industrial minerals and rocks (7th edition): Littleton, Colorado, Society for Mining, Metallurgy, and Exploration, Inc., p. 971–986.

Meshkovsky, A.E., Dvonnikov, G.S., and others, 1965, Report on the results of prospecting–reconnoitering works for flux raw material, refractory and moulding materials: Kabul, unpub. data.

Mikhailov, K.Ya., 1967, Report on geological surveying and prospecting for coal at scale 1:200000 (sheets 222–C, 502–D, 503–B; part of sheets 221–F, 222–D, 222–F, 502–C, 502–F, 503–C, 503–D, 503–E, 504): Kabul, Department of Geological and Mineral Survey, scale 1:200,000, unpub. data.

Orris, G.J., and Bliss, J.D., 2002, Mines and Mineral Occurrences of Afghanistan: U.S. Geological Survey Open–File Report 2002–110, 95 p., available on web at *http://geopubs.wr.usgs.gov/open–file/of02–110/*.

Page, N.J, 1998a, Preliminary descriptive model of ultramafic-hosted talc, *in* Orris, G.J., ed., Additional descriptive models of industrial mineral deposits: U.S. Geological Survey Open-File Report 98-505, p. 5–7.

Page, N.J, 1998b, Preliminary descriptive model of ultramafic hosted magnesite, *in* Orris, G.J., ed., Additional descriptive models of industrial mineral deposits: U.S. Geological Survey Open-File Report 98–505, p. 2–4.

Paradis, S., and Simandl, G.J., 1996, Cryptocrystalline ultramafic-hosted magnesite veins, in Lefebure, D.V., and Hoy, T, eds., Selected British Columbia Mineral Deposit Profiles, v. 2—Metallic Deposits: British Columbia Ministry of Employment and Investment, open-File Report 1996-13, p. 97–100.
Pohl, W., 1990, Genesis of magnesite deposits—Models and trends: Geologische Rundschau, v. 79, no. 2, p. 291–299.
Shcherbina, Yu.I., Petrov, S.E., and Silkin, V.G., 1975, The geology and minerals of the central part of the Kabul median mass: Department of Geological and Mineral Survey, Kabul, unpub. data.
Simandl, G.J. and Ogden, D.,1999, Ultramafic-hosted talc-magnesite, *in* Simandl, G.J., Hora, Z.D., and Lefebure, D.V., eds., Selected British Columbia Mineral Deposit Profiles, V. 3, Industrial Minerals: British Columbia Ministry of Energy and Mines. Available online at *http://www.em.gov.bc.ca/Mining/GeolSurv/MetallicMinerals/MineralDepositProfiles/profiles/m07.htm.*
U.S. Geological Survey, 2000, U.S. talc—Baby powder and much more: U.S. Geological Survey Fact Sheet FS-065-00, 1 sheet [2 p.]
Virta, R.L., 2005, Talc and pyrophyllite, in 2005 Minerals Yearbook: U.S. Geological Survey, p. 75.1–75.7.

2.3 Serpentine-Hosted Asbestos

Contributions by David M. Sutphin, Greta J. Orris, and Walter J. Bawiec.

The commercial term "asbestos" is applied to a group of six fibrous (large length-to-width ratio) silicate minerals amenable to mechanical separation into fine filaments of considerable tensile strength and flexibility; these minerals are essential to modern technology in certain relatively low-volume uses by virtue of their unique combinations of physical and chemical properties (Shride, 1973; Jensen and Bateman, 1981). These fibrous minerals share several properties which qualify them as asbestiform fibers: (1) they are found in bundles of fibers which can be easily separated from the host matrix or cleaved into thinner fibers; (2) the fibers exhibit high tensile strengths, they show high length: diameter (aspect) ratios, from a minimum of 20 up to greater than 1,000; (3) they are sufficiently flexible to be spun; and (4) macroscopically, they resemble organic fibers such as cellulose (Virta, 2002). Properties that are used to evaluate asbestos as to its ultimate use are flexibility, length of fiber, tensile strength, chemical reactivity, and resistance to heat, electrical conductance, and filtration characteristics (Shride, 1973). Uses for asbestos include roofing products, gaskets, and friction materials. Asbestos was once used in automobile brake pads and shoes, but since the mid-1990s, a majority of brake linings, new or replacement, have been asbestos free. The resistance of asbestos to fire has long been exploited for a variety of purposes. In ancient Egypt, asbestos was used in fabrics used as burial cloths (*http://en.wikipedia.org/wiki/Asbestos*). Nearly all asbestos produced worldwide is chrysotile (Virta, 2002). In 2005, world production was 2.40 million metric tons, an increase from 2.36 million metric tons in 2004 (Virta, 2005).

The asbestos minerals, which differ in chemical composition and physical properties, fall into two broad groups—serpentine and amphibole. The serpentine group is composed of the mineral chrysotile, traditionally the most valuable variety of asbestos and produced in the greatest quantity. The amphibole group includes anthophyllite, crocidolite, amosite, tremolite, and actinolite (Jensen and Bateman, 1981). Chrysotile asbestos is the most valuable variety of asbestos making up the vast majority of production. Riebeckite (known under the variety name crocidolite) and amosite make up much of the remaining production, with very minor production of anthophyllite, tremolite, and actinolite (Shride, 1973).

Chrysotile or "white asbestos" has fine fibers that can be spun into as much as 4.35 km of thread per kilogram. Some varieties withstand 2,750 °C (Jensen and Bateman, 1981). Chrysotile asbestos occurs in two geologic settings, (1) from stockworks of veins in serpentinized peridotite, pyroxenite, and dunite (ultramafic-hosted asbestos), and (2) from veins confined to thin serpentine layers in limestone and other carbonate rocks. This assessment of asbestos resources in Afghanistan deals exclusively with ultramafic-hosted chrysotile deposits. Chrysotile is less harmful than the other types of asbestos since it is less friable, and therefore less inhalable (*http://www.uvm.edu/~envprog/formslinks/Vermont%20Mining/Asbestos.html*).

Crocidolite or "blue asbestos" comes chiefly from South Africa where it occurs as long coarse, flexible spinning fiber with low fusibility and high resistance to acids (Jensen and Bateman, 1981). Anthophyllite occurs as mass fiber, and is short, brittle, non-spinning fiber used mostly in insulation. Amosite is an iron-rich variety of asbestos that occurs in long splintery, coarse fibers, some of which can be spun. Amosite is chiefly used as a binder for heat insulators (Jensen and Bateman, 1981). Tremolite and actinolite have little commercial value.

Health concerns

Asbestos is a serious health hazard. It is a contaminant from natural and man-made sources in the air and some of the water. Asbestos has not been mined in the United States since 2002, and forty countries worldwide, including Europe, have banned its use, including chrysotile (white asbestos) because of the health risks it poses (Virta, 2005). Health concerns regarding asbestos started to surface in the early

1900s, and by World War II, it was apparent that fine asbestos fibers caused cancer. When asbestos fibers become airborne and are inhaled, they are so small that the lungs cannot expel them. Major diseases caused by asbestos include asbestosis, mesothelioma, and cancer of the larynx. When produced and consumed, asbestos-related diseases can be expected to occur in workers from mining, milling, and manufacturing as well as construction and maintenance workers having secondary exposure to asbestos-containing materials. End users of asbestos-containing consumer products and occupants of asbestos-containing buildings are also at risk for asbestos-related diseases.

2.3.1 Serpentine-Hosted Asbestos Deposit Models

This deposit type occurs as chrysotile asbestos in stockworks of veins in serpentinized ultramafic rocks that consist of harzburgite, dunite, wehrlite, and pyroxenite (Duke, 1984; Page, 1986; Hora, 1997; Obolenskiy and others, 1999). Serpentinites may be part of an ophiolite sequences in unstable accreted oceanic terranes, within Alpine-type ultramafic rocks, or in synvolcanic intrusions of komatiitic affinity in Archean greenstone belts.

The serpentinite host rocks must have a nonfoliated texture and must be located near a fault that was active during a change in orientation of the regional stress field (Hora, 1997). Subsequent deformation and igneous intrusion may be important. The serpentinized ultramafic rocks are highly fractured and veined and may be intruded by pegmatite dikes (Obolenskiy and others, 1999). White chrysotile asbestos replaces massive ultramafic and serpentinized ultramafic bodies and fills fractures developed in shear zones near contacts between serpentinized bodies and igneous rocks emplaced into serpentinite (Wrucke, 1995). Associated minerals include magnetite, brucite, talc, and actinolite-tremolite (Page, 1986).

Orris (1986) modeled the grades and tonnages of 50 serpentine-hosted asbestos deposits and determined that 80 percent have between 2.7 and 8.0 wt. percent asbestos and from 4.6 to 150 Mt of material. The mean grade and tonnage are 4.6 wt. percent asbestos and 26 Mt.

***Exploration guides*—**Serpentinized ultramafic bodies are commonly associated with faults and shear zones. Hora (1997) suggests that magnetite, which can be a product of the processes that produce serpentinization and chrysotile, may lead to well-defined magnetic anomalies. Serpentinite is less dense than peridotite and may be distinguished using gravity. Asbestos fibers might be present in overlying soils.

***Examples of deposit type*—**The Cassiar asbestos deposit, Ontario, Canada, the Cana Brava deposits, Brazil, and the Zidani deposit, Greece, are all chrysotile deposits hosted by serpentinized ultramafic rocks.

***Known asbestos deposits*—**There are two known asbestos deposits in Afghanistan (fig. 2.3-1) and more than 20 identified occurrences in the Afghanistan mineral database. A cluster of these occurrences is centered about 35 to 45 km S to SW of Kabul. Another more widely spread cluster is north of Kabul, and a third cluster is roughly 30 to 35 km SW of Khost along the Pakistani border. The Logar asbestos deposit in Logar Province (figs. 2.3-1, 2.3-2) consists of asbestos in serpentinized zones in fault zones along the contact of porphyry and lamprophyre dikes in Eocene peridotite. The chrysotile occurs in stockworks of variable size in serpentinized zones that are a few tens of meters to 600 m long and as much as 5 or 6 m thick. The stockworks are composed of thin veinlets containing 0.8 to 9.0 wt. percent asbestos fiber (ESCAP, 1995). Two orebodies are located in the northern area, one 40 m by 90 m and the other 30 m by 400 m in size. Measured reserves are 350,000 t chrysotile asbestos (Gumerov, 1973) (fig. 2.3-1).

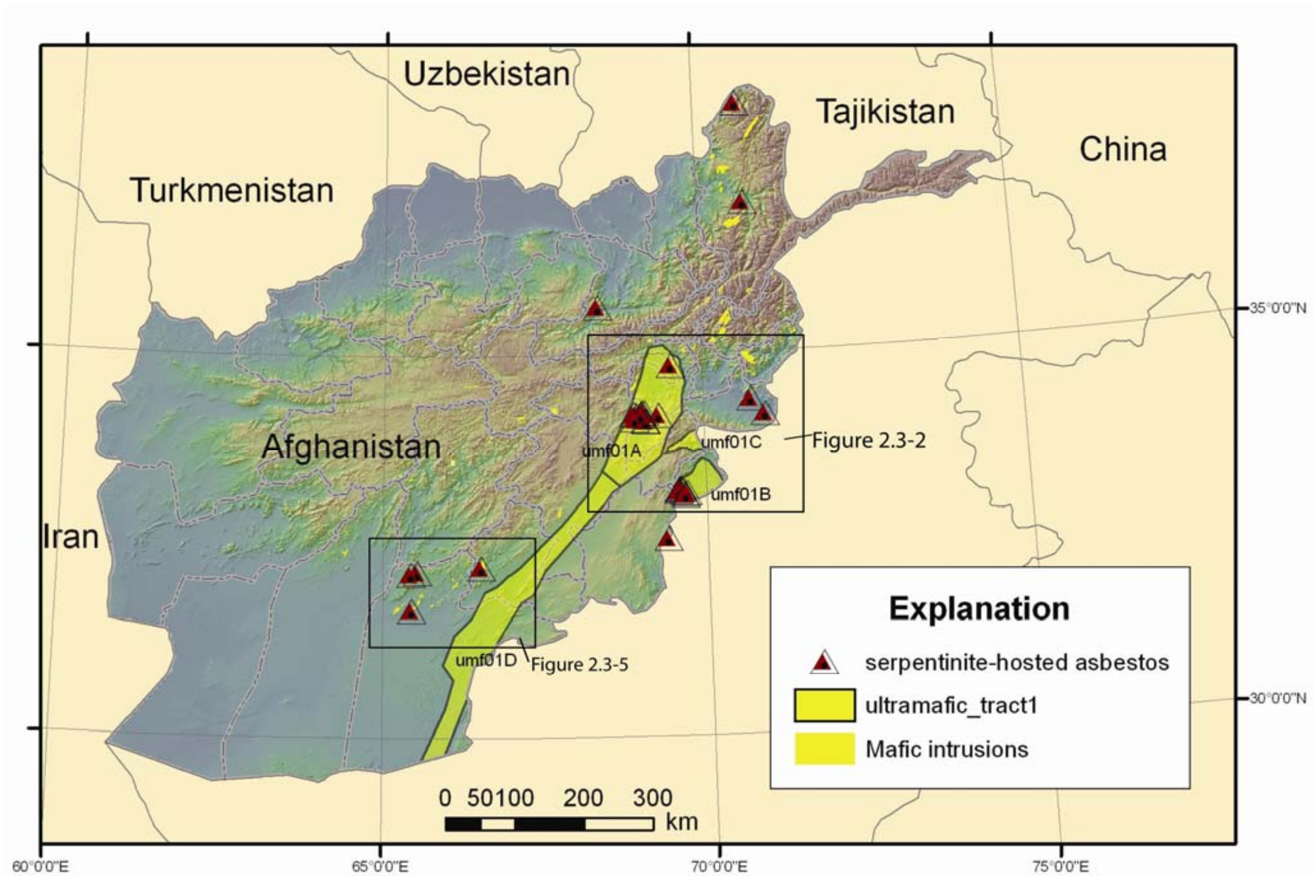


Figure 2.3-1. Locations of serpentine-hosted asbestos occurrences in Afghanistan with known ultramafic intrusions and ultramafic tracts and areas of interest.

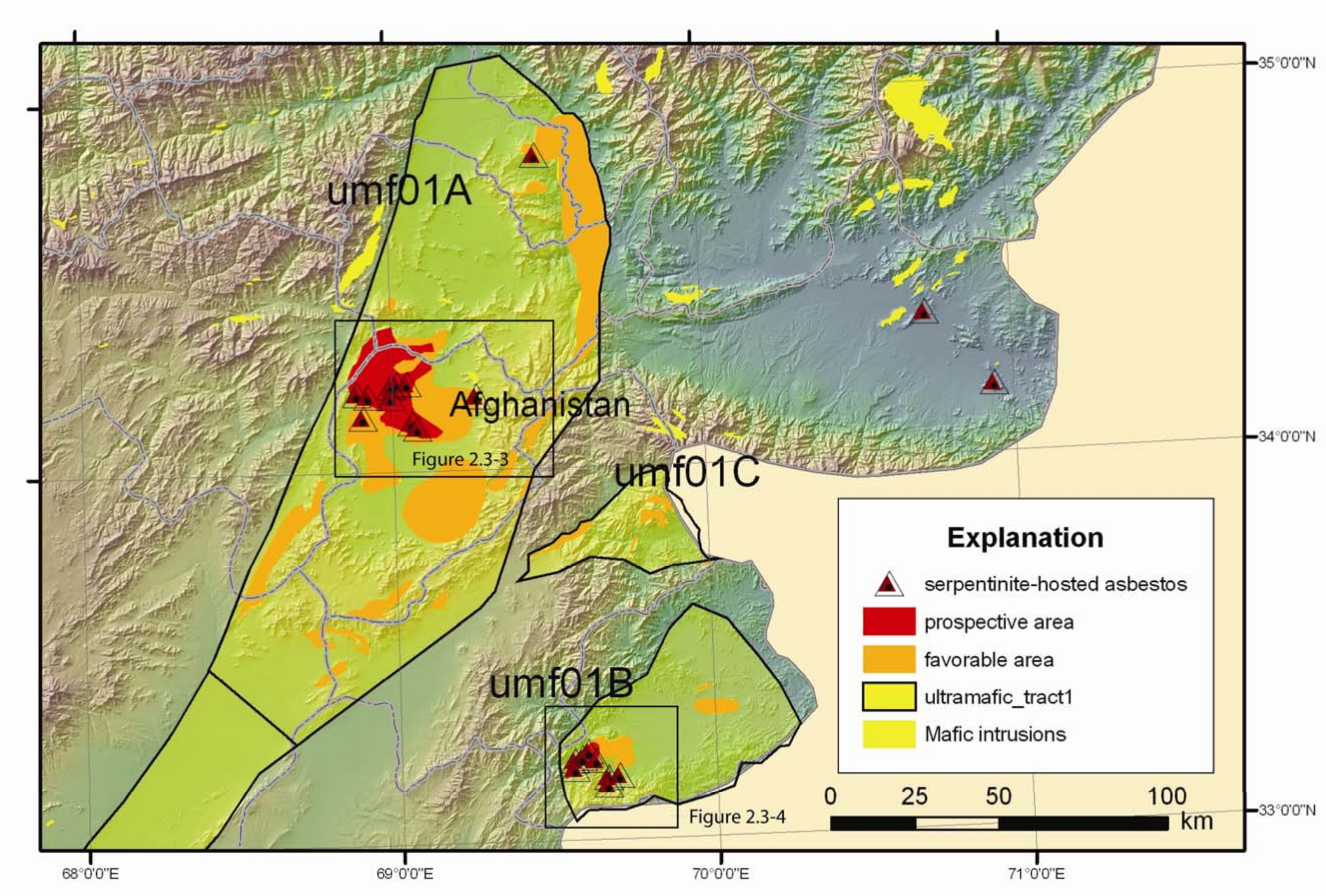


Figure 2.3-2. Mineral resource tracts and areas of interest in Logar Valley and near Khost in eastern Afghanistan.

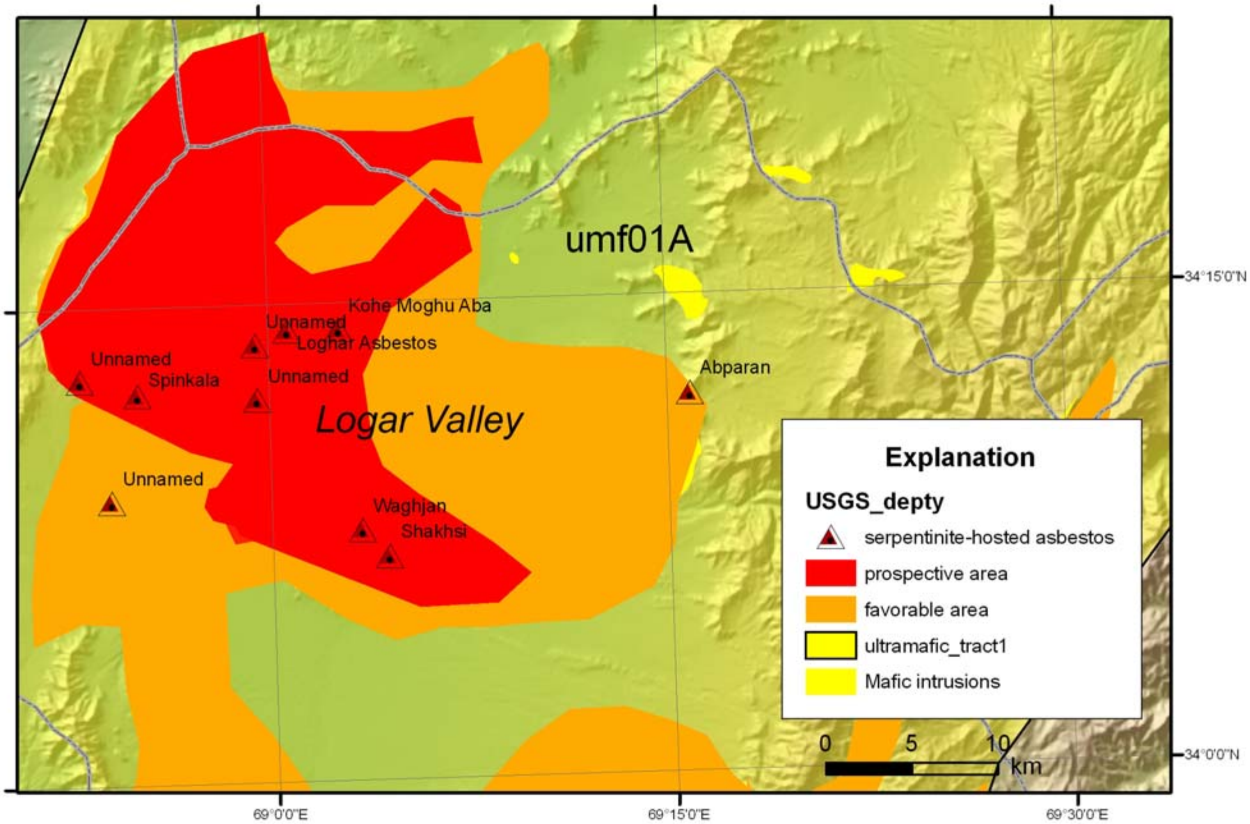


Figure 2.3-3. Serpentine-hosted asbestos occurrences of tract umf01A, the Eocene Ultramafic Rocks of Logar Valley permissive tract, with prospective and favorable areas.

At Shodal in Paktya Province, are six asbestos-bearing zones over an area of 19 km^2 along faults in Eocene ultramafic rocks. The zones contain low strength chrysotile asbestos 15 to more than 20 cm long associated with serpentinites. Only zone 4, which is 640 m long and 130 m thick, has been studied. It was speculated to contain 1.5 Mt of asbestos to a depth of 100 m in material assaying as much as 39.37 wt. percent chrysotile asbestos (Gumerov, 1973).

Known occurrences**—**Asbestos occurrences and showings are found in six of Afghanistan's provinces.

Badakhshan Province

There are two ultramafic-hosted asbestos showings in the province. The first occurs in Early Carboniferous ultramafic rocks as white, slip-fiber asbestos in veinlets up to 3 m long and 10 cm thick. The fibers are 1 to 5 cm long (Kafarskiy and others, 1974). The second showing occurs close to the contact of a small ultramafic plug where there are rock fragments containing chrysotile asbestos veinlets as much as 1.5 cm thick (Sborshchikov and others, 1974).

Baghlan Province

The Saidy-Kayon occurrence is a strongly fractured zone in a small Early Carboniferous ultramafic plug. The zone is as much as a few meters long and 1 m long and contains fracture-filling asbestos (Mikhailov and others, 1967).

Logar Province

The Spinkala occurrence occurs in Eocene peridotite in a serpentinized zone 50 to 700 m wide with predominant slip-fiber asbestos and minor cross-fiber asbestos. The occurrence assays 0.25 to 7.88 percent chrysotile asbestos (Shcherbina and others, 1975). Cross-fiber asbestos at the Kohe Moghu Aba occurrence is found in a 300 m long by 20 to 50 m thick zone along diabase dikes in Eocene serpentinite. The mineralized zone assays 3.83 wt. percent asbestos (Shcherbina and others, 1975). The Abparan occurrence has been identified as an asbestos-bearing zone in a 500 m long Eocene peridotite zone. The mineralized zone is about 300 m long and 5 to 20 m wide with asbestos in veinlets 1 to 15 mm thick (Shcherbina and others, 1975). The Waghjan occurrence is found in Eocene peridotite along a 500 m long zone where lenticular asbestos-bearing bodies 30 to 80 m long and 0.3 to 3.0 m thick have cross-fiber veinlets 0.5 to 5.0 mm thick (Shcherbina and others, 1975). At the Shakhsi occurrence, strongly serpentinized asbestos-bearing zones 30 to 200 m long and 0.3 to 6 m thick occur along faults in Eocene peridotite. These mineralized zones carry as much as 9.5 percent chrysotile asbestos with an average of 0.8 wt. percent asbestos (Shcherbina and others, 1975) (fig. 2.3-2).

There are four additional asbestos showings in Logar Province. At the first showing, cross-fiber asbestos veinlets having fibers 4 to 5 mm long are found in a serpentinized zone 150 to 200 m long and 20 to 30 m wide in Eocene ultramafic rocks (Shcherbina and others, 1975). The second showing occurs as serpentinized zones in Eocene peridotite. The zones are a few tenths of meters long and 0.3 to 0.5 m thick with cross-fiber asbestos in veinlets (Shcherbina and others, 1975). The third showing is composed of serpentinite zones as much as 30 m long and 0.1 to 1.0 m thick in Eocene peridotite. The zones carry cross-fiber asbestos in veinlets 2 to 5 mm thick (Shcherbina and others, 1975). The last reported asbestos showing in Logar Province is located mainly along the contact between diorite-gabbro and Eocene peridotite where a zone 1,200 m long and 100 to 200 m thick contains chrysotile asbestos veinlets having fibers 1.5 to 2 mm long (Shcherbina and others, 1975).

Nangarhar Province

The Gerdab asbestos occurrence is in a small Early Carboniferous ultramafic plug that manifests as a strongly foliated serpentinized zone 2 km long and about 200 m wide. There are numerous calcareous slip-fiber asbestos veins 5 to 10 m long and 0.1 to 0.3 m thick (Denikaev and others, 1970) (fig. 2.3-1).

Paktia Province

The Sperkaw podiform chromite and asbestos occurrence is located in Eocene peridotite among 10 massive chromite bodies as much as 110 m long and 1 to 10 m thick. Associated with the podiform chromite deposits is asbestos mineralization in two sericite carbonate zones 20 to 60 m thick and 3 to 4 km along strike. Asbestos fibers occur in veinlets and are as much as 10 to 12 cm long (Sborshchikov and others, 1974). The Kopra occurrence is located in a strongly jointed, altered peridotite hosting numerous slip-fiber asbestos veinlets 3 to 4 cm thick having fine needle-like calcite crystals (Nikitin and others, 1974). The Roghay occurrence is situated 30 to 50 m off the contact between a small ultramafic plug and an Eocene siltstone. The occurrence is a sheared and pronounced hydrothermally altered zone 350 to 400 m long and 8 to 10 m thick. Slip-fiber asbestos occurs along fissures and assays 5 to 8 percent asbestos (Nikitin and others, 1974). Another asbestos site is the Rosana occurrence where serpentinized peridotite contains a cross-fiber asbestos vein 50 m long and 10 to 30 cm thick (Nikitin and others, 1974). The Afdzalkhel occurrence is located at the endocontact of a strongly serpentinized brecciated peridotite as a 600-m long by 10 to 15 m wide zone having slip-fiber asbestos in veinlets (Nikitin and others, 1974) (fig. 2.3-4).

The Samandkay occurrence contains cross-fiber asbestos in numerous small zones and individual veinlets as much as 10 m long and 30 cm thick. The fibers are 0.2 to 1.5 mm long. The host rock is a small Eocene ultramafic intrusion (Nikitin and others, 1974). Another occurrence in a small Eocene serpentinized peridotite, the Kandinkhel occurrence, contains a slip-fiber chrysotile asbestos zone. The specific gravity is 2.51 g/cm3 and the alkalinity is 2.4 (Nikitin and others, 1974). The Sperkhay occurrence contains cross-fiber asbestos in veinlets 0.5 to 0.7 cm thick in a small Eocene ultramafic plug (Nikitin and others, 1974). "The Frontier-Side Occurrence" is located in a small Eocene ultramafic rock exposure where small asbestos veinlets occur in calcareous serpentine fissures over a 10-m thick zone. Asbestos fibers there are 10 to 12 cm long (Sborshchikov and others, 1974) (fig. 2).

Parwan Province

At the Farenjal talc occurrence, serpentinite contains cross-fiber chrysotile veinlets 15 to 20 cm thick. The talc-asbestos mineral occurrence is situated at the contact between a small serpentinized plug and Lower Carboniferous schist (Kazak and others, 1965). Another ultramafic-hosted asbestos deposit is the Baghram occurrence which consists of seven small, isolated asbestos-bearing zones 10 to more than 200 m long and 3 to 50 m thick in Eocene ultramafic rocks. The zones are scattered in an area up to 17 km long and 1 to 3 km wide. Extremely irregular cross-fiber asbestos makes up as much as 5.65 percent of the rock. It is speculated that several of the zones contain 51,900 t having 1.73 percent asbestos (Gumerov, 1973).

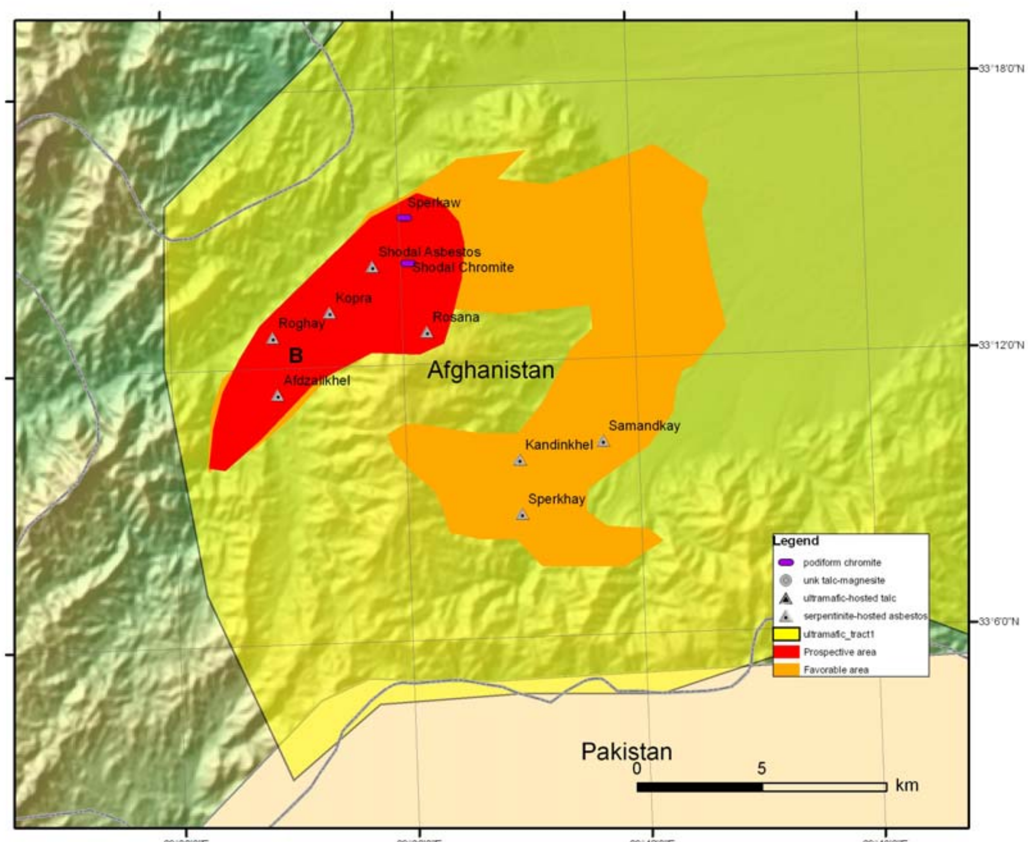


Figure 2.3-4. Location of serpentine-hosted asbestos occurrences and favorable and prospective areas in tract umf01B, Khost and Paktia Provinces, Afghanistan.

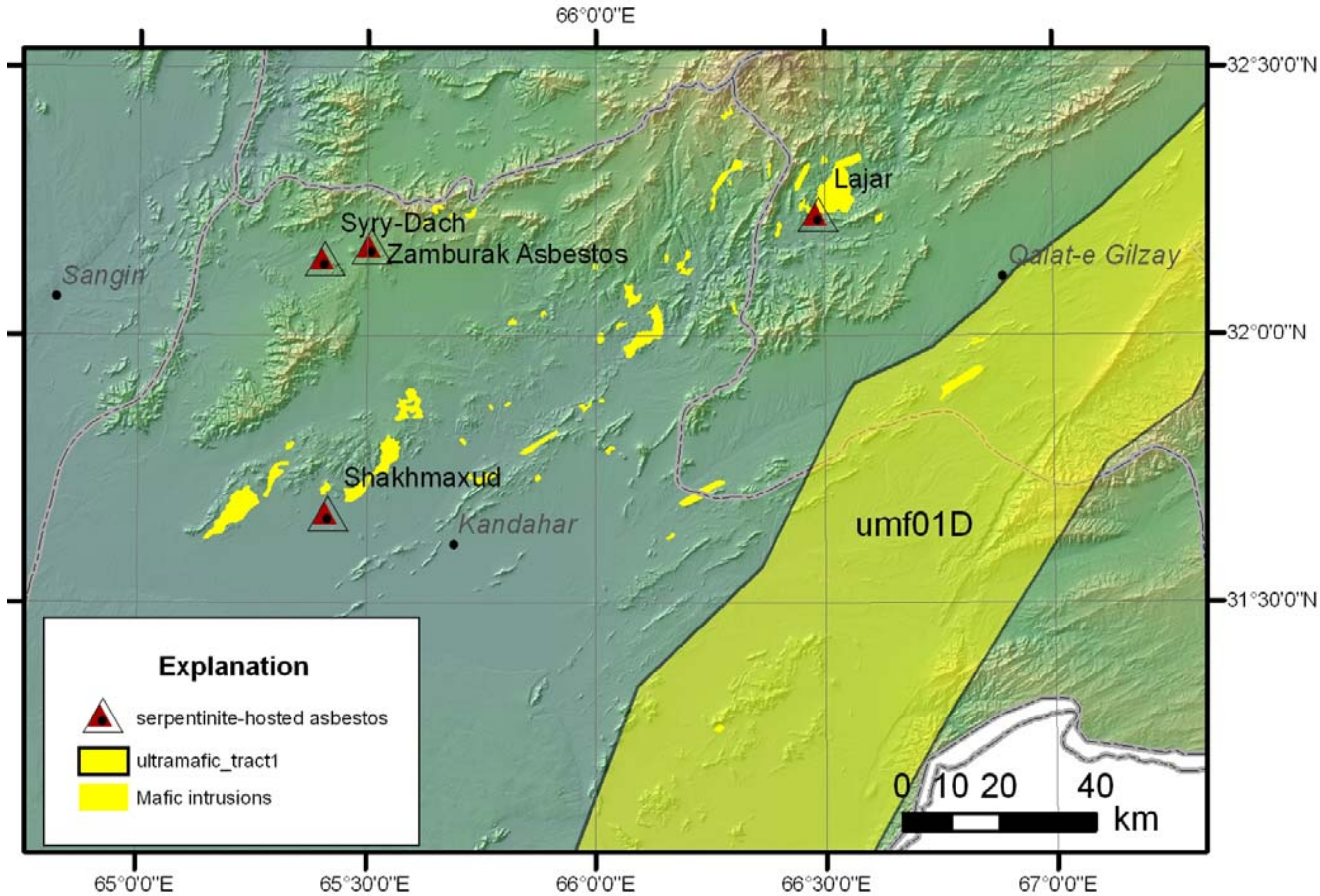


Figure 2.3-5. Serpentine-hosted asbestos occurrences north of Kandahar and north of area of interest umf01D.

Mineral resource Tracts and Areas of Interest

Tracts and areas of interest for serpentine-hosted asbestos are identical to those for podiform chromite and ultramafic-hosted talc-magnesite. Two tracts (umf01A and B) were delineated as being permissive for the occurrence of mineral deposit types related to ultramafic rocks. They were selected based on the presence of those rock types of Eocene age and the presence of known podiform chromite, ultramafic-hosted talc-magnesite, and serpentine-hosted asbestos occurrences, often in clusters. For two of the tracts, estimates were made of the numbers of undiscovered mineral deposits for podiform chromite, ultramafic-hosted talc-magnesite, and serpentine-hosted asbestos.

Five additional areas of interest were delineated based of the presence of ultramafic rocks. Two of the areas were based on the presence of ultramafic rocks of Eocene age (umf01C and D). The other three areas of interest were based on ultramafic rocks of specific geologic eras, Proterozoic, Paleozoic, and Mesozoic (umf02, 03, and 04, respectively. Areas of interest are permissive for the occurrence of ultramafic-hosted mineral deposits; however, few if any occurrences have been identified in them. Estimates of undiscovered mineral deposits were not made for areas of interest. The two tracts and five areas of interest are described in the podiform chromite section (2.1).

Tract ID: umf01A— Eocene Age Ultramafic Rocks of Logar Valley

For information on tract umf01A, see section 2.1.

***Quantitative assessment*—**Recognizing that better mapping and geophysics would make for a better assessment, estimates of undiscovered serpentine-hosted asbestos deposits in tract umf01A were made (table 1).

Table 2.3-1. Probability estimates of undiscovered serpentine-hosted asbestos deposits in tract umf01A.

Estimator	Probability					Total
	90 percent	50 percent	10 percent	5 percent	1 percent	
1	2	3	5	7	12	3.466
2	3	4	7	8	10	4.534
3	2	2	4	---	---	2.466
4	2	3	3	5	8	2.806
5	2	4	5	7	8	3.746
Consensus	2	3	5	7	8	3.346

The figures in table 2.3-1 show that the geoscientists' estimates varied from about 2.5 deposits to more than 4.5 deposits, a factor of about 1.8. For the Eocene Ultramafic Rocks of Logar Valley tract (umf01A), the assessment team found that there is a 90 percent chance of 2 or more undiscovered serpentine-hosted asbestos deposits, a 50 percent chance of 3 or more, a 10 percent chance of 5 or more, a 5 percent chance of 7 or more, and a 1 percent chance of 8 or more. The estimate is subjective and is based on expert opinion and analogy with geologically similar well-explored areas in other parts of the world. This estimate results in a mean estimate of 3.346 undiscovered deposits. These estimates were used to generate probabilistic estimates of the amounts of asbestos contained in the undiscovered deposits using Monte Carlo simulation (see section 1.1). The results are tabulated in table 2.3-2 and shown graphically in figures 2.3-5 and 2.3-6.

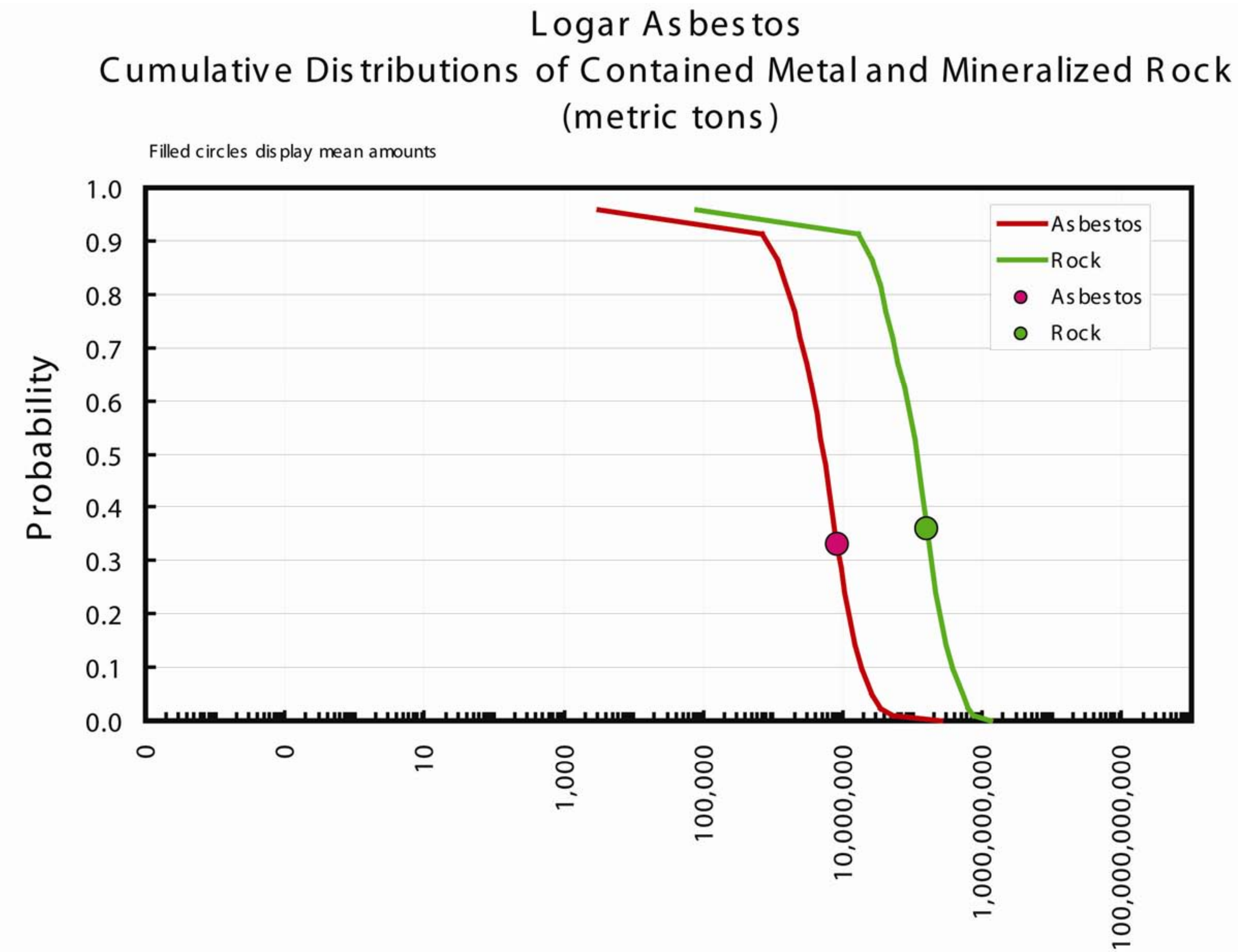


Figure 2.3-6 Cumulative distributions for asbestos and mineralized rocks for the probabilistic estimates of tract umf01A—Eocene Ultramafic Rocks of Logar Valley permissive tract.

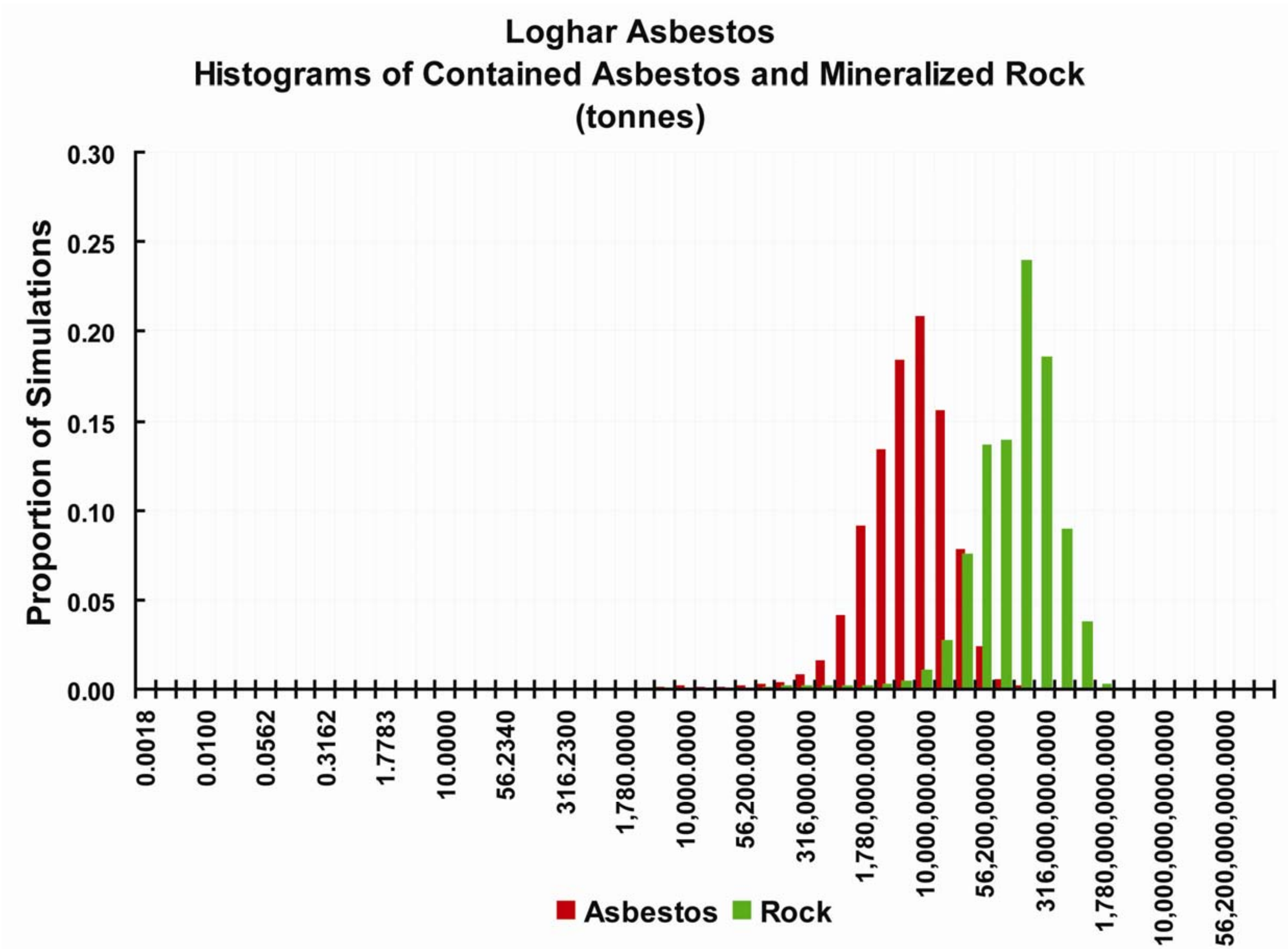


Figure 2.3-7 Histograms of estimated contained asbestos and mineralized rock for undiscovered serpentine-hosted asbestos deposits for the probabilistic estimate for tract umf01A—Eocene Ultramafic Rocks of Logar Valley permissive tract.

Table 2.3-2. Table showing probabilistic distribution of estimated contained asbestos and mineralized rock for undiscovered serpentine-hosted asbestos deposits for the probabilistic estimates of tract umf01A—Eocene Ultramafic Rocks of Logar Valley permissive tract.

There is a 90 percent or greater chance of 2 or more deposits.
There is a 50 percent or greater chance of 3 or more deposits.
There is a 10 percent or greater chance of 5 or more deposits.
There is a 5 percent or greater chance of 7 or more deposits.
There is a 1 percent or greater chance of 8 or more deposits.

Quantile	Asbestos (tonnes)	Rock (tonnes)
0.95	110,000	2,200,000
0.90	830,000	19,000,000
0.50	5,200,000	120,000,000
0.10	19,000,000	370,000,000
0.05	26,000,000	520,000,000
mean	8,400,000	160,000,000
Probability of mean	0.33	0.36
Probability of zero	0.04	0.04

-

Tract ID: umf01B—Eocene Age Mafic and Ultramafic Rocks of the Khost Area

For information on tract umf01A, see section 2.1.

Quantitative assessment—Recognizing that better mapping and geophysics would make for a better assessment, estimates of undiscovered serpentine-hosted asbestos deposits in tract umf01B were made (table 1).

Table 2.3-3. Probability estimates of undiscovered serpentine-hosted asbestos deposits in tract umf01A.

	Probability					
Estimator	**90 percent**	**50 percent**	**10 percent**	**5 percent**	**1 percent**	**Total**
1	1	2	3	---	---	1.933
2	1	1	3	---	---	1.533
3	1	2	3	3	3	1.933
4	1	2	3	3	3	1.933
5	1	2	4	5	6	2.338
Consensus	1	2	3	3	4	1.963

The figures in table 2.3-2 show that the geoscientists' estimates varied from about 1.5 deposits to more than 2.3 deposits, a factor of about 1.5. For the Eocene Ultramafic Rocks near Khost tract (umf01B), the assessment team found that there is a 90 percent chance of 1 or more undiscovered serpentine-hosted asbestos deposits, a 50 percent chance of 2 or more, a 10 percent chance of 3 or more, a 5 percent chance of 3 or more, and a 1 percent chance of 4 or more. The estimate is subjective and is based on expert opinion and analogy with geologically similar well-explored areas in other parts of the world. This estimate results in a mean estimate of 1.963 undiscovered deposits. These estimates were used to generate probabilistic estimates of the amounts of asbestos contained in the undiscovered deposits using Monte Carlo simulation (see section 1.1). The results are tabulated in table 2.3.3 and shown graphically in figures 2.3-7 and 2.3-8.

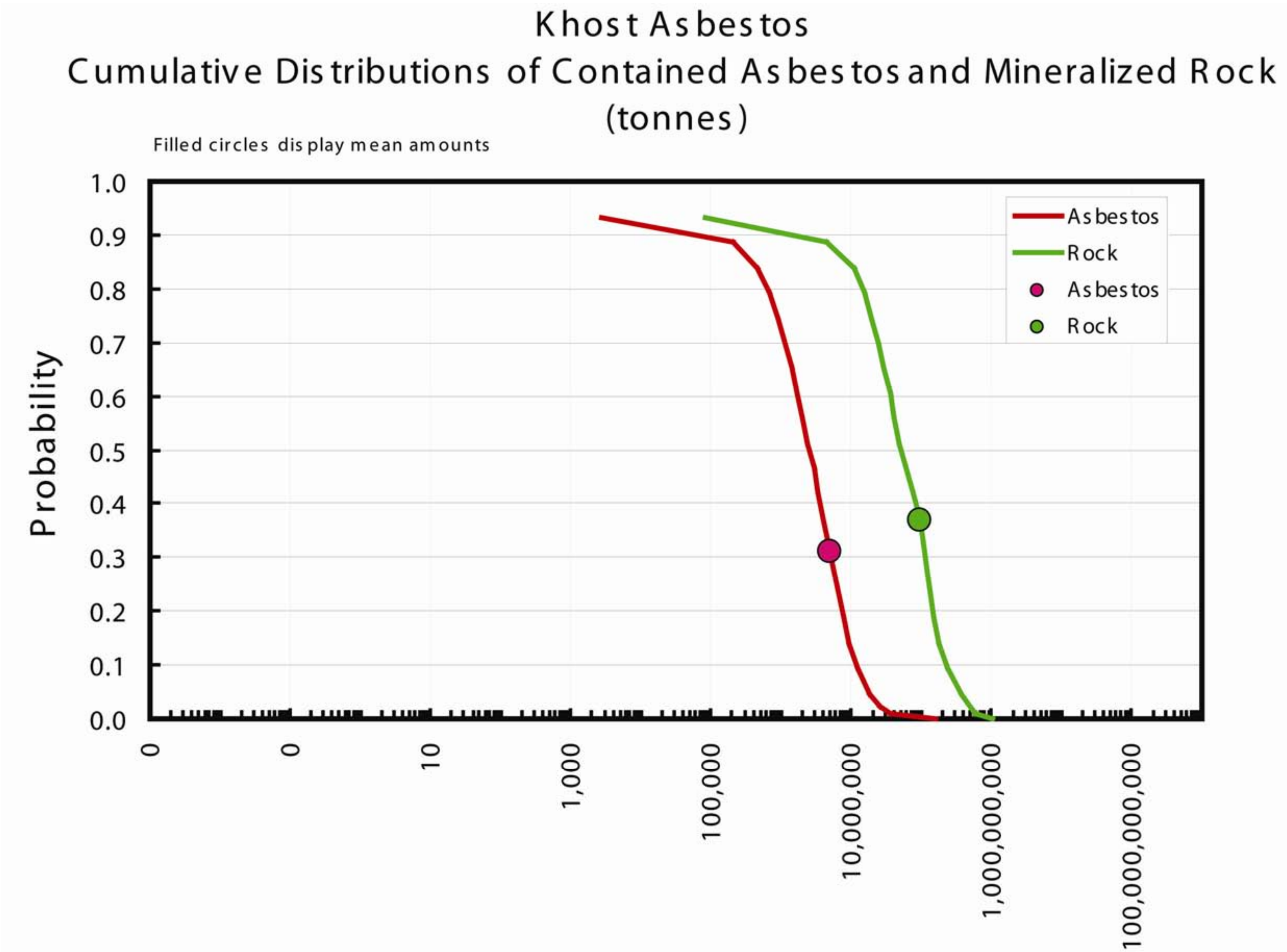


Figure 2.3-8. Cumulative distributions for asbestos and mineralized rocks for the probabilistic estimates of the tract umf01B—Eocene Ultramafic Rocks near Khost permissive tract.

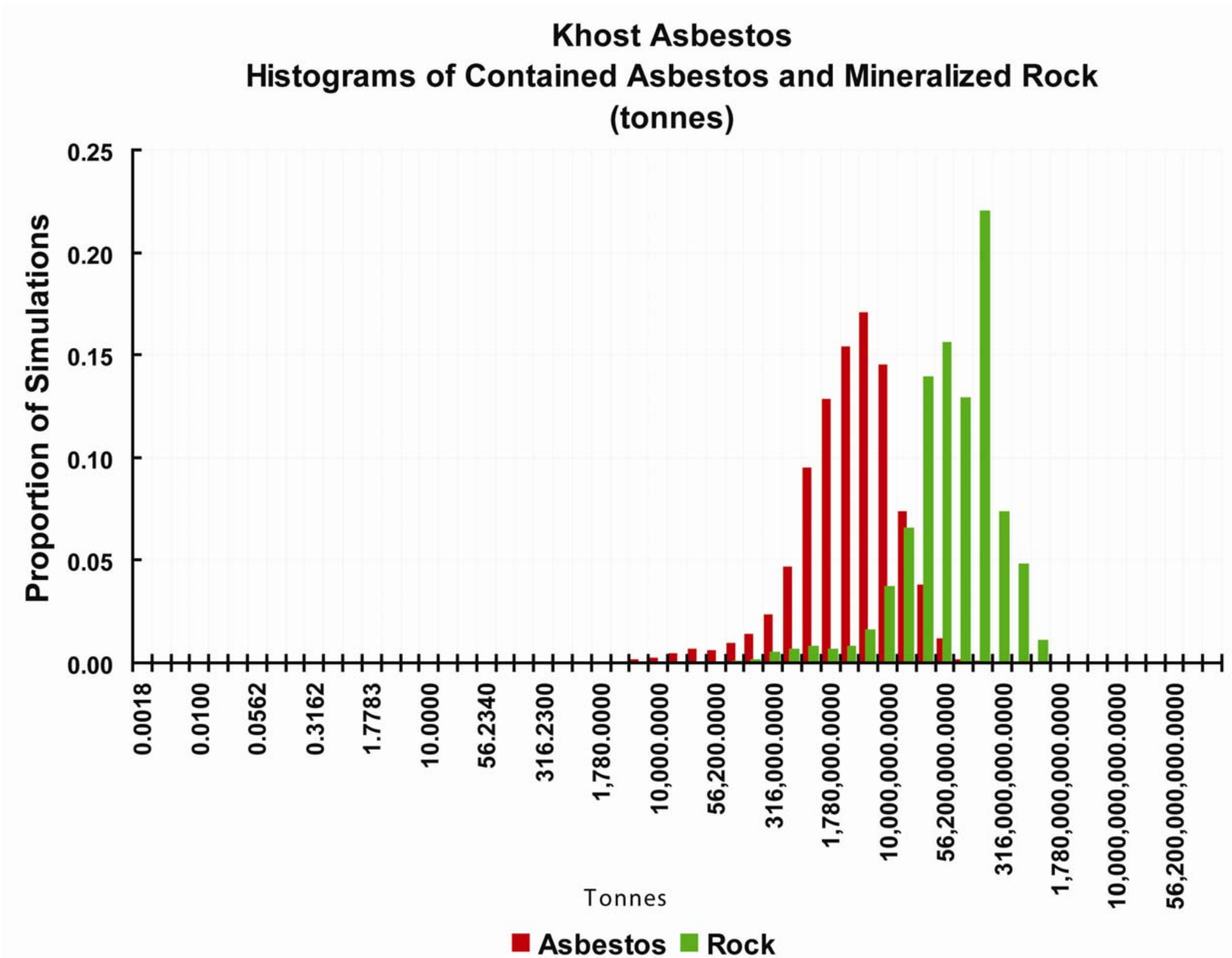


Figure 2.3-9. Histograms of estimated contained asbestos and mineralized rock for undiscovered serpentine-hosted asbestos deposits for the probabilistic estimate for tract umf01B—Eocene Ultramafic Rocks near Khost permissive tract.

Table 2.3.4. Table showing probabilistic distribution of estimated contained asbestos and mineralized rock for undiscovered serpentine-hosted asbestos deposits for the probabilistic estimates of tract umf01B—Eocene Ultramafic Rocks Near Khost permissive tract.

There is a 90 percent or greater chance of 1 or more deposits.
There is a 50 percent or greater chance of 2 or more deposits.
There is a 10 percent or greater chance of 3 or more deposits.
There is a 5 percent or greater chance of 3 or more deposits.
There is a 1 percent or greater chance of 4 or more deposits.

Quantile	Asbestos (tonnes)	Rock (tonnes)
0.95	0	0
0.90	120,000	2,600,000
0.50	2,500,000	52,000,000
0.10	12,000,000	220,000,000
0.05	18,000,000	360,000,000
mean	5,000,000	96,000,000
Probability of mean	0.31	0.37
Probability of zero	0.07	0.07

2.3.2 Description of tracts for Older Serpentine-Hosted Asbestos and Ultramafic-Hosted Talc-Magnesite

Contributions by David M. Sutphin, and Greta J. Orris

Tracts were delineated for ultramafic rocks of Proterozoic, Mississippian, and Mesozoic age. These rocks lie along northeast-trending discontinuous belts (fig. 2.3-9). Few asbestos or chromite occurrences are known to be associated with these older rocks.

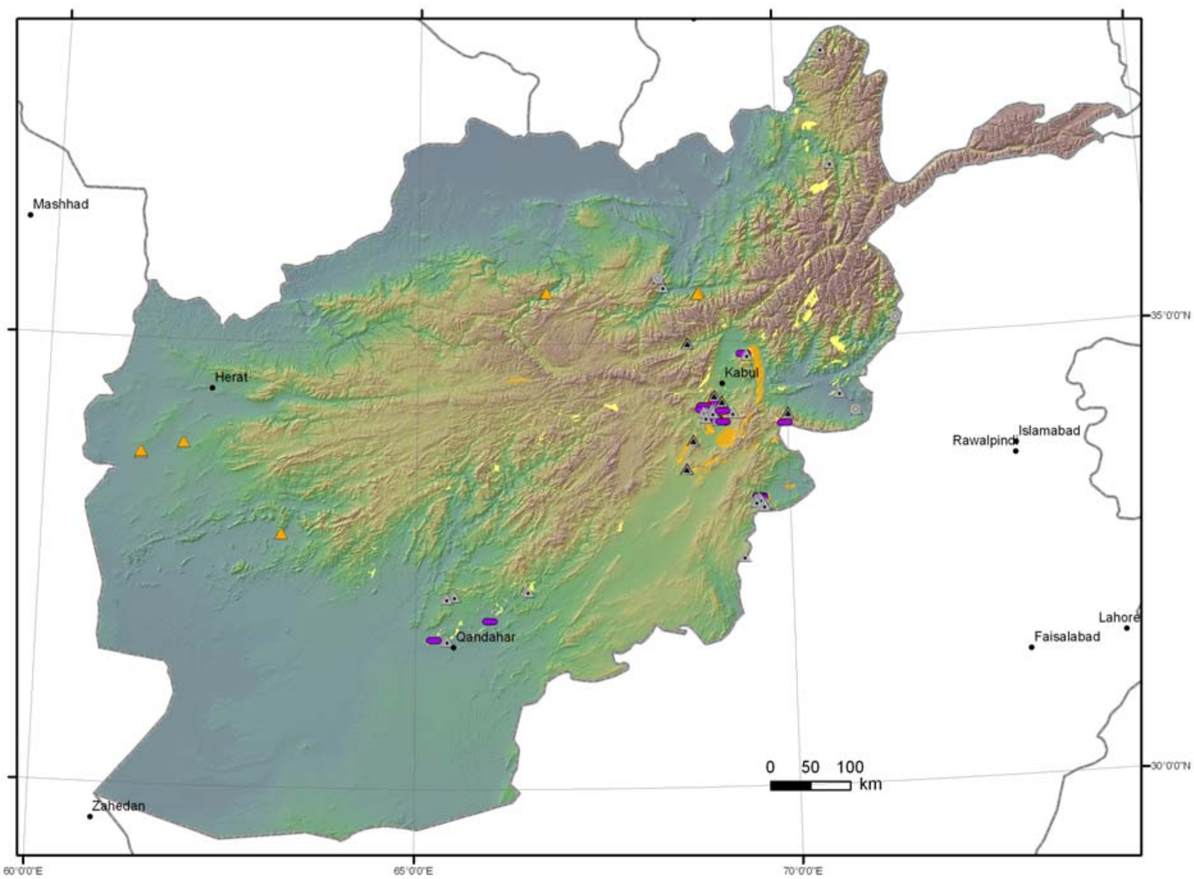


Figure 2.3-10 Locations of permissive tracts mir01-mir04 and favorable and prospective areas of interest for undiscovered serpentine-hosted asbestos deposits in Afghanistan.

Tract ID: mir01—Asbestos, magnesite, and talc in Proterozoic age mafic and ultramafic intrusive rocks

Deposit type—Serpentine-hosted asbestos, ultramafic-hosted talc magnesite

Age of mineralization—Proterozoic

Examples of deposit type—There are no known serpentine-hosted asbestos, ultramafic-hosted magnesite veins, or ultramafic-hosted talc deposits located with the Proterozoic age intrusive rocks in Afghanistan.

Exploration history—No known exploration has taken place within the tract other than regional stream geochemistry by the Russians. Proterozoic age mafic intrusive rocks are generally seen as small patches located in river valleys, along faults, and in areas where erosion and tectonics has exposed them. These rocks may have been well explored by rudimentary means and lack significant mineralization.

Tract boundary criteria—Tract mir01 was delineated on the presence of Proterozoic age mafic and ultramafic intrusive rocks as described by the Russian 1:500,000-scale geologic map (figures 2.3.1 and 2.3.2). The rocks in the tract are described as gabbro, metadiabase, amphibolite, diorite, and plagiogranite intrusions. These are rock types permissive for the occurrence of serpentine-hosted asbestos, ultramafic-hosted magnesite veins, or ultramafic-hosted talc deposits (fig. 2.3-10).

Important data sources—Geologic map, mineral deposit database (Doebrich and Wahl, 2006; Orris and Bliss, 2002; Abdullah, and others, 1977).

Needs to improve assessment—Large-scale geologic map, and geochemical and geophysical exploration of these intrusions.

Optimistic factors—The remoteness of some of the exposures and the ruggedness of the terrain may mean that the rocks have not been sufficiently explored by modern methods.

Pessimistic factors—Some exposed intrusive bodies of this age are in Parwan and Logar Provinces south or west of Kabul with relatively easy access for anyone wanting to explore for asbestos, magnesite, or talc deposits in mafic intrusions.

Quantitative assessment—No quantitative assessment of tract mir01 was attempted. Although the rocks in the tract are permissive for the occurrence of asbestos, magnesite, and talc deposits, there is no evidence that the rocks contain such mineralization.

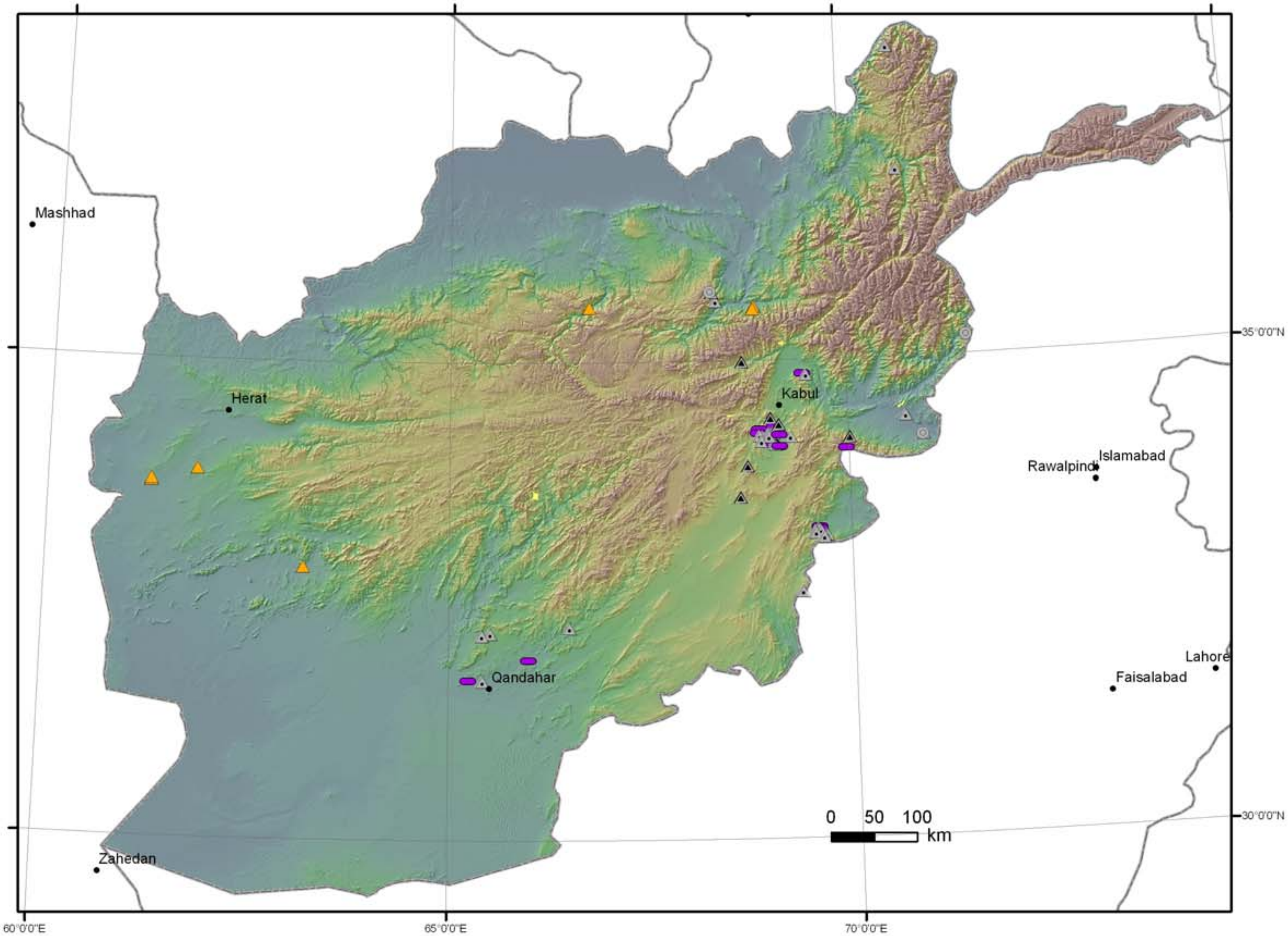


Figure 2.3-11. Locations of tract mir01 comprised of Proterozoic age mafic and ultramafic intrusive rocks permissive for undiscovered serpentine-hosted asbestos deposits in Afghanistan.

Tract ID: mir02—Asbestos, magnesite, and talc in Mississippian (Lower Carboniferous) and Permian age mafic and ultramafic intrusive rocks

Deposit type**—**Serpentine-hosted asbestos, ultramafic-hosted magnesite veins, and ultramafic-hosted talc

Age of mineralization**—**Mississippian and Permian

Examples of deposit type**—**There is one known unnamed serpentine-hosted asbestos occurrence located in tract mir02. It is in northern Badakhshan Province, not far from the Tajikistan border, in of several small partly fault-bounded Mississippian (Lower Carboniferous) dunite, peridotite, and serpentinite exposures.

Exploration history**—**Regional stream geochemistry was done by the Russians. The presence of the one serpentine-hosted asbestos occurrence in remote Badakhshan Province is evidence of past rudimentary exploration.

Tract boundary criteria**—**Tract mir02 was delineated on the presence of Mississippian and Permian age mafic and ultramafic intrusive rocks (fig. 2.3-11). The rock types are reported as gabbro and diorite, dunite, peridotite, serpentinite, diorite, gabbrodiorite, plagiogranite, granodiorite, granophyre, and undifferentiated ultramafic rocks. The largest part of the tract is in Badakhshan Province, but other parts of the tract are as far south as Nangarhar Province and as far west as Ghor Province. Numerous parts of the tract are in southern Takhar Province and in Parwan Province.

Important data sources**—**Geologic map, mineral deposit database (Doebrich and Wahl, 2006; Orris and Bliss, 2002; Abdullah, and others, 1977).

Needs to improve assessment**—**Large-scale geologic map, and geochemical and geophysical exploration of these intrusions.

Optimistic factors**—**The remoteness of some of the exposures and the ruggedness of the terrain may mean that the rocks have not been sufficiently explored by modern methods.

Pessimistic factors**—**Some exposed intrusive bodies of this age are in Parwan and Logar Provinces south or west of Kabul with relatively easy access for anyone wanting to explore for asbestos, magnesite, or talc deposits in mafic intrusions.

Quantitative assessment**—**No quantitative assessment of tract mir02 was attempted. Although the rocks in the tract are permissive for the occurrence of asbestos, magnesite, and talc deposits, there is no evidence that the rocks contain such mineralization.

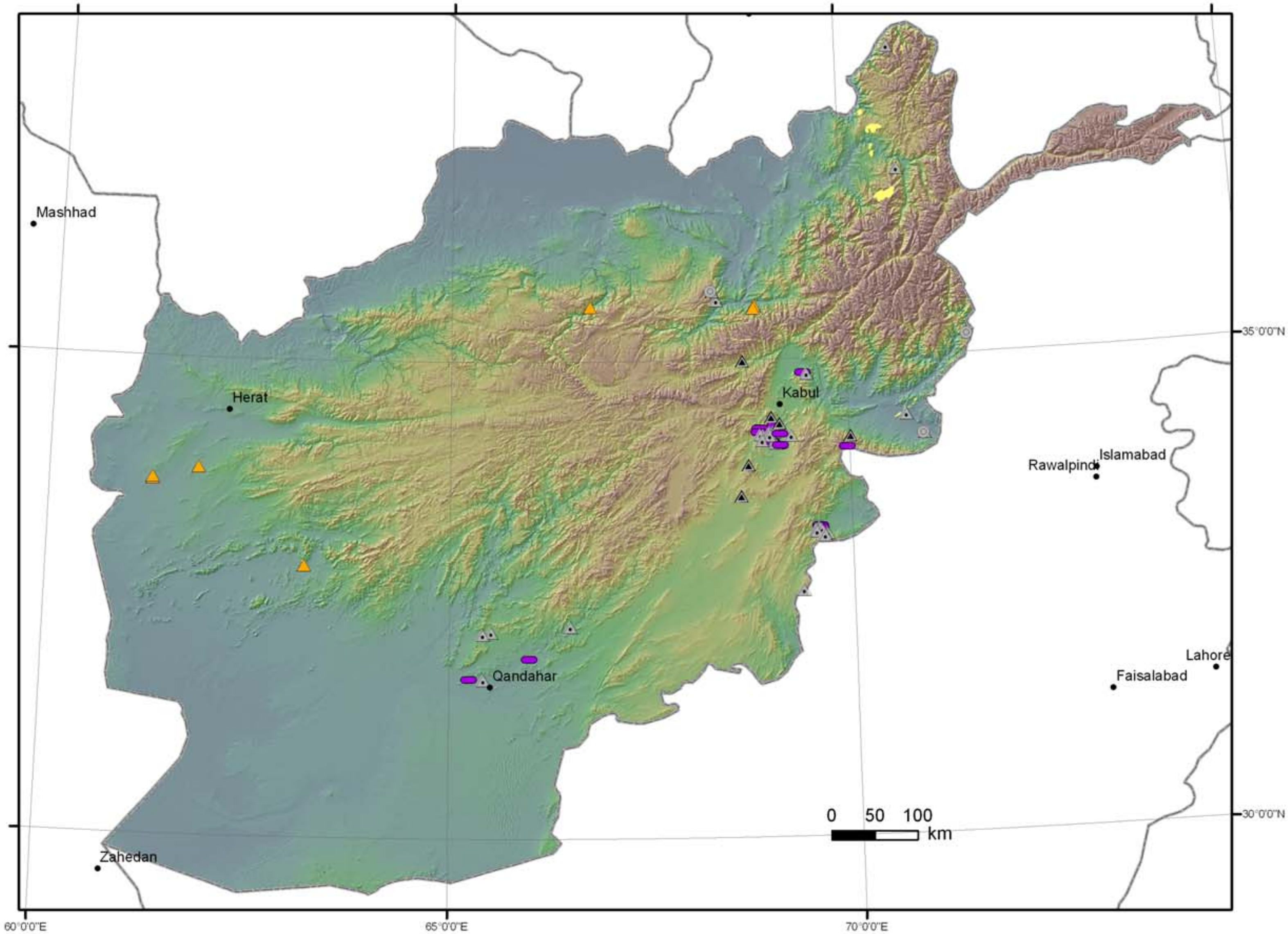


Figure 2.3-12. Location of tract mir02 delineating Mississippian age mafic and ultramafic intrusive rocks permissive for undiscovered serpentine-hosted asbestos deposits in Afghanistan.

Tract ID: mir03—Asbestos, magnesite, and talc in Mesozoic age mafic and ultramafic intrusive rocks

Deposit type—Serpentine-hosted asbestos, ultramafic-hosted magnesite veins, and ultramafic-hosted talc

Age of mineralization—Late Jurassic-Early Cretaceous, Early Cretaceous, and Cretaceous-Paleocene

Examples of deposit type—The Lajar serpentine-hosted asbestos occurrence northeast of Kandahar in low mountains in Zabul Province is located in tract mir03. A podiform chromite showing also occurs in the tract in Kandahar Province in low mountains nearly due west of Kandahar in Lower Cretaceous peridotites (Orris and Bliss, 2002).

Exploration history—Regional stream geochemistry was done by the Russians. The presence of the one serpentine-hosted asbestos occurrence in Zabul Province and one podiform chromite showing in Kandahar Province is evidence of at least past rudimentary exploration.

Tract boundary criteria—Tract mir03 was delineated on the presence of mostly Mesozoic age mafic and ultramafic intrusive rocks (fig. 2.3-12). The rocks types are reported as Late Jurassic to Early Cretaceous diabase and gabbrodiabase; Early Cretaceous dunite, peridotite, and serpentinite, gabbro monzonite, diorite, and granodiorite and gabbro, diorite, and plagiogranite; Late Cretaceous to Paleocene gabbro, monzonite, diorite, granite, granosyenite, syenite porphyry, and syenite. All the rocks in the tract are south of the Herat fault from Nuristan and southern Badakhshan Provinces to Ghor and Helmand Provinces (fig. 2.3-12).

Important data sources—Geologic map, mineral deposit database (Doebrich and Wahl, 2006; Orris and Bliss, 2002; Abdullah, and others, 1977).

Needs to improve assessment—Large-scale geologic map, and geochemical and geophysical exploration of these intrusions.

Optimistic factors—The remoteness of some of the rocks exposures and the ruggedness of the terrain especially in Nuristan Province may mean that some of the rocks have not been sufficiently explored.

Pessimistic factors—Despite being geographically wide spread in south Afghanistan, these rocks contain only one serpentine-hosted asbestos deposit and one podiform chromite showing.

Quantitative assessment—No quantitative assessment of tract mir03 was attempted. Although the rocks in the tract are permissive for the occurrence of mafic and ultramafic deposit types, there is no evidence that the rocks contain such mineralization.

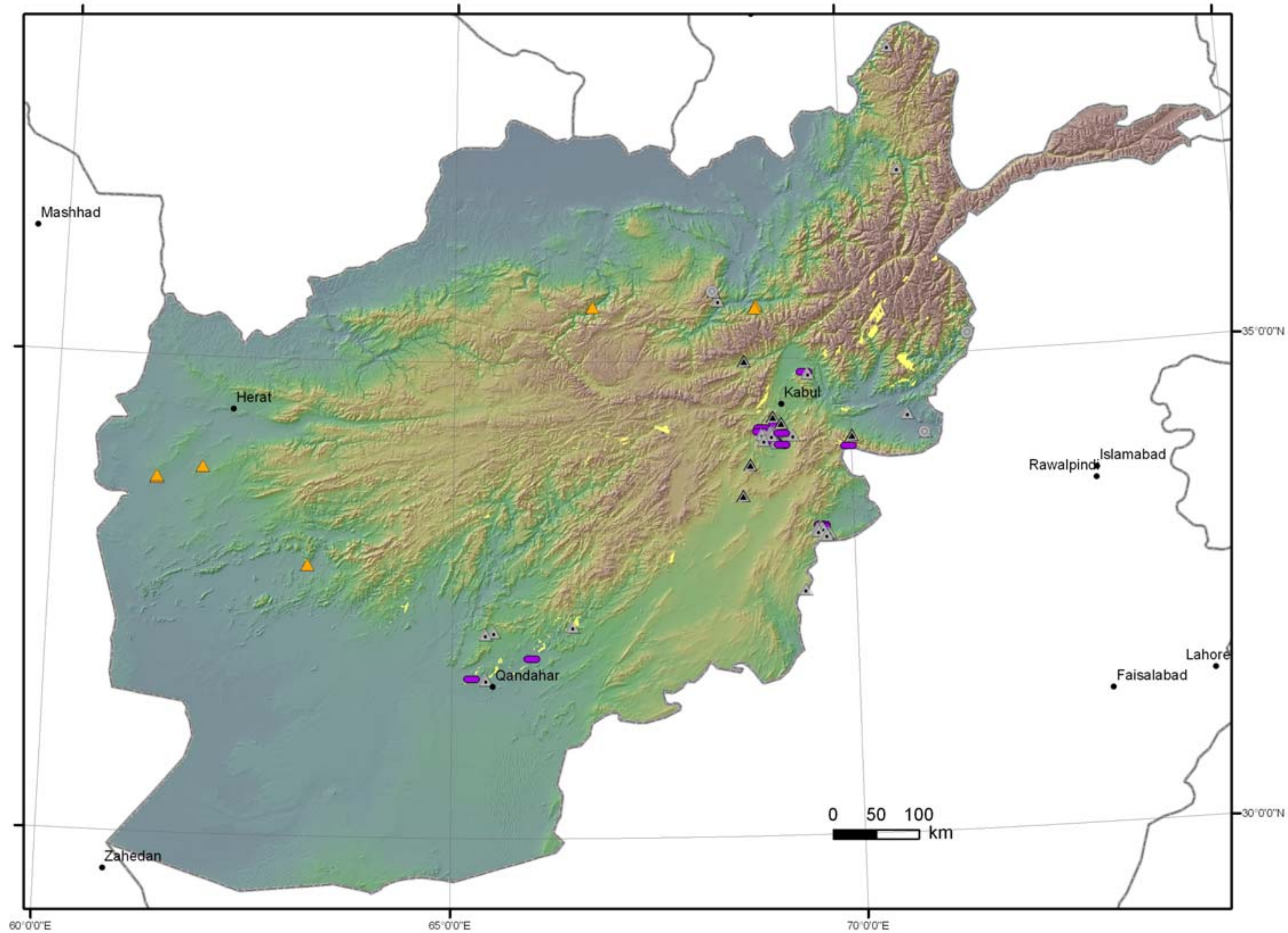


Figure 2.3-13 Locations of tracts (mir03) of Mesozoic mafic and ultramafic intrusive rocks determined to be permissive for undiscovered serpentine-hosted asbestos deposits in Afghanistan.

Tract ID: mir04—Asbestos, magnesite, and talc in Eocene age mafic and ultramafic intrusive rocks

Deposit Type—Serpentine-hosted asbestos, ultramafic-hosted magnesite veins, and ultramafic-hosted talc

Age of Mineralization—Eocene

Examples of Deposit Type—The Eocene-age mafic and ultramafic intrusive rocks of tract mir04 host eight of the reported podiform chromite occurrences, 14 serpentine-hosted asbestos, and one ultramafic-hosted talc showing. These include the small Logar and Shodal deposits. Brief descriptions of these occurrences are found in the podiform chromite section.

Serpentine-hosted asbestos mineral occurrences

Logar Province

Spinkala occurrence, Abparan occurrence, Waghjan occurrence, and Shakhsi occurrence are located in the province as are three additional unnamed serpentine-hosted asbestos showings.

Parwan province

Baghram occurrence is in Parwan Province

Paktia Province

Kopra, Afdzalkhel, and "Frontier-Side" occurrences are found in the province.

Ultramafic-hosted talc mineral occurrences

Maydan Province

One unnamed talc showing is known in Maydan Province.

Exploration history—There are numerous identified mineral occurrences associated with the mafic intrusive rocks, so it is assumed that the exposed rocks have been explored by at least rudimentary means. Modern exploration techniques have probably not been employed and may yield positive results.

Tract boundary criteria—Tract mir04 was drawn on the presence of Eocene-age intrusive mafic and ultramafic rocks (figure 2.3-5). All these rocks were considered as favorable for the occurrence of Serpentine-hosted asbestos, ultramafic-hosted talc-magnesite deposits because of the occurrence of the majority of these deposits in or nearby these rocks (fig. 2.3-13).

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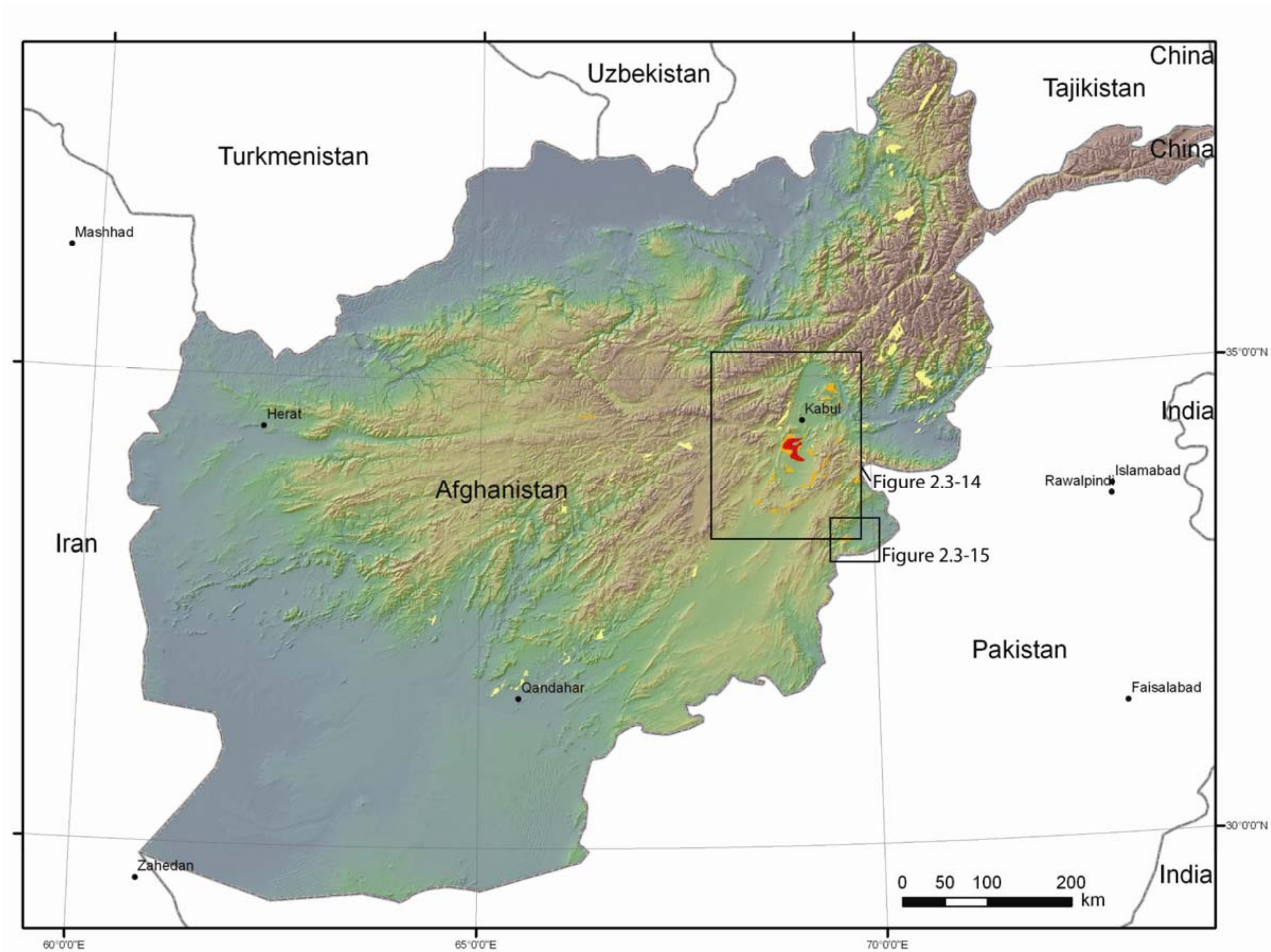

Figure 2.3-14. Locations of tracts (mir04) of Eocene age mafic and ultramafic intrusive rocks determined to be permissive, favorable, or prospective for undiscovered serpentine-hosted asbestos deposits in Afghanistan

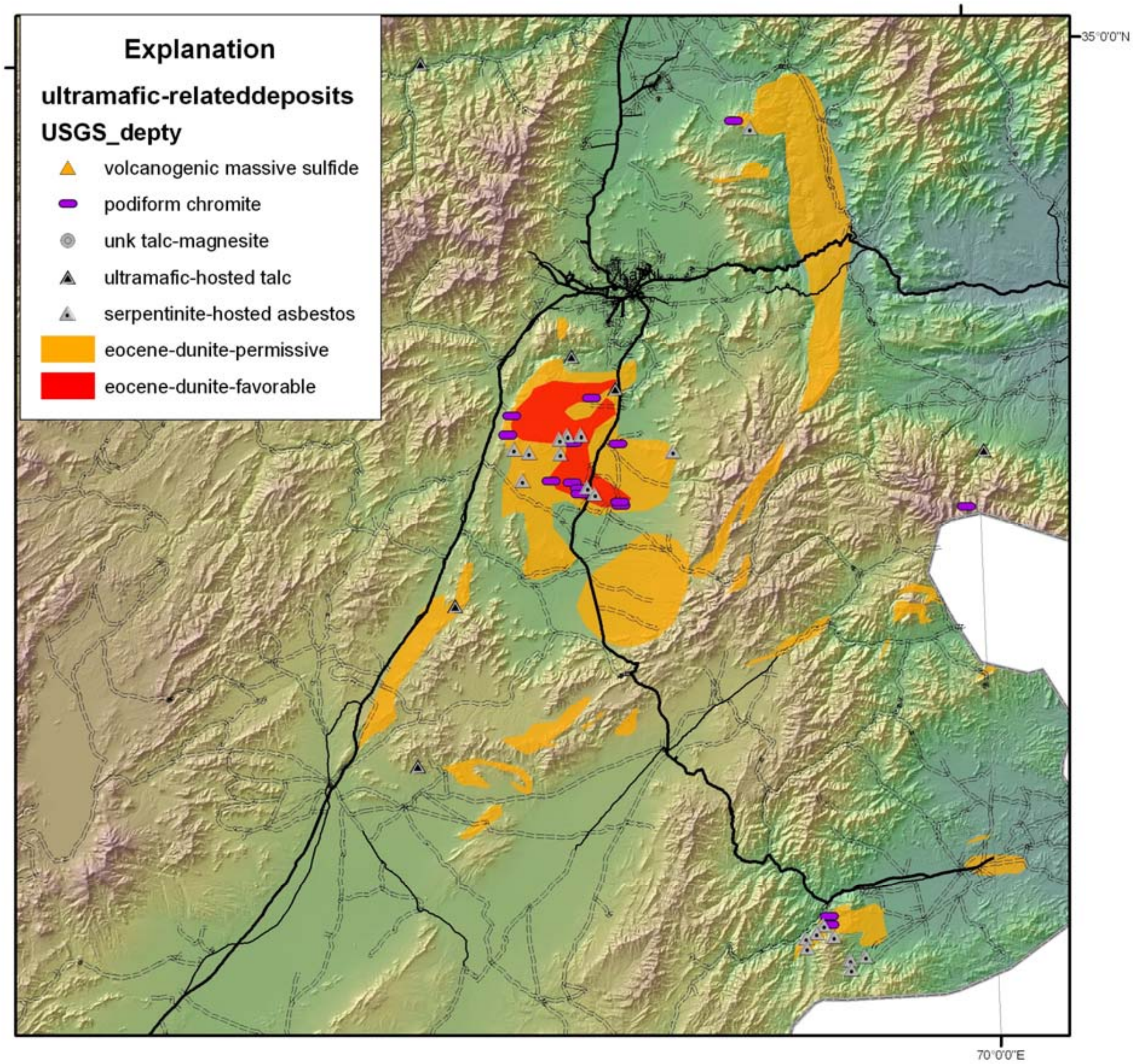

Figure 2.3-15. Locations of tracts of Eocene age mafic and ultramafic intrusive rocks determined to be favorable, or prospective for undiscovered serpentine-hosted asbestos deposits in Afghanistan.

Favorable tract mir04-f1

Favorable tract mir04-f1 is recognized in intermittent patches northeast to southwest of Kabul. It was constructed to include almost of the Eocene mafic rocks in Paktya, Kabul, Ghazni, and Logar Provinces and many of the mineral occurrences related to mafic igneous rocks that populate that area (figure 2.3.6). Only the few smallest mafic bodies away from the main mafic units were omitted from the favorable tract. Tract mir04-f1 makes up the majority of tract mir04. The favorable rocks are described solely as dunite, peridotite, and serpentinite. The tract contains 9 serpentine-hosted asbestos occurrences including Logar asbestos, Spinkala, Kohe Moghu Aba, Waghjan, Shaksi, and 4 unnamed showings, 11 podiform chromite occurrences, and 2 unnamed ultramafic-hosted talc showings.

Prospective tract mir04-p1

Within tract mir04-f1 is prospective tract mir04-p1. This tract is delineated to contain Eocene dunite, peridotite, serpentinite rocks and many of the numerous mafic and ultramafic related mineral occurrences.

Because of the coincidence of several mineral occurrences related to the presence of mafic igneous intrusions tract mir04-p1 is the one that is most prospective for these types of deposits in all of Afghanistan.

Favorable tract mir04-f2

Tract mir04-f2 was drawn to include three small patches of Eocene dunite, peridotite, and serpentinite and associated mafic related mineral occurrences east and southwest of Khost in southeast Afghanistan. The tract encompasses eight reported serpentine-hosted asbestos and two podiform chromite occurrences. These include Shodal asbestos deposit, Kopra, Roghay, Rosana, Afdzalkhel, Samandkay, Kandinkhel, and Sperkhay asbestos occurrences and the Sperkaw and Shodal chromite occurrences. The southern lobe of the southwestern part of the tract is traced to include a magnetic high where the Samandkay, Kandinkhel, and Sperkhay asbestos occurrences sit.

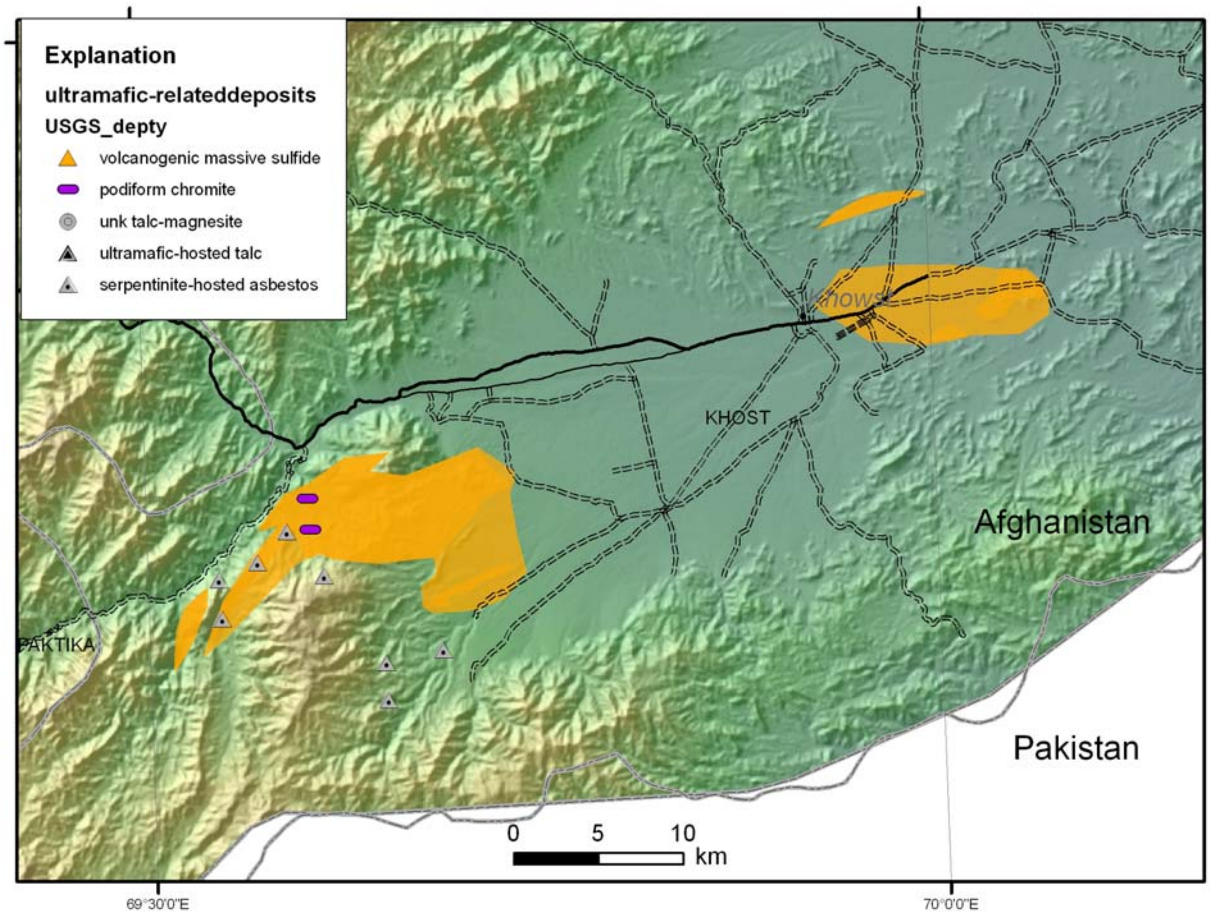

Figure 2.3-16. Locations of tracts of Eocene age mafic and ultramafic intrusive rocks determined to be permissive, favorable, or prospective for undiscovered serpentine-hosted asbestos deposits in Afghanistan.

Prospective tract mir04-p2

Tract mir04-p2 is the most prospective part of tract mir04-f2. It was drawn to include Eocene dunite, peridotite, and serpentinite intrusive rocks the five serpentine-hosted asbestos and 2 podiform chromite occurrences that form a cluster of occurrences southwest of Khost. This prospective is considered here as the second most likely tract to contain exploitable deposits of serpentine-hosted asbestos and ultramafic-hosted talc-magnesite deposits in the country because of the coincidence of ultramafic host rocks and known mineral occurrences.

***Important data sources*—**Geologic map, mineral deposit database (Doebrich and Wahl, 2006; Orris and Bliss, 2002; Abdullah, and others, 1977).

***Needs to improve assessment*—**Large-scale geologic map and geophysics to further locate the ultramafic rocks. Stream-sediment mineral surveys for heavy minerals would locate chromite anomalies that may be indicative of nearby ultramafic rocks.

***Optimistic factors*—**The presence of numerous serpentine-hosted asbestos, and ultramafic-hosted talc-magnesite occurrences within and proximal to the favorable and prospective areas makes tract mir04 the most promising of the tracts for the presence for undiscovered deposits of these types.

***Pessimistic factors*—**The scale of the 1:500,000 Russian map makes it difficult to further select the rocks where these deposit types may occur.

***Quantitative assessment*—**Permissive, favorable, and prospective tracts have been delineated for the presence of serpentine-hosted asbestos deposits. The permissive tract was selected to include the known occurrences and the ultramafic rock types known to host these deposit in other parts of the world. No quantitative assessment of tract mir04 was attempted.

Serpentine-Hosted Asbestos References

Abdullah, S., Chmyriov, V.M., Stazhilo–Alekseyev, K.F., Dronov, V.I., Gannan, P.J., Rossovskiy, L.N., Kafarskiy, A.Kh., and Malyarov, E.P., 1977, Mineral resources of Afghanistan (2d ed.): Kabul, Afghanistan, Republic of Afghanistan Geological and Mineral Survey, 419 p.

Denikaev, Sh.Sh., Feoktistov, V.P., Pyzhyanov, I.V., Adjruddin, A., Narbaev, Sh.N., and Konev, Yu.M., 1971, The geology and minerals of the southern part of Eastern Afghanistan (an intermediate report by the Kabul crew on the work of 1970): Kabul, Department of Geological and Mineral Survey, unpub. data.

Doebrich, J.L., and Wahl, R.R., compilers, 2006, Geologic and mineral resource map of Afghanistan: U.S. Geological Survey Open–File Report 2006–1038, scale 1:850,000, available only on line at *http://pubs.usgs.gov/of/2006/1038/*.

Duke, J.M., 1984, Ultramafic-hosted asbestos, *in* Eckstrand, O.R., ed., Canadian mineral deposit types—A geological synopsis: Geological Survey of Canada Report 36, p. 67.

Gumerov, L.G., 1973, A preliminary report on prospecting for chrysotile–asbestos in 1970–1972 and further trend of the work: Kabul, Department of Geological and Mineral Survey, unpub. data.

Hora, Z.D., 1997, Ultramafic-hosted chrysotile asbestos, in Geological Fieldwork 1997: British Columbia Ministry of Employment and Investment Paper 1998-1, p. 24K-1–24K-4.

Jensen, M.L., and Bateman, A.M., 1981, Economic mineral deposits, third edition, revised printing: New York, John Wiley and Sons, 593 p.

Kazak, Yu. M., Lapke, F .F., Galstukhin, E. A., and Koretskiy, M.S., 1965, Report on the geological exploration at the Farenjal barite deposit in 1963–64 and prospecting–exploration investigations at the Tangi–Murch celestite deposit in 19 V. 1–3: Kabul, Department of Geological and Mineral Survey, unpub. data.

Mikhalov K.Ya, Kolchanov V.P., Kulakov V.V., Pashkov B.R., Androsov M.A., and Chalyan M.A., 1967, unknown/incomplete, scale 1:200,000, unknown/incomplete, scale 1:200,000, unpub. data.

Nikitin, O.A., Kononykhin, E.T., Korol, A.N., and Fakir, A., 1973, Report on the results of prospecting within the Spira lead–and–zinc occurrence: Kabul, Department of Geological and Mineral Survey, unpub. data.

Obolenskiy, A.A., Rodionov, S.M., Ariunbileg, Sodov, Dejidmaa, Gunchin, Distanov, E.G., Dorjgotov, Dangindorjiin, Gerel, Ochir, Hwang, Duk Hwan, Sun, Fengyue, Gotovsuren, Ayurzana, Letunov, S.N., Li, Xujun, Nokleberg, W.J., Ogasawara, Masatsugu, Seminsky, Z.V., Smelov, A.P., Sotnikov, V.I., Spiridonov, A.A., Zorina, L.V., and Yan, Hongquan, 2003, Mineral deposit models for Northeast Asia,

in Nokleberg, W.J., and 10 others, eds.: Preliminary Publications Book 2 from Project on Mineral Resources, Metallogenesis, and Tectonics of Northeast Asia: U.S. Geological Survey Open–File Report 03-203 (CD-ROM), 47 p.
Orris, G.J., 1986, Grade and tonnage model of serpentine-hosted asbestos, *in* Cox, D.P., and Singer, D.A., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p.46-48.
Page, N.J, 1986, Descriptive model of serpentine-hosted asbestos, *in* Cox, D.P., and Singer, D.A., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p.46.
Sborshchikov, I.M., Drannikov, V.S., and Bilan, I.K., 1974, The geology and minerals of Southern and Southeastern Afghanistan: Kabul, Department of Geological and Mineral Survey, unpub. data.
Shcherbina, Yu.I., Petrov, S.E., and Silkin, V.G., 1975, The geology and minerals of the central part of the Kabul median mass: Kabul, Department of Geological and Mineral Survey, unpub. data.
Shride, A.F., 1973, Asbestos, *in* Brobst, D.A., and Pratt, W.P., eds., United States Mineral Resources: U.S. Geological Survey Professional Paper 820, p. 63–73.
Virta, R.L., 2002, Asbestos—Geology, mineralogy, mining, and uses: U.S. Geological Survey Open-File Report 02-149, version 1.0. Available online at *http://pubs.usgs.gov/of/2002/of02-149/*.
Virta, R.L., 2005, Asbestos, *in* 2005 Minerals Yearbook: U.S. Geological Survey, p. 8.1-8.6.
Wrucke, C.T., 1995, Serpentine-and carbonate-hosted asbestos deposits, *in* du Bray, E.A., ed., Preliminary compilation of descriptive geoenvironmental mineral deposit models: U.S. Geological Survey Open–File Report OF95–831, p. 39-46. Available online at *http://greenwood.cr.usgs.gov/pub/open-file-reports /ofr-95-0831/*.