6.0 Deposits related to felsic to intermediate extrusive rocks

Deposits related to felsic to intermediate extrusive rocks in Afghanistan are represented by epithermal deposits of mercury and possibly precious and base metals (section 6.1) and volcanogenic massive sulfide deposits (VMS deposits) that are associated with submarine volcanic flows (section 6.2). Mercury deposits are known in western Afghanistan and VMS deposits may be present in a number of stratigraphic units throughout the country. Both deposit types require further field study and evaluation.

6.1 Mercury deposits

Contributions by James J. Rytuba, Stephen G. Peters, Stephen D. Ludington, Walter J. Bawiec, and Bernard E. Hubbard.

Mercury occurrences in western Afghanistan define a linear mercury mineral belt that is over 400 km in length and about 25 km in width. Although there has been no historic mercury production, this mercury mineral belt is similar to productive global mercury mineral belts, because the mercury occurrences have similar alteration, mineralogy, and host rock associations. Over 70 percent of the deposits are hosted in Early Cretaceous calcareous continental sedimentary rocks that have been intruded by diorite dikes and stocks with the remainder occurring in volcanic rocks that are likely coeval with the intrusive rocks. The hydrothermal alteration consists of dickite and carbonate minerals and is spatially associated with the intrusive rocks that were the heat source for the hydrothermal systems. Cinnabar is the primary ore mineral and arsenopyrite and realgar are present in minor amounts in the Qalat occurrence. Low levels of Sn, Cu, Pb, Zn and Ag have been reported in two of the deposits (see table 6.1-1). Mercury mineralization includes disseminations and veinlets of cinnabar, which locally are accompanied by pyrite, chalcopyrite, and arsenic sulfide minerals.

The mercury occurrences are present in Farah, Ghor, Uruzgan and Bamyan Provinces (tract ephg01, fig. 6.1-1) and are typical of hot-spring type mercury deposits that are a common deposit type in most of the world's mercury mineral belts. Additionally, a similar geologic environment and numerous mercury geochemical halo anomalies are hosted in Eocene sedimentary and volcanic rocks in eastern Afghanistan in northeast Kandahar Province, and in east Zabul, Paktika and Paktya Provinces (tract ephg05, fig. 6.1-1). In addition, three smaller permissive tracts were delineated in Herat Province (ephg02, ephg03, and ephg04, figs. 6.1-1 and 6.1-2).

Environmental concerns associated with the use of mercury have resulted in closure of most of the world's mercury mines. Only two countries, China and Kyrgyzstan, continue to report primary production from mercury ores with grades that average 0.4 wt. percent. In the industrialized world, mercury continues to be recovered as a by-product from gold-silver and from massive sulfide deposits. This is because environmental regulations restrict the release of mercury into the environment from these mines and therefore require its recovery. The largest producers of by-product mercury include: the Yannacocha gold-silver mine, Peru, 104 metric tons of mercury; the Red Dog massive sulfide deposit (SEDEX type), United States; and massive sulfide deposits (VMS type) in the Boliden mining district in Sweden, 600 flasks of mercury. Minor quantities of mercury also are mined and recovered by artisanal miners in Mexico because the capital cost of mining and recovery of mercury is relatively small.

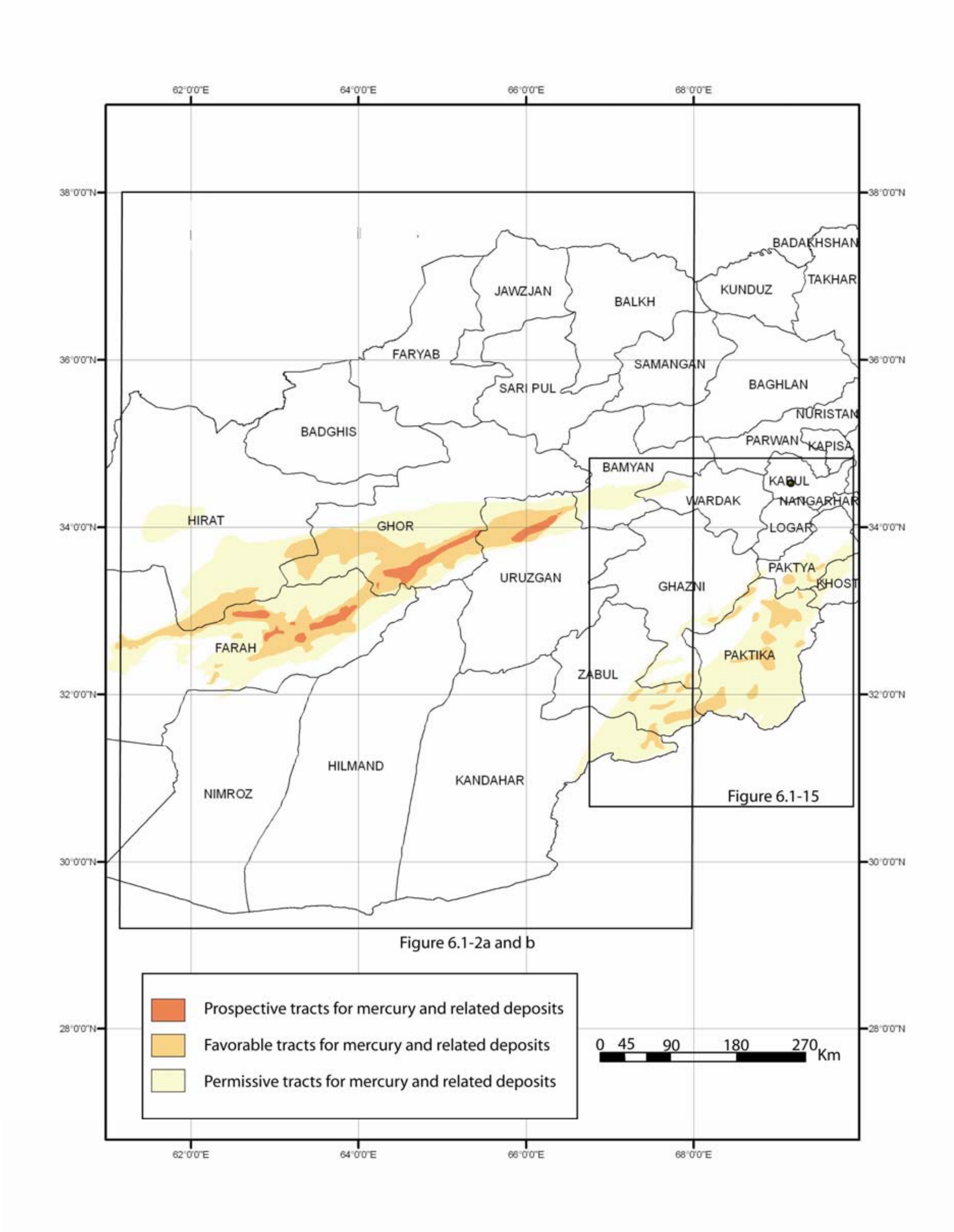

Figure 6.1-1. Permissive (yellow), favorable (orange) and prospective (red) tracts for undiscovered epithermal mercury deposits in Afghanistan. Se subsequent figures for details of favorable and prospective tracts.

Table 6.1-1. Mercury-rich mineral occurrences of Afghanistan.

Name	Province	Long	Lat	Hg Grade	Ore	Age	Host Rock	Ore control	Size of alteration mineralization	Alteration	Ore mineralogy	Gangue Mineralogy
Ore grade deposits and occurrences with and without diorite porphyry intrusives												
Kharnak	Ghowr	64.527	33.458	.1-.63%	Hg	Intrusive Stock	A subvolcanic body intruding Lower Cretaceous lime siltstones	Mineralized zone	extent: 140-180 m; thickness: 1-24 m; thickness: 1-5 m; extent: 20-100 m	Carbonate-dickite alteration ; Dickitization; Carbonatization	Cinnabar	Dickite; carbonate
Solghoi	Bamian	66.887	34.266	.1-.7%	Hg	-	Lower Cretaceous pebble conglomerates	Mineralized zone; Linear ore-bearing shatter zone; Cr	300x500 m	Recrystallization; Bleaching; Silicification; Dickitization	Cinnabar; metacinnabarite; pyrite; hematite; chalcopyrite	Quartz; dickite; calcite; siderite; ankerite; barite
Duwalak	Ghowr	64.650	33.456	.07-.72%	Hg	Early Cretaceous	Lower Cretaceous carbonate-terrigenous deposits	Mineralized zone; Lenticular lodes	width: 10-160 m; extent: 0.75--1 km; thickness: 4-6 m; extent: 40-140 m	Dickitization; Carbonatization ; Limonitization	Cinnabar	Dickite; carbonate; limonite
Sahebdad	Oruzgan	65.091	33.800	.06-.78%	Hg	Early Cretaceous	Lower Cretaceous lime terrigenous deposits	Shatter mineralized zone; Veinlets; Pockets	area: 10-20x160 m	Dickitization; Carbonatization	Cinnabar; pyrite; chalcopyrite; sphalerite; metacinnabarite; arsenopyrite; antimonite; realgar	Dickite; calcite; quartz; ankerite; siderite; barite
Qalat	Oruzgan	65.089	33.790	.1-.38%	Hg	Diorite porphyry dikes	Lower Cretaceous carbonate-terrigenous deposits intruded by diorites porphyry dikes	Mineralized zone; High-angle cross veins of fissure-f	extent: 145-300 m; thickness: 3-22 m.	Dickite-carbonate alteration; Quartz-dickite-carbonate alteration	Cinnabar; pyrite; arsenopyrite; realgar	Dickite; barite; calcite; gypsum
Darwaza Mercury	Oruzgan	65.975	33.906	0.003	Hg	Early Cretaceous ?	Lower Cretaceous red terrigenous rocks among Upper Jurassic - Lower Cretaceous	Mineralized zone; Linear ore-bearing shatter zone; Cr	thickness: 2-10 m (up to 35 m in the bulges); extent: 860 m	Recrystallization; Bleaching; Silicification; Dickitization	Cinnabar; metacinnabarite; pyrite; hematite; chalcopyrite	Quartz; dickite; calcite; siderite; ankerite; barite

							volcanogenic - sedimentary deposits					
Khanjar	Oruzgan	65.390	33.951	.35-.96	Hg	Early Cretaceous	Lower Cretaceous lime sandstones	Shatter mineralized zone	thickness: 2- 4 m; extent: more than 1 km	Carbonatization ; Dickitization; Limonitization	Cinnabar	Dickite; calcite; limonite
Sebak	Ghowr	64.673	33.499	.08-.xx%	Hg	ore grade	Lower Cretaceous carbonate-terrigenous deposits intruded by diorites porphyry dikes	Shatter mineralized zone	width: 0.4 km	Carbonatization ; Dickitization	Cinnabar	Dickite; carbonate
Katif	Ghowr	64.636	33.455	.51-.86%	Hg	Early Cretaceous	Lower Cretaceous carbonate-terrigenous deposits	Mineralized zone; Veinlets; Lenticular lodes	Zone - thickness: 10-20 m; extent: 100-150 m; thickness: up to 1.5 cm; Ore lodes - extent: 43 m; thickness: 1 m	Calcite alteration; Dickitization	Cinnabar	Dickite; calcite
Occurrences associated with diorite porphyry dikes and volcanics												
Pushwara	Ghowr	64.553	33.335		Hg	Dikes (Miocene)	Lower Cretaceous siltstones and sandstones , Miocene porphyry dikes	Mineralized zone; Veinlets	width: up to 0.7 km; area: occasionally 1.5 sq. km	Dickitization; Carbonatization	Cinnabar	Dickite; carbonate
Alibali	Oruzgan	65.222	33.864	0.001	Hg	Diorite porphyry dikes						
Alibali II	Oruzgan	65.219	33.861		Hg	Diorite porphyry dikes	Lower Cretaceous sandstones intruded by diorites porphyry dikes	Shatter mineralized zone	extent: more than 1 km; width: 0.1-0.25 km; thickness: 0.05-0.2 m	-	Cinnabar	Not data

Gulgadam	Oruzgan	65.193	33.825	.005-.01%	Hg	Diorite porphyry dikes	Lower Cretaceous carbonate-terrigenous deposits intruded by diorites porphyry dikes	Shatter mineralized zone	extent: 150--170 m; thickness: 3-8 m;	Carbonatization ; Dickitization	Cinnabar	Calcite
Chashnak	Farah	63.622	32.930	.001-.1%	Hg	Mafic Dikes (Eocene - Oligocene	Eocene - Oligocene volcanogenic-terrigenous deposits in subcontact parts of intermediate and basic dikes	Mineralized zone; Cross shatter zone	Not data	Dickitization; Silicification; Calcite alteration	Cinnabar; chalcopyrite; sphalerite; galena	Quartz; carbonate
Panjshah	Ghowr	64.317	33.452	.01-.05%	Hg	Diorite porphyry dikes	Lower Cretaceous marbled limestones intruded by diorites porphyry dikes	Mineralized zone; Pockets	Not data	Dickitization; Carbonatization	Cinnabar; metacinnabarite; pyrite; hematite; chalcopyrite	Quartz; dickite; calcite; siderite; ankerite; barite
Mushkan	Farah	63.887	32.957	.01-.001%	Hg	Diorite porphyry dikes	Lower Cretaceous carbonate-terrigenous deposits intruded by diorites porphyry dikes	Mineralized zone; High-angle cross veins of fissure-f	thickness: 1 m; extent: 120 m	Dickitization; Silicification; Calcite alteration	Cinnabar	Dickite; calcite; quartz;
Duaba	Farah	63.848	32.950	0.000	Hg	Diorite porphyry dikes	Lower Cretaceous carbonate-terrigenous deposits intruded by diorites porphyry dikes	Mineralized zone; Veinlets	thickness: 0.5-1 m; extent: up to 160 m	Dickitization; Silicification; Calcite alteration	Cinnabar	Dickite; calcite; quartz; ankerite
Mullayan	Ghowr	64.369	33.434	0.001	Hg	Diorite porphyry dikes	Lower Cretaceous siltstones and limestones near diorites porphyry stocks and dikes	Mineralized zone; High-angle cross veins of fissure-f	area: 3.5x2 m (up to 9 m); extent: 200 m	Argillic alteration of quartz-dickite facies ; Dickitization; Silicification; Calcite alteration	Cinnabar; pyrite; chalcopyrite; sphalerite; metacinnabarite; arsenopyrite; antimonite; realgar	Dickite; calcite; quartz; ankerite; siderite; barite

Unnamed	Ghowr	64.331	33.414		Hg	Early Cretaceous	Lower Cretaceous terrigenous and carbonate-terrigenous deposits ; diorites and andesite porphyry dikes	Mineralized zone	thickness: 2-8 m; extent: 25-60 m	Carbonate-dickite alteration	Cinnabar	Dickite; carbonate
Zarmardan	Farah	62.731	32.952	.03-.05%	Hg	volcanics (Paleocene)	Paleogene volcanogenic-terrigenous deposits ; subvolcanic bodies of intermediate composition	Shatter mineralized zone	Not data	Silicification; Calcite alteration; Quartz-carbonate alteration; Carbonatization	Cinnabar; chalcopyrite; sphalerite; galena	Quartz; carbonate
Nayak	Herat	62.446	34.440	.01-.16%	Hg Cu	volcanics (Eocene)	Eocene sandstones , conglomerates and volcanites	Sheetlike lodes ; Pockets	thickness: 30-35 m; 0.3-1x1-6 m; thickness: 1.5-3 m; extent: 15-25 m	-	Cinnabar; chalcocite; chalcopyrite; bornite; malachite	Not data
Occurrences in sedimentary carbonate containing rocks												
Sewak	Bamian	66.879	34.241		Hg	Late Jurassic - Early Cretaceous	Upper Jurassic - Lower Cretaceous limestones	Shatter mineralized zone	70x150 m	Hematitization	Cinnabar; hematite	Not data
Unnamed	Oruzgan	66.592	33.993		Hg	Proterozoic	Proterozoic metamorphic rocks	Shatter mineralized zone	thickness: 30 cm; extent: up to 100 m	Carbonatization ; Dickitization; Limonitization	Cinnabar	Limonite; carbonate
Gardesh	Oruzgan	66.326	34.103	0.000	Hg	Early Cretaceous	Lower Cretaceous limestones , sandstones and siltstones	Mineralized zone; Veinlets	Not data	Dickitization; Calcite alteration	Cinnabar; pyrite; hematite; realgar	Dickite; calcite; siderite; ankerite
Surkh-Joi	Oruzgan	66.285	34.046	0.000	Hg	Early Cretaceous ?	Lower Cretaceous red rocks	Mineralized zone	area: 350x400 m; thickness: 0.3-8 m; extent: from a few up to 50 m (less often 100-120 m)	Pyritization	Cinnabar; pyrite	Calcite; siderite; ankerite

Awlamqul	Oruzgan	66.042	33.837	0.000	Hg	Early Cretaceous	Lower Cretaceous limestones	Mineralized zone	Not data	Recrystallization; Calcite alteration	Cinnabar; pyrite; hematite; realgar	Calcite; siderite; ankerite
Alibali I	Oruzgan	65.227	33.857	0.000	Hg	Early Cretaceous	Lower Cretaceous carbonate deposits	Shatter mineralized zone; Veinlets	extent: 250--530 m; thickness: 5.4 m; thickness: 1-4 mm	Carbonatization ; Dickitization	Cinnabar	Dickite; carbonate
Pasaband	Ghowr	64.845	33.672		Hg	Early Cretaceous	Lower Cretaceous carbonate-terrigenous deposits intruded by diorites porphyry dikes	Shatter mineralized zone; Veinlets; Pockets	thickness: 3-8 m; extent: 400 m.	Hornfels; Dickitization; Carbonatization	Cinnabar; realgar; sulfur native; pyrite; hematite	Calcite; ankerite; siderite; dickite; carbonate
Surkhnow	Ghowr	64.684	33.476	0.003	Hg	Early Cretaceous	Lower Cretaceous carbonate-terrigenous deposits	Shatter mineralized zone	area: up to 0.01 sq. km; width: 100-400 m; extent: more than 2 km.	Carbonatization ; Dickitization; Limonitization	Cinnabar	Dickite; carbonate
Koh-i-Katif	Ghowr	64.635	33.442	0.001	Hg	Early Cretaceous	Lower Cretaceous siltstones and sandstones	Mineralized zone	area: 1000 sq. m	Dickitization; Carbonatization	Cinnabar	Dickite; carbonate
Qasem	Ghowr	64.625	33.424	0.000	Hg	Early Cretaceous	Lower Cretaceous carbonate-terrigenous deposits	Shatter mineralized zone	area: from 1x3-5 up to 20x100 m	Dickitization; Carbonatization	Cinnabar	Dickite; carbonate

The price of mercury remained at low levels from 1980 to 2000 when it progressively decreased from $400 to $100 per flask (a flask equals 76 pounds) as demand for mercury decreased, because of environmental concerns related to its use in medical, electrical and chemical products. More recently, however, the price has dramatically increased by almost 300 percent reaching a historic high of $1,000 per flask; this is a result of a limited supply caused by the closure of most of the mercury mines, to controls put on the use and sale of mercury by industrialized nations. In 2006 and early 2007, the mercury price decreased to about $600 per flask, but this is still historically very high. There is a significant demand for mercury by artisanal gold miners in Africa, South America, and S.E. Asia where it is used to recover gold and silver by amalgamation. In contrast, the industrialized countries, such as the EU, are implementing policies to eliminate the use and sale of mercury. Thus the high price of mercury reflects two competing world views on the use of mercury: industrialized nations have instituted policies to eliminate mercury use and sale, whereas less developed nations continue to produce and use mercury.

Mercury ore grades reported for nine of the mercury deposits and occurrences in Afghanistan range from 0.06 to 0.96 wt. percent mercury (table 6.1-1), and, at the present price of mercury, are of sufficient value to be considered economic ore grade. The size of the mineralized and altered area in these nine occurrences is comparable to hot-spring type mercury deposits that have been developed and mined elsewhere in the world. It is likely that further exploration would delineate sufficient tonnage of mercury ore at these occurrences to be comparable to the median hot-spring type mercury deposit on the world-wide grade tonnage curve (Rytuba, 1986b). Mercury occurrences with lower mercury ore grades within the mercury mineral belt (table 6.1-1) have similar alteration, mineralogy and geology. Thus there is no clear distinction that separates the occurrences with higher grades of mercury from those with lower grades. However, there appears to be a spatial distribution of the mercury occurrences associated with intrusive rocks and those with higher mercury ore grades.

The southwestern part of the mercury mineral belt has intrusive stocks or porphyry dikes associated with the mercury occurrence. In the northeastern part of mercury mineral belt the occurrences generally do not have intrusive rocks associated with the mercury mineralization. In this northeastern part of the belt, there are a few occurrences that have somewhat higher grades, but overall these occurrences tend to have lower grades than in the central zone. Within the central part of the belt, the mercury occurrences consistently have the highest ore grades and the largest areas of hydrothermal alteration and mineralization; only some of the mercury occurrences are associated with intrusive rocks in this central zone. The Kharnak mercury occurrence has economically significant mercury ore grades over a relatively large area and is associated with a diorite stock. Also with the central zone, the mercury occurrences are located in a transition zone between those occurrences with porphyry diorite stocks and dikes and those without dikes located somewhat to the northeast.

Change in the distribution of intrusive rocks and mercury grades within the mercury mineral belt can be explained by differences in the level of exposure of the mercury mineralization. The mercury mineralization was structurally controlled by faults that were intruded by diorite porphyry dikes. Although some mercury mineralization occurs in the dikes, most of the mineralization is hosted in brecciated and altered calcareous sedimentary rocks adjacent to or just above the intrusive rocks. In the southwest part of the mercury mineral belt, deeper levels of the hydrothermal system are exposed as evidenced by the presence of intrusive rocks and lower grades of mercury. In the northeast part of the belt the level of erosion generally does not expose the mineralized area immediately above the intrusive rocks and therefore the mercury ore grades are relatively low. Presumably the higher ore grades of mineralization are present at depth. In the central part of the belt the favorable area of mercury mineralization, as exposed near the present surface and mercury ore grades generally high enough to be economically significant. The geologic map of the Qalat occurrence shows a highly altered and brecciated zone that has relatively high mercury ore grades. This zone of mineralization and brecciation is presumed to have formed just above an intrusive diorite that was emplaced along the fault zone.

The hydrothermal alteration in the mercury occurrences consists of dickite and carbonate minerals. This is not a common alteration assemblage because the two minerals assemblages form under different pH conditions. Dickite is an aluminum silicate that is similar to kaolinite and forms under acid conditions. Dickite does not occur within the steam-heated environment of hot-spring type systems and supergene environments. Dickite alteration is common within high sulfidation type of gold-copper deposits that formed from hypogene hydrothermal fluids in which magmatic SO_2 disproportionates to form H_2SO_4 and H_2S. The diorite dikes associated with the mercury occurrences are the likely source for the sulfur dioxide, and resulting H_2SO_4, in the hydrothermal system that formed the dickite alteration. As the acidic hydrothermal fluid moved from the intrusive upward and outward from the fault zone, it apparently dissolved carbonate minerals in the host rocks. Interaction of the acid hydrothermal fluid resulted in an increase in pH because of neutralization by and the buffering capacity of the carbonate host rocks. The carbonate assemblage would form away from the intrusive rock as the hydrothermal fluid pH increased to weakly acid. The dickite alteration formed early in the evolution of the hydrothermal system adjacent to the intrusion of the dikes and the carbonate alteration formed later, overprinting the early alteration as the acidic hydrothermal fluid was neutralized by the carbonate host rocks. Emplacement of diorite magma was critical in developing the hydrothermal alteration, and it is likely that these magmas were also the source of mercury. Based on this hypothesis, the mineral potential of the mercury mineral belt is related to the distribution of dioritic intrusive rocks. Because these intrusives are relatively small, they have generally not been mapped and their distribution is poorly known. The age of the intrusive rocks is Miocene but this is not well constrained. Favorable tracts for mercury deposits within the mineral belt have been delineated to include areas permissive for intrusions of this age and composition.

The mercury deposits in the northeast part of the trend will be different because the host rocks consist of serpentinite associated with major faults zones. The type of alteration present in serpentinite is dominantly carbonate, because the serpentinite buffers the hydrothermal fluid which becomes saturated with respect to carbon dioxide. This type of mercury deposit has been termed silica-carbonate and this deposit type is common throughout the world in suture and major fault zones in which serpentinite is present (Rytuba, 1986c). Silica-carbonate type mercury deposits tend to be much larger and economically more significant than hot-spring type mercury deposits.

Mercury occurs as trace to recoverable amounts in many types of ores. The deposits types that have the highest concentrations of mercury include SEDEX, VMS, and hot spring and high sulfidation type gold-silver deposits. Cinnabar is the main mercury phase in hot spring and high sulfidation gold-silver deposits, and in SEDEX and VMS deposits, mercury is present in solid solution in sphalerite. The numerous mercury haloes that have been reported throughout the various regions of Afghanistan reflect the presence of trace amounts of mercury in most ore deposits.

6.1.1 Descriptive Models for Epithermal Deposits and Associated Models

The principle types of epithermal deposits present in Afghanistan are those of mercury, but these may also indicate occurrences and deposits that contain precious- and base-metals. Most known mercury occurrences are in Upper Cretaceous sedimentary and volcanic rocks and probably formed during Miocene intrusion and volcanism. The two major types of mercury descriptive deposit models used in this assessment are hot-spring Hg and silica-carbonate Hg deposits. The hot-spring type mercury deposit model is typical of the mercury occurrences in the mercury mineral belt in western Afganistan and the silica-carbonate deposit type is typical of the few deposits associated with serpentinite (Abdullah and others, 1977). The following summarizes the characteristics of these two models from Cox and Singer (1986).

Hot-spring Hg deposits (model 27a, Rytuba, 1986a; mean tonnage 0.0095, mean grade 0.35 wt. percent) are synonymous with Sulfur Bank type or sulfurous type. The deposits typically contain cinnabar and pyrite, which are disseminated in siliceous sinter superjacent to greywacke, shale, andesite, basalt flows and diabase dikes. Rock types directly associated with ore are siliceous sinter, andesite-basalt flows, diabase dikes, andesitic tuff, and tuff breccia. Age is usually Tertiary. The depositional environment is near the paleo ground-water table in areas of fossil hot-spring systems. The tectonic setting is continental margin rifting with associated small-volume mafic to intermediate volcanism. Associated deposit types include hot-spring gold. Mineralogy includes cinnabar + native mercury + minor marcasite, as well as pyrite, zeolites, potassium feldspar, chlorite, and quartz. These are present as disseminations and coatings on fractures in hot-spring sinter. Opal is deposited near the ground-water table. Alteration is found above the paleo ground-water table and includes kaolinite-alunite-iron oxide minerals and native sulfur. Ore controls are the paleo ground-water table within hot-spring systems that formed along the high-angle faults. Geochemical signature is Hg + As + Sb + Au.

Silica-carbonate Hg deposits (model 27c, Rytuba, 1986c; mean tonnage 0.6 Mt, mean grade 0.39 wt. percent Hg), also called New Almaden type deposits, consist of cinnabar at the contacts with serpentine and siltstone-greywacke above subduction-related thrust faults. Rock types associated with the deposits are serpentine and siltstone-greywacke. Age is usually Tertiary. The depositional environment consists of fractured country rocks and serpentinized intrusive rocks (sills and dikes) that have been intruded into siltstone, greywacke, and siltstone, as well as in fractures in altered serpentinite. Tectonic setting of the deposits is accreted terranes above subduction-related thrust faults. Associated deposit types are stibnite veins. Mineralogy consists of cinnabar, native mercury, and other minor sulfide minerals, such as pyrite, stibnite, chalcopyrite, sphalerite, galena, and bornite. These minerals are present as replacements and minor veins. Alteration consists of replacement of serpentine by quartz and dolomite and local minor hydrocarbons to form “silica-carbonate” rock. Ore controls involve the contact of serpentine bodies with siltstone, especially where the contact forms antiforms. Ore is primarily in silica-carbonate rock. The geochemical signature is not well known, but is probably Hg + Sb + Cu.

Associated Models

Deposits commonly associated with the hot-spring and silica-carbonate type mercury deposits are epithermal gold-silver deposits. Although no significant gold-silver occurrences or anomalies are known to be associated with the mercury occurrences in Afghanistan, the geochemical association of arsenic, base metals, and silver reported in the Alibali mercury occurrence (table 6.1-1) indicates the potential for epithermal gold-silver mineralization. The following descriptive models are presented to illustrate the similarities between the mercury epithermal deposits and those containing precious metal.

Epithermal gold deposits are divided into a number of different types (Cox and Singer, 1986). The quartz-adularia (25e), Berger (1986), and quartz-alunite (25c), Mosier and others (1986) models contain characteristics that are similar to epithermal mercury deposits in Afghanistan because of their temporal and spatial association.

The epithermal quartz-alunite gold is also called acid-sulfate, or enargite gold. The deposits contain gold, pyrite, and enargite in vuggy veins and breccias in zones of high-alumina alteration related to felsic volcanism. Rock types include volcanic dacite, quartz latite, rhyodacite, and rhyolite, which are hypabyssal, porphyritic and which also occur in intrusions or domes. The deposits generally are Tertiary in age. The depositional environment is within the volcanic edifice, ring fracture zones of calderas, or in areas of igneous activity with sedimentary evaporite deposits in the basement rocks. Tectonic setting involves through-going fracture systems, such as keystone graben structures, ring fracture zones, normal faults, fractures related to doming, and joint sets. Associated deposit types are porphyry copper, polymetallic replacement, and volcanic-hosted Cu-As-Sb. Pyrophyllite, hydrothermal clay, and alunite deposits also are associated.

Mineralogy of epithermal quartz-alunite gold deposits consists of native gold + enargite + pyrite + silver-bearing sulfosalt minerals ± chalcopyrite ± bornite ± precious-metal telluride minerals ± galena ± sphalerite ± huebnerite. The deposits may have hypogene oxidation phases such as chalcocite + covellite ± luzonite with late-stage native sulfur. These minerals are present in veins, breccia pipes, pods, and dikes. Replacement veins are often porous, and vuggy, with comb structure, and crustified banding. Alteration typically consists of early quartz + alunite + pyrophyllite with pervasive alteration of the host rock and veins of these minerals. This early zone may also contain corundum, diaspore, andalusite, or zunyite. Zoned around quartz-alunite is an assemblage of quartz + alunite + kaolinite + montmorillonite. The extent of pervasive propylitic alteration (chlorite + calcite) depends on the extent of early alunitization. Ammonium-bearing clays may be present. Ore controls are through-going fractures, centers of intrusive activity, and upper and peripheral parts of porphyry copper systems. Weathering of the deposits results in abundant yellow limonite, jarosite, goethite, white argillization with kaolinite, fine-grained white alunite veins, and hematite. Geochemical signatures are gold + As + copper, increasing to base metals at depth, as well as Te and W.

The epithermal quartz-adularia gold deposits consist of gold, electrum, silver sulfosalts, and argentite in vuggy quartz-adularia veins hosted by felsic to intermediate volcanic rocks that overlie predominantly clastic sedimentary rocks, or their metamorphic equivalents. Approximate synonyms are epithermal gold (quartz-adularia), Comstock epithermal veins, low-sulfidization, and alkali-chloride type. Host rocks are andesite, dacite, quartz latite, rhyodacite, and rhyolite, and associated sedimentary rocks. Mineralization is related to calc-alkaline or bimodal porphyritic volcanism. Ages mainly are Tertiary (most are 40 to 3.7 Ma.). The depositional environment is calc-alkaline and bimodal volcanism and associated intrusive activity over clastic sedimentary rocks or metamorphic equivalents and volcanic-related geothermal systems. Tectonic setting consists of through-going fracture systems, major normal faults, fractures related to doming, ring fracture zones, and joints. Associated deposits are placer gold and epithermal quartz-alunite gold and porphyry copper-gold.

Mineralogy of epithermal quartz-adularia gold deposits consists of argentite + gold or electrum ± silver sulfosalt minerals ± laumantite. Galena, sphalerite, chalcopyrite, telluride minerals, hematite, and arsenopyrite are moderate to sparse. Gangue minerals are quartz + pyrite ± adularia ± calcite ± sericite ± chlorite. Barite, fluorite, rhodochrosite, kaolinite, and montmorillonite are moderate to sparse. Ore minerals constitute only a few percent of the vein. These minerals typically form in banded veins, with open space filling, lamellar quartz, and stockworks. Alteration consists from top to bottom: quartz + kaolinite + montmorillonite ± zeolite ± barite ± calcite; quartz + illite; quartz + adularia ± illite; quartz + chlorite. The presence of adularia is variable. Ore controls are through-going anastamosing fracture systems and centers of intrusive activity. Hanging wall rocks commonly are more favorable host rocks. Weathering of the deposits leads to leached country rock and the formation of limonite, jarosite, goethite, alunite, and hematite, argillization with kaolinite. Geochemical signature higher in the systems is gold + As + Sb + Hg or gold + As + copper; gold + Ag + Pb + copper, was well as Te and W.

6.2.1 Epithermal Deposit Tract Descriptions

Geologic provinces identified as permissive for the occurrence of hot-spring type and silica-carbonate mercury deposits in Afghanistan are delineated in two areas, and were identified by mercury geochemical anomalies and locally by the presence of numerous mercury occurrences (fig. 6.1-). Distinct tracts were created that were permissive for the occurrences of hot-spring type deposits for a combination of characteristics, primarily age or presumed age. Although relatively little is known about the specific characteristics of the mercury occurrences in Afghanistan, the ore grades reported in nine (9) of the mercury occurrences (table 6.1-1) were sufficiently high to suggest that the Hg deposit models of Rytuba (1986a, b and c) could be used in a quantitative assessment. In some cases, a few tracts are also considered to be permissive for epithermal gold deposits, but estimates of numbers of undiscovered deposits of this type were not conducted. Accordingly, there are 5 main permissive tracts for hot-spring type mercury deposits (ephg-01, 02, 03, 04, 05). Figure 6.1-2 shows the generalized location of the tracts in pehg-01 through 04.

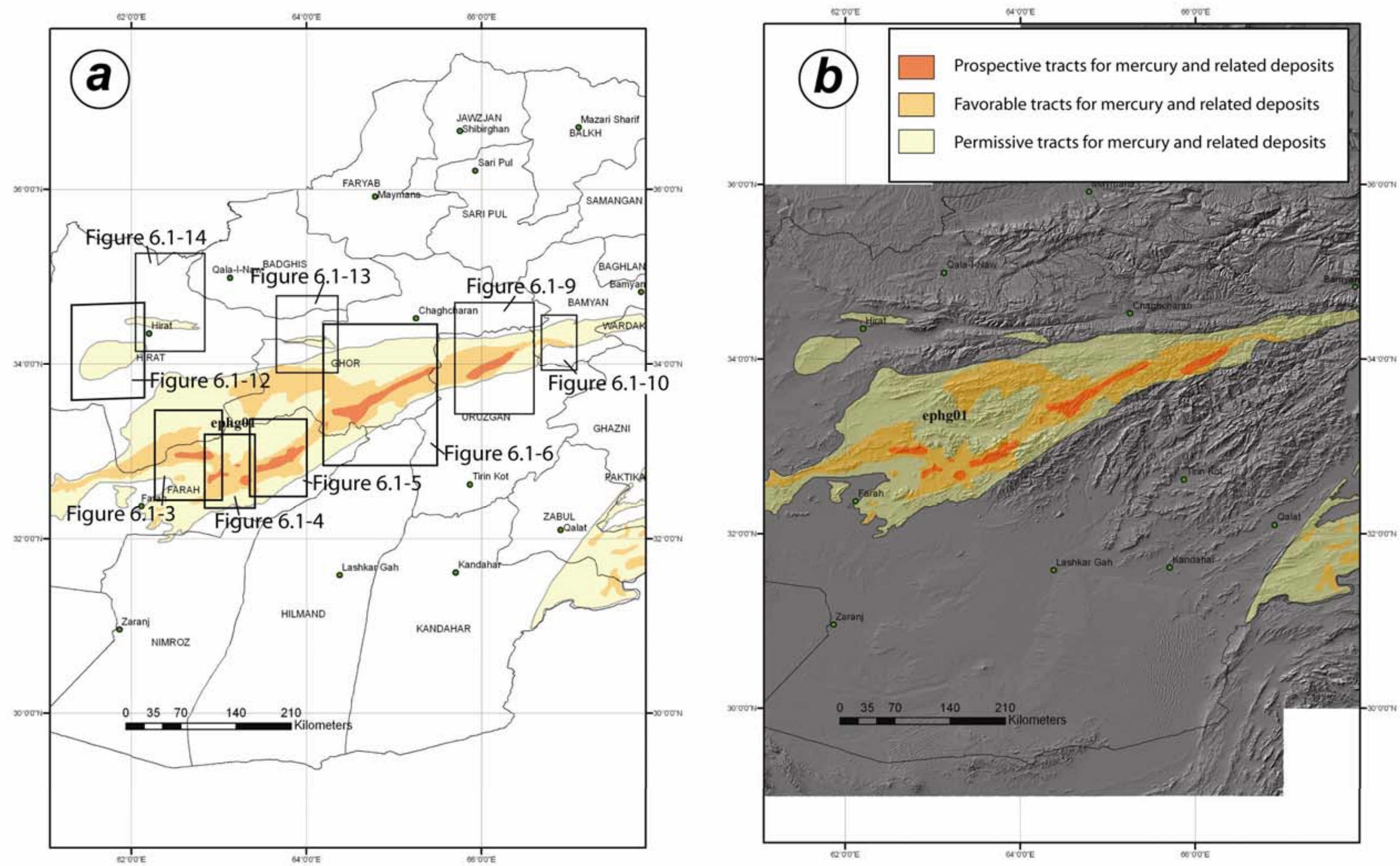

Figure 6.1-2. Location of permissive tract for epithermal (mercury) deposits, ephg01 Taywara mercury, showing province boundaries and shaded relief and internal favorable and prospective tracts.

Permissive tract ephg01 Karnak-Kanja Hg

***Deposit Typ*e—**Hot-spring mercury and epithermal precious metal deposits

***Age of Mineralization*—**Miocene

***Examples of Deposit Type*—**There are numerous mercury occurrences and locally some base-metal polymetallic vein and skarn deposits. The two largest deposits are the Kharnak and Duwalak mercury deposits.

***Exploration history*—**There has been some mining as evidenced in "ancient workings" in the Kharnak and Duwalak areas. Most of the major occurrences were visited, measured, and assayed by the Russians during the 1970s. Ancient workings are also found around the Kharnak, Qasem and Kho-i-Katif mercury prospects (Abdullah and others, 1977).

***Tract boundary criteria*—**The western most permissive ephg01 Karnak-Kanja tract is elongated east-northeast within the Provinces of Farah, southern Herat, Ghor, and northern Uruzgan (figs. 6.1-1 and 6.1-2a). The tract was delineated to encompass mainly Early Cretaceous sandstone, siltstone, limestone, and marl (map units K_1vhssl, K_1baplss, K_1berssl from Doebrich and Wahl, 2006) that was intruded locally by plutons and stocks of Oligocene granite, granite porphyry, granodiorite, quartz syenite, and granosyenite; these are overlain by Eocene to Oligocene basalt, andesitic basalt, trachyte, dacite, rhyolite, ignimbrite, tuff, conglomerate, sandstone, siltstone, and limestone. Locally included in the permissive tract eph01 are thin cover deposits of Late Pleistocene alluvial and colluvial deposits in the southwest parts, and Late Jurassic sedimentary rocks in the Farakhrud Basin. Numerous mercury-dominant epithermal occurrences are present along a central zone of the permissive tract eph01 and are associated with silicified bodies in Paleogene volcanic and sedimentary sequences. A favorable tract, eph01-f1, was constructed along the central part of the permissive zone to encompass the main mineral occurrences and Miocene intrusive centers (fig. 6.1-2). In addition, seven (7) prospective tracts (eph01-p1, p2, p3, p4, p5, p6, and p7) were delineated around clusters of mercury-rich mineral occurrences within the favorable tract that are suspected of being mineralized centers. Each of the prospective tracts is discussed below.

***Most important data sources*—**Geologic map, mineral occurrence data base (Doebrich and Wahl, 2006; Abdullah and others, 1977; Orris and Bliss, 2002).

***Needs to improve assessment*—**The information that is most needed is intermediate-scale (1:100,000) geologic mapping and geochemical sampling. Local prospects should be visited and resampled and mapped in detail. Both would require site visits.

***Optimistic factors for deposit numbers*—**There are numerous mercury-bearing occurrences, prospects, deposits, all with similar geologic characteristics, many of which contain grades and sizes that proximate the hot-spring mercury and associated models. The central occurrences particularly are of large size and high grade in mercury. A number of the better described deposits also have base-metal sulfide minerals.

Pessimistic factors for deposit numbers**—**Many of the occurrences are small and have low grades. No stibnite has been described. Some of the prospective tract may be igneous-related base-metal systems and not part of the mercury metallogenic event.

Numerical estimate:

90%	11
50%	28
10%	78

Quantitative assessment**—**The estimate was made for undiscovered hot-spring type mercury deposits in tract ephgh01. The assessment team found that there is a 90 percent chance of 11 or more undiscovered deposits, a 50 percent chance of 28 or more, and a 10 percent chance of 78 or more (table 7.1-1). 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 37.16 undiscovered deposits and mean expected 32,234 metric tons Hg.

These estimates were used to generate probabilistic estimates of the amounts of copper and cobalt contained in the undiscovered deposits using Monte Carlo simulation (see section 1.3). The results are tabulated in table 6.1-2 and shown graphically in figures 6.1-11, and 6.1-12.

Prospective tract ephg01-p1 Zarmardan

The western-most prospective tract (ephg01-p1), in Farah Province and containing the Zarmardan mercury occurrence and lies along a 30–km-long, 5– to 8–km-wide, east-striking zone (fig. 6.1-3). The Zarmardan occurrence is present in a northeast-trending mass of Paleogene volcanic and sedimentary rocks that contain interbedded subvolcanic layers of intermediate composition. The southern parts of the mineralized occurrence are overlain by younger Tertiary sedimentary sequences. The ore zone is brecciated, hydrothermally altered, and contains thin quartz-calcite and calcareous veins, with minor disseminated cinnabar films assaying 0.03 to 0.05 wt. percent mercury (Litvinenko and others, 1972; Abdullah and others, 1977).

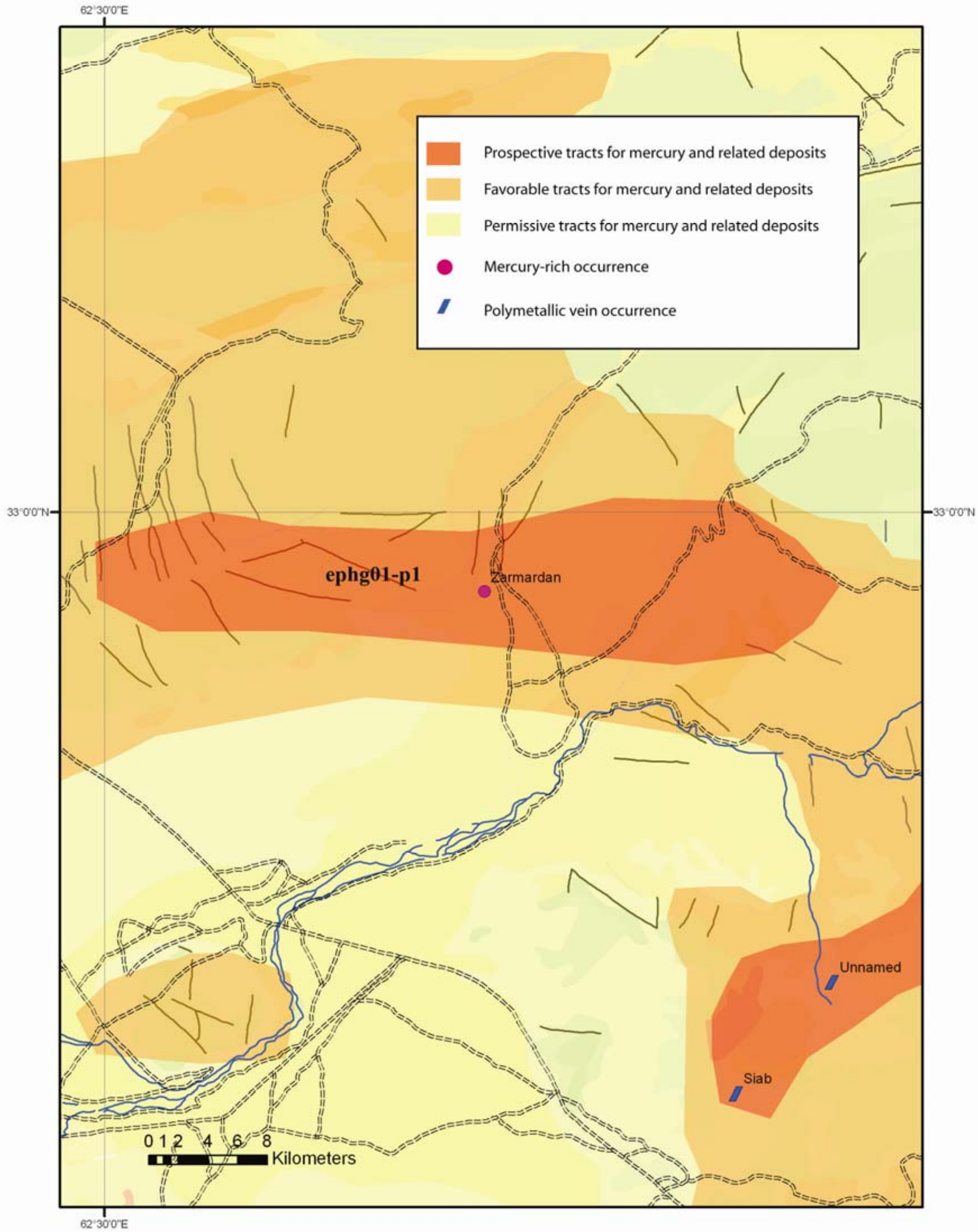

Figure 6.1-3. Location of prospective tract ephg01-p1 in northern Farah province, showing location of the Zarmardan mercury occurrence.

Prospective tract ephg01-p2 Rode-Duzd

A second group of prospective tracts (ephg01-p2, p3, and p4) (fig. 6.1-4) contains a number of base-metal veins and volcanic-hosted mineralized bodies associated with Eocene to Oligocene granitic plutons. These three clusters are mercury poor, but have epithermal characteristics. The western most of the prospective tracts (ephg01-p2) contains the Siab polymetallic vein and the Rode-Duzd copper occurrence, in addition to an unnamed polymetallic vein occurrence. The Saib occurrence is in Lower Cretaceous volcanic sedimentary rocks along an 800–m-long, 120– to 130–m-wide fault zone and contains 15– to 30–m-long, 1–m-wide quartz veins with disseminated copper sulfide minerals and galena, grading up to 2.98 wt. percent copper and 4.55 wt. percent lead with trace amounts of zinc (Dronov and others, 1972). The Rode-Duzd occurrence is present in ferruginous, partly chloritized Eocene to Oligocene andesite within a 10– to 20–m-thick zone containing 0.10 to 0.28 wt. percent copper as oxide minerals (Dronov and others, 1972).

Prospective tract ephg01-p3 Durbas

The northern prospective tract (ephg01-p3) in this area contains the two Durbas occurrences (fig. 6.1-4). The Durbar II occurrence has volcanogenic massive sulfide characteristics and is contained in an Oligocene subvolcanic dacite porphyry body that is hydrothermally altered in a 3,000– to 5,000–m-long, 20– to 200–m-wide with assays grading 0.01 to 0.30 wt. percent copper and up to 0.07 wt. percent zinc (Dronov and others, 1972). The adjacent Durbas 2–m-thick, 30–m-long barite vein contains base metals (Abdullah and others, 1977).

Prospective tract ephg01-p4 Ghurma

The Ghurma occurrence lies in the eastern prospective tract (ephg01-p4) of the cluster also containing tracts ephg01-p3, p3, p4 and can be divided into eastern and western parts along the contact between Oligocene granitic rocks and Eocene-Oligocene volcanic rocks (fig. 6.1-4). The eastern part lies along the northeastern contact of a granite body and consists of pyrite-bearing rhyolite dacite volcanic rocks lying in a 1–km-long, 100– to 120–m-wide zone grading 0.01 to 0.05 and up to 1.0 wt. percent copper. The western area contains several irregular-shaped quartz-calcite veins in a >40–m-wide zone containing abundant chalcopyrite, pyrite, and siderite. Mineralized rocks grade 0.01 to 9.68 wt. percent copper and trace amounts of lead and zinc (Dronov and others, 1972).

Prospective tract ephg01-p5 Chashnak-Mushkan

A fifth prospective tract (ephg01-p5) lies in northeast Farah Province and contains the Chashnak mercury occurrence in the northwest part, and the Duaba and Mushkan mercury occurrences in the northeast part. The existing measured ore grades of the mercury in each of the mineralized zones in these occurrences are in the thousandths wt. percent and not economic. The tract is elongated northeast and is parallel to the underlying Cretaceous stratigraphy and to northeast-striking faults. The Chashnak occurrence lies in Eocene to Oligocene terrestrial volcanic rocks along the contact of intermediate to mafic dikes where mercury mineralization is present in small hydrothermally altered zones. The Duaba occurrence is hosted in Lower Cretaceous sedimentary rocks along the contacts with a diorite porphyritic dikes that are altered to carbonate assemblages in 160–m-long, 0.5– to 1.0–m-wide zones these zones contain thin veinlets with disseminated cinnabar. The Mushkan occurrence has similar geology to the Duaba occurrence and is present in a 180–m-long, 1.0–m-wide altered zone (Litvinenko and other s, 1972).

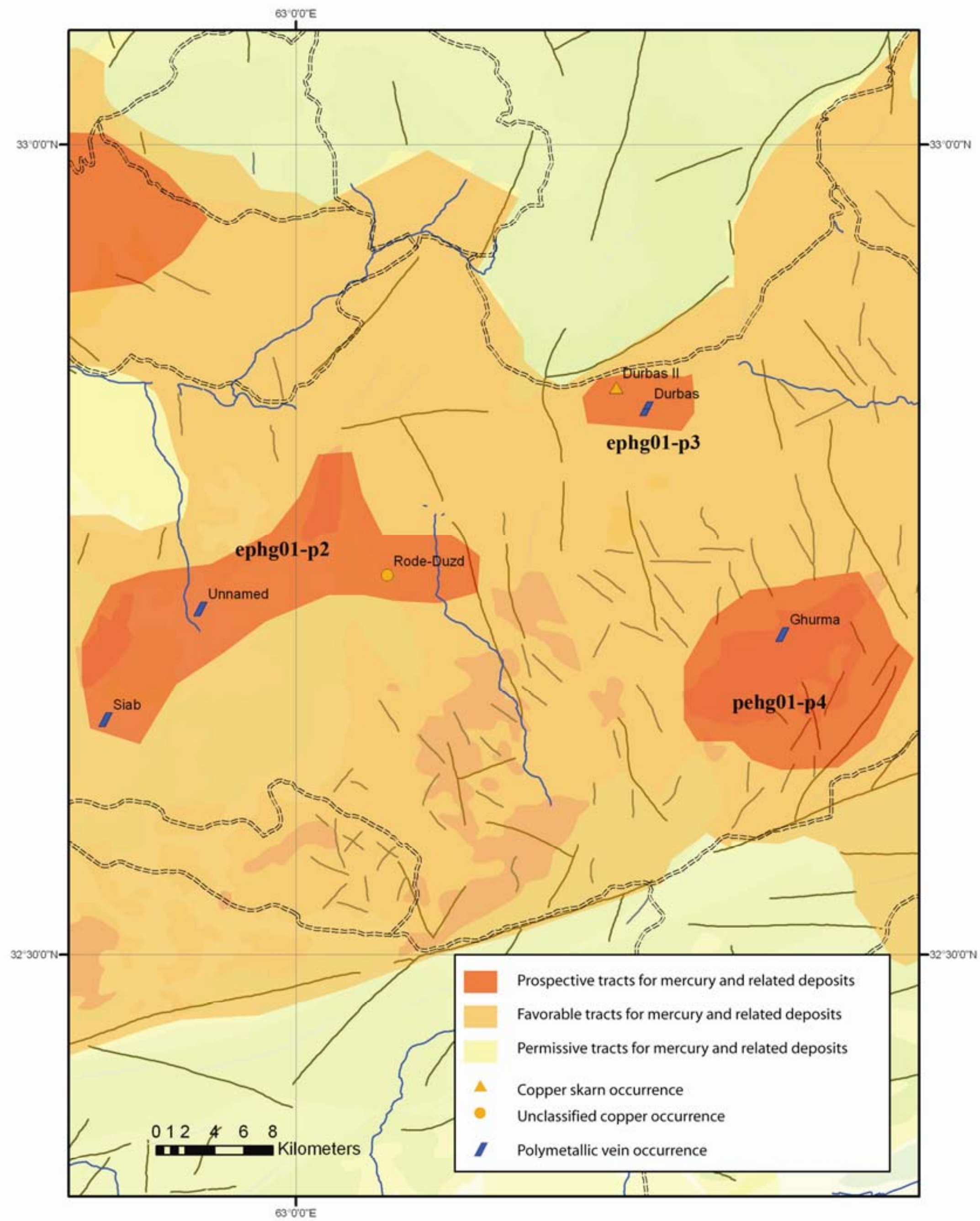

Figure 6.1-4. Location of prospective tracts ephg01-p2, p3, and p4 containing vein and contact-related base-metal occurrences associated with Eocene to Oligocene plutons and stocks.

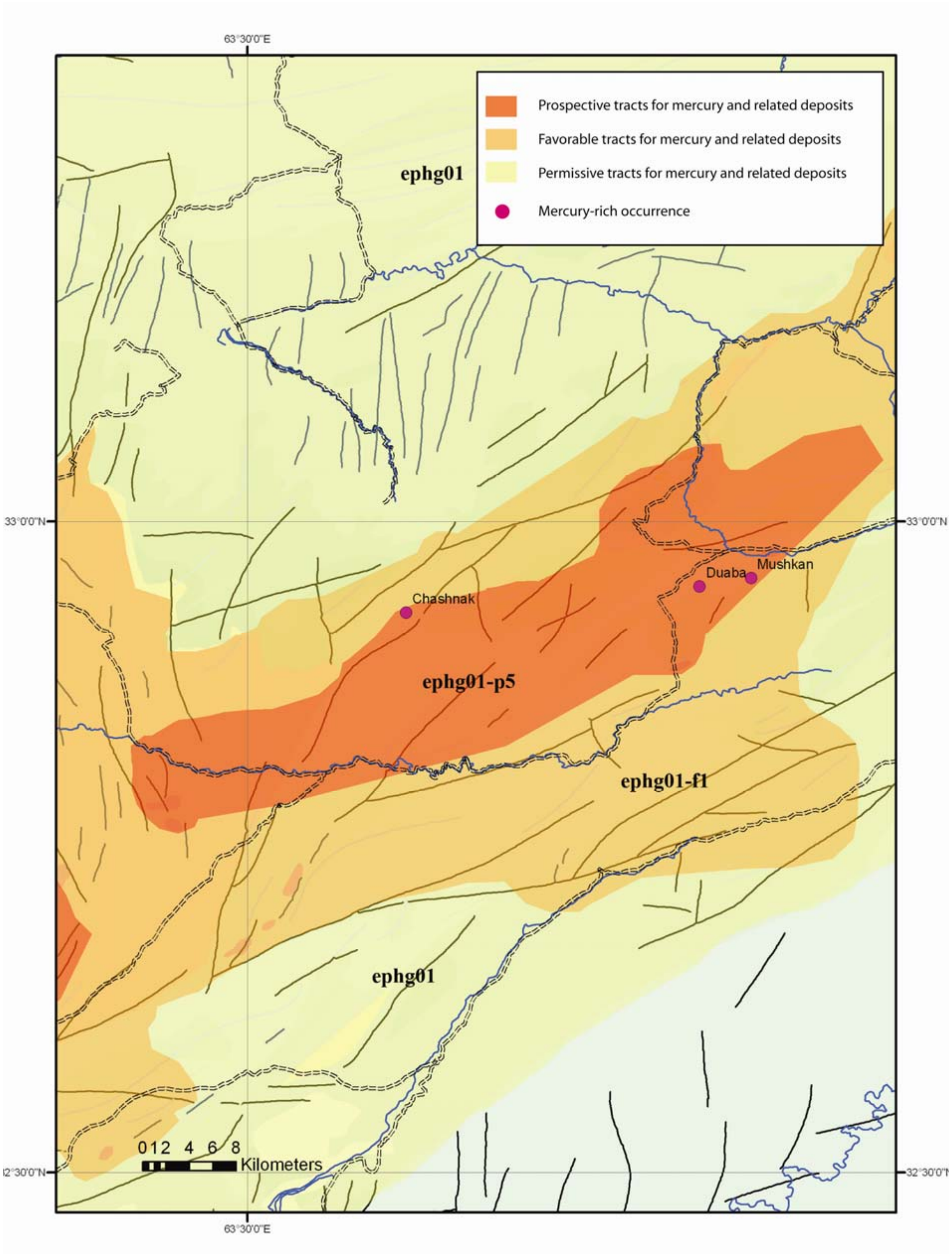

Figure 6.1-5. Prospective tract ephg01-p5 in northeastern Farah Province, showing the location of the three known mercury-bearing mineral occurrences there.

Prospective tract ephg01-p6 Gariba

In the southwest part of Ghor Province a small prospective tract (ephg01-p6) and a larger prospective tract (ephg01-p7) were delineated around mineral occurrences within the favorable tract ephg01-f1 (fig. 6.1-6). The smaller ephg01-p6 tract contains the Gariba copper skarn occurrence, is associated with a group of Late Cretaceous to Paleocene diorite bodies and north-striking faults, and forms a 3,000–m-long and 40– to 60–m-wide skarn zone in Lower Cretaceous limestone assaying 0.18 to 3.24 wt. percent copper with anomalous values of lead, zinc, molybdenum and tungsten (Dronov and others, 1973).

Prospective tract ephg01-p7 Kharnak-Kanjar

The larger prospective tract in southwest Ghor Province is ephg01-p7 that contains most of the larger mercury occurrences in Afghanistan (figs. 6.1-6 and 6.1-7). The 120–km-long and approximately 10–km-wide tract is elongated east northeast and lies roughly parallel to the structural grain of the enclosing Cretaceous volcanic and sedimentary rocks. The tract contains about 20 major occurrences in two main groups. One group is present in the southwest and the other group lies in the northeast. The southwest part of the prospective ephg01-p7 tract lies south of the city of Taywara (figs. 6.1-6 and 6.1-7) and contains the Parjshah and Mullayan mercury prospects in the west, the Kharnak deposit and Pushwara prospect in the central part, and the Qasem, Kho-i-Katif, Katif, Duwalak, Srukhnow and Sebak mercury occurrences in the east parts.

The Panjshah prospect is hosted in Lower Cretaceous, continental carbonate rocks that are intruded by porphyritic diorite dikes and cut by steep faults. The mineralized zones contain dickite and carbonate with disseminations of cinnabar in up to 1.6– by 1.4– by 1.0–m-size pods grading thousandths of wt. percent mercury (Likvinenko and others, 1972; Orlov and others, 1972). The Mullayan prospect is present along a fault containing zones of carbonate, silica, and dickite in Lower Cretaceous siltstone and limestone that is intruded by diorite dikes and contains two areas of intensive quartz-dickite alteration. The first area is 3.5 by 2.0 m containing narrow cinnabar veinlets and disseminations with an average grade of 0.01 wt. percent mercury. The second area is up to 200 m long and 9 m wide and grades 0.09 wt. percent mercury.

The Kharnak mercury deposit is large and rich and the site of abundant ancient workings. The ores are hosted in Lower Cretaceous calcareous siltstone in contact with an intrusive. Mineralization is present in 500–m-long, 100– to 170–m-wide, strongly altered dickite-calcite zones. There are three zones at Kharnak with continuous mercury mineralization as disseminations and minor veinlets that lie strongly altered zones. Some zones are 160 m long and 1 to 5 m wide and grade between 0.10 and 0.63 wt. percent mercury and locally up to 3.2 wt. percent mercury. Mercury mineralization is also present between the main three zones and grades between 0.12 and 0.40 wt. percent mercury (Kornev and others, 1975). The Pushwara prospect lies in a similar geologic setting to the Kharnak deposit consisting of a 700–m-wide fault zone containing carbonate-dickite altered Miocene porphyry dikes. The mineralized area is 2,200 by 700 m in size and contains 6 separate occurrences of cinnabar as veinlets and disseminations (Kornev and others, 1975).

To the northeast (fig. 6.1-7), the Qasem mercury occurrence contains ancient workings and lies in brecciated, altered (carbonate-dickite) Lower Cretaceous sedimentary rocks. The Qasem area contains zones that are between 1 by 3 to 5 m and 20 by 100 m in size containing sparse cinnabar in calcareous veinlets or disseminations (Kornev and others, 1975). The Kho-i-Katif occurrence lies within an area of 20 by 50 m that contain ancient workings (Kornev and others, 1975). The Kho-i-Katif mercury occurrence is restricted to highly altered (calcite-dickite) 100– to 150–m-long, 10– to 20–m-thick major fault zones. One of these zones contains up to 1.5–cm-thick veinlets and dissemination of cinnabar and ore grades of 0.86 wt. percent mercury. An additional mineralized zone at Kho-i-Katif is 43 m long and 1 m wide, and grades 0.51 wt. percent mercury (Orlov and others, 1972).

The adjacent Duwalak occurrence is hosted in Lower Cretaceous rocks and contains two northeast-striking zones comprised of brecciated siltstone, mudstone, sandstone and limestone that have been altered to calcite and dickite. The three (3) mineralized bodies in the eastern zone are 4 to 140 m long, 4 to 6 m wide and assay 0.2 to 0.72 wt. percent mercury. The western zone is 750 m long and 75 to 160 m wide, but has grades less that 0.07 wt. percent mercury (Kornev and others, 1975).

In the far eastern part of this cluster, in the southwest part of prospective tract ephg01-p7, the Surkhnow occurrence also is present along a 2,000–m-long, 100– to 400–m-wide fault zone that encloses three areas, some up to 1,000 m^2, in Lower Cretaceous sedimentary rocks. The zones contain dickite and calcite and disseminations of cinnabar assaying 0.25 wt. percent mercury (Kornev and others, 1975). The Sebak occurrence to the north lies in a 300– to 400–m-wide fault zone in dickite- and calcareous-altered Lower Cretaceous rocks and is intruded by numerous Miocene (?) altered porphryitic dikes containing cinnabar disseminations and thin cinnabar veinlets, grading 0.08 wt. percent mercury. The area lies within a 1,300–m-long cinnabar geochemical-mineralogical halo (Kornev and others, 1975).

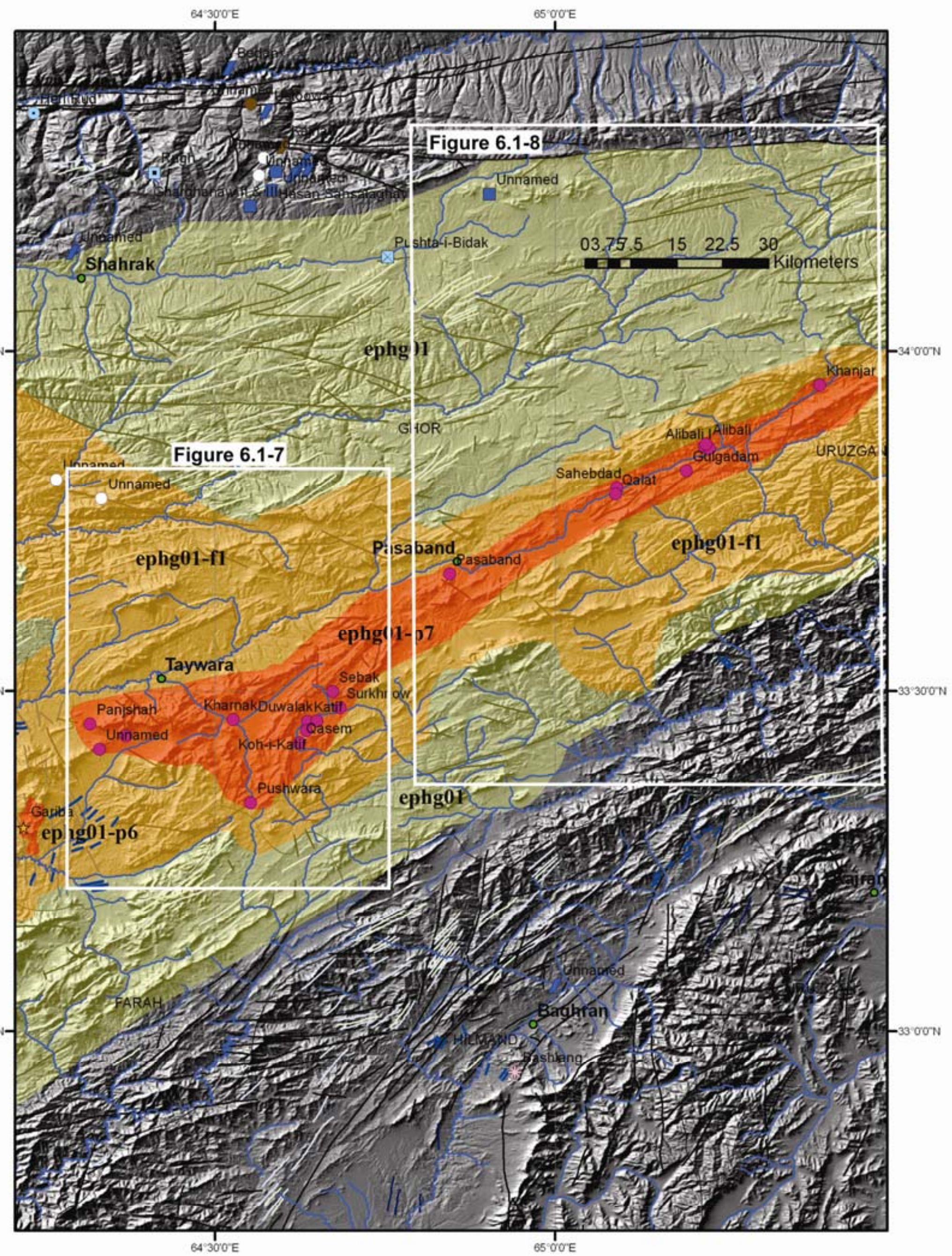

Figure 6.1-6. Prospective tracts ephg01-p6 and ephg01-p7 within favorable tract ephg01-f1 and permissive tract epgh01, for undiscovered mercury deposits in southwest Ghor Province.

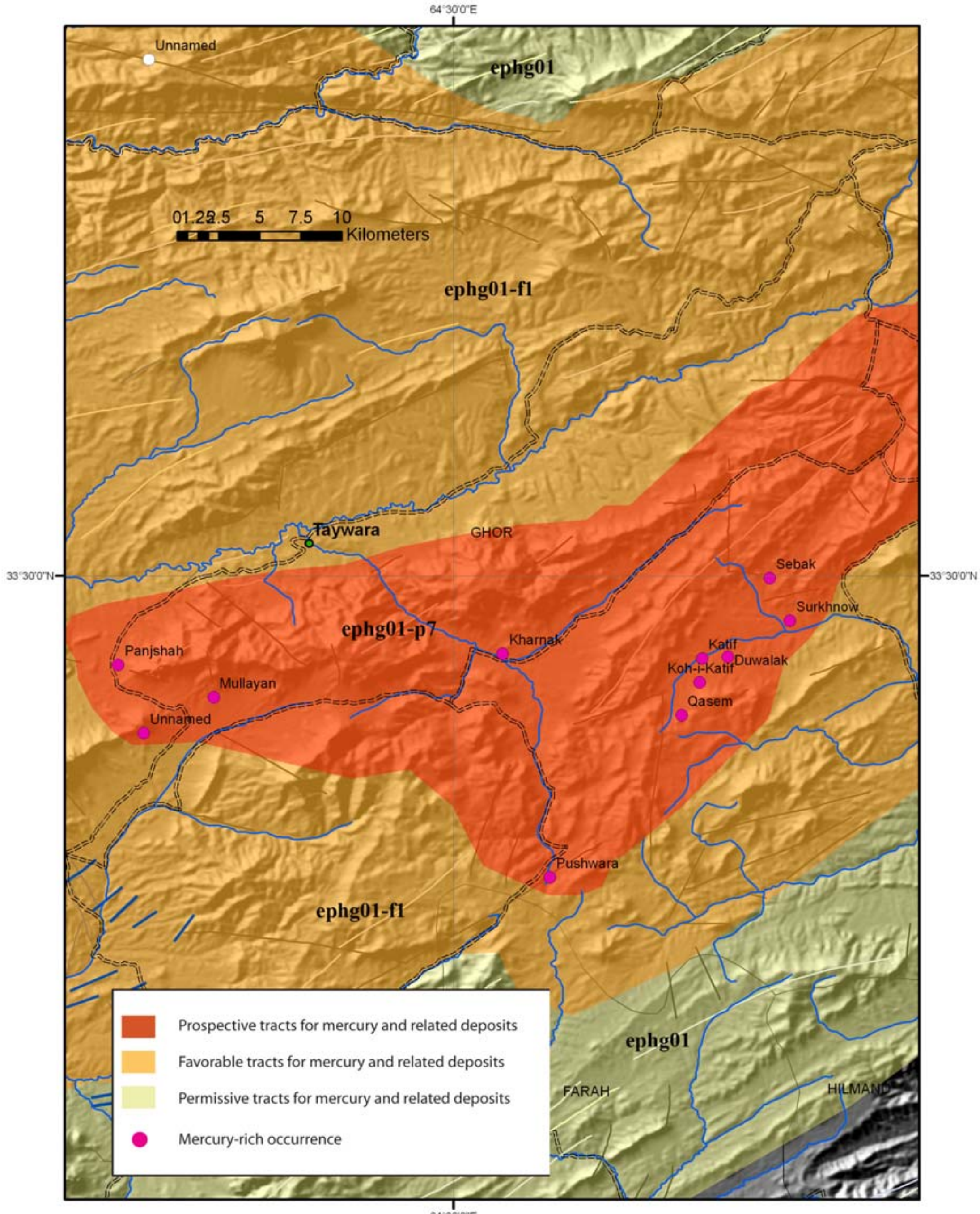

Figure 6.1-7. Clusters of mercury occurrences, many with ancient workings, in the southwest lobe of prospective tract ephg01-p7 south of Taywara in southwest Ghor Province. This is the most highly mineralized area known in Afghanistan for mercury.

The northeast part of prospective tract ephg01-p7 lies in Oruzgan Province and is about 7 km wide and contains eight (8) or nine (9) mercury occurrences along a linear, east northeast-trending tectonic zone (figs 6.1-7 and. 6.1-8). From the southwest to the northeast, the mercury occurrences are the Pasaband, Qalat, Sahebdad, Gulgadam, Alibali Group, and Khanjar occurrences. The Pasaband occurrence is hosted in Lower Cretaceous sedimentary rocks and that are intruded by diorite porphyry dikes and shattered by faults. The 400–m-long and 3– to 8–m-wide mineralized zones are hydrothermally altered to dickite and calcite-bearing breccia zones, which grade a few hundredths wt. percent mercury (Orlov and others, 1972).

The Qalat mercury occurrence has similar geology and has 145– to 300–m-long and 3– to 22–m-wide mineralized zones with intense dickite-carbonate-quartz alteration of siltstone and porphyritic dikes. The mineralized disseminations and veinlets carry cinnabar, pyrite, and locally arsenopyrite and realgar, grading 0.0001 to 0.440 wt. percent mercury. Zones I, II, and III at Qalat are 60 to 90 m long and average about 2 m thick and grade 0.38, 0.16 and 0.10 wt. percent mercury respectively (Mesechko and others, 1972; Pokidyshev and others, 1974). The Sahebdad mercury occurrence north of Qalat has similar geology to Pasaband and Qalat and is present in 160–m-long, 10– to 20–m-wide zones containing minute cinnabar disseminations and veinlets grading 0.6 (and up to 0.78) wt. percent mercury (Mesechko and others, 1972).

The Gulgadam mercury occurrence, in the northeast part of prospective tract ephg01-p7, is present along fault zones in Lower Cretaceous calcareous sedimentary rocks that are intruded by diorite porphyry dikes and contains thin veinlets, films, and minute cinnabar disseminations. Two *en echelon* structures are hosted in sheared, hydrothermally altered, brecciated siltstone. Both are about 150 to 170 m long and 5 to 8 m wide with low (~0.006 wt. percent mercury) ore grades (Pokidyshev and others, 1974).

Three prospects bear the name Alibali and are all hosted in Lower Cretaceous sandstone and siltstone, which are severely altered and associated with porphyritic diorite dikes. The first is 1,000 m long and 100 to 250 m wide with small <1.0–m-scale zones that contain finely disseminated cinnabar grading 0.1.0 wt. percent mercury. A second prospect is 530 m long and 5.4 m wide grading 0.015 and up to 0.34 wt. percent mercury. The third prospect is 250 m long and 5.3 m wide and contains grades up to 1.56 wt. percent mercury with values of tin, copper, lead, zinc and silver (Pokidyshev and others, 1974). At the north-northeast part of the ephg01-p7 prospective tract, the Khanjar mercury occurrence is present along faults in Lower Cretaceous continental carbonate-bearing sedimentary rocks; these rocks occur as brecciated, shattered zones that have been hydrothermal altered over 1.0 km long and 2 to 40 m wide. Smaller meter-scale mineralized zones also are present within these shattered zones and grade from 0.35 to 0.96 wt. percent mercury (fig. 6.1-8)

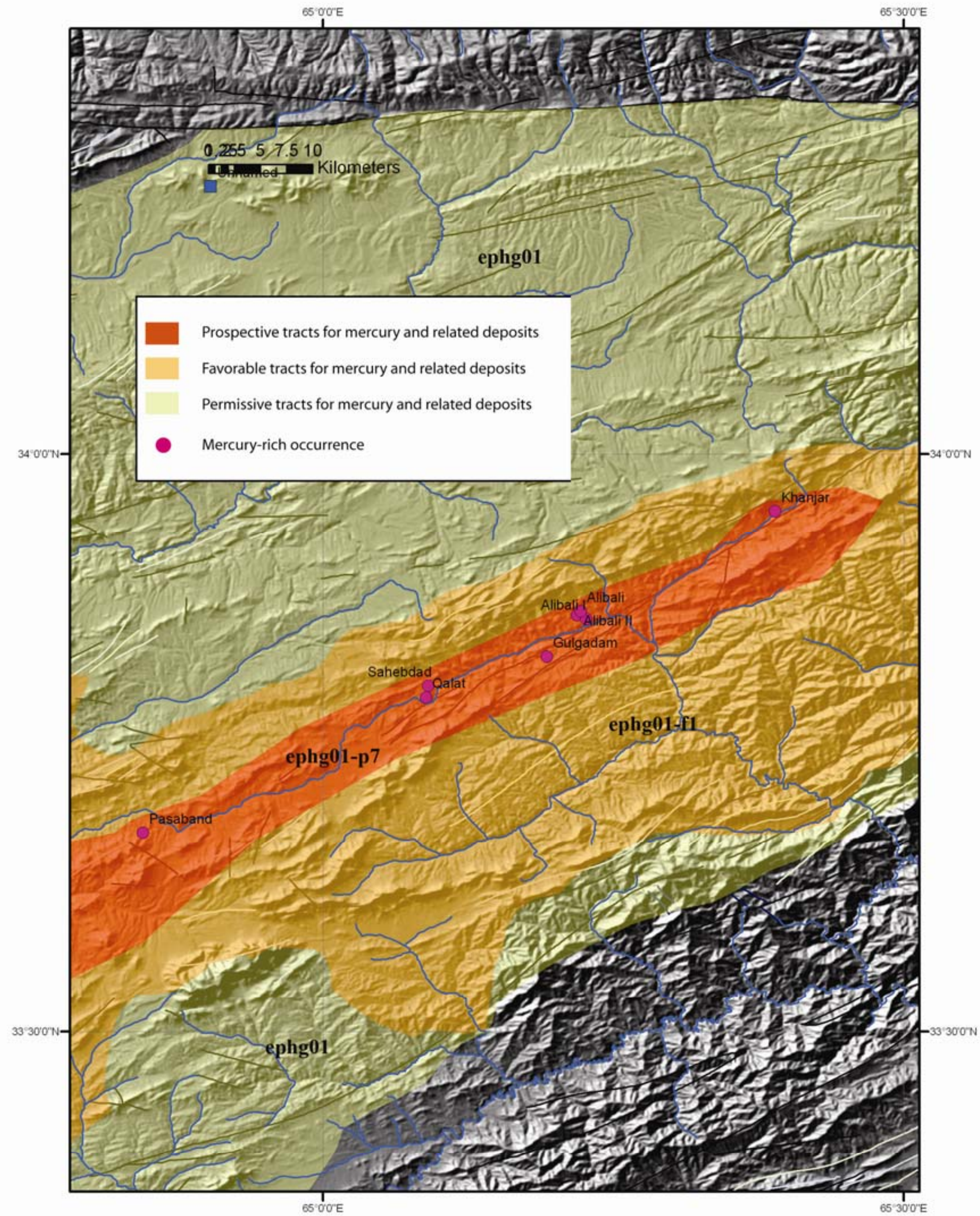

Figure 6.1-8. Prospects and shape of northeast part of the prospective tract ephg01-p7 for mercury deposits in Uruzgan Province.

Prospective tract ephg01-p8 Darwaza-Surkh-Joi-Gardesh

A 45–km-long prospective tract, ephg01-p8 Darwaza-Surkh-Joi-Gardesh, was delineated to encompass the northeast-trending zone within favorable tract epgh01-f1 that encompasses the Darwaza Mercury, Surkh-Joi and Gardesh mercury occurrences. The Darwaza Mercury occurrence is the largest mercury occurrence in the tract and is present along a fault zone in Upper Jurassic to Lower Cretaceous volcano-sedimentary rocks. The 100–m-wide, 860–m-long, brecciated, mineralized zone is hosted in Lower Cretaceous red beds and contains 2– to 10–m-wide zones that grade 0.34 wt. percent mercury. The Surkh-Joi occurrence is contained in Lower Cretaceous red beds along a 400–m-long, 250–wide-zone containing 12 bleached zones that are between 30 and 50 m to 100 to 200 m long and 0.2 to 0.5 m, and up to, 6.1 t 8.0 m wide, typified by disseminated cinnabar and anomalous concentrations of mercury (Litvinenko and others, 1972). The Gardesh mercury occurrence lies within a zone of intense dickite alteration in sandstone, siltstone and limestone that contains lenses with cinnabar veinlets and disseminations also with highly anomalous concentrations of mercury.

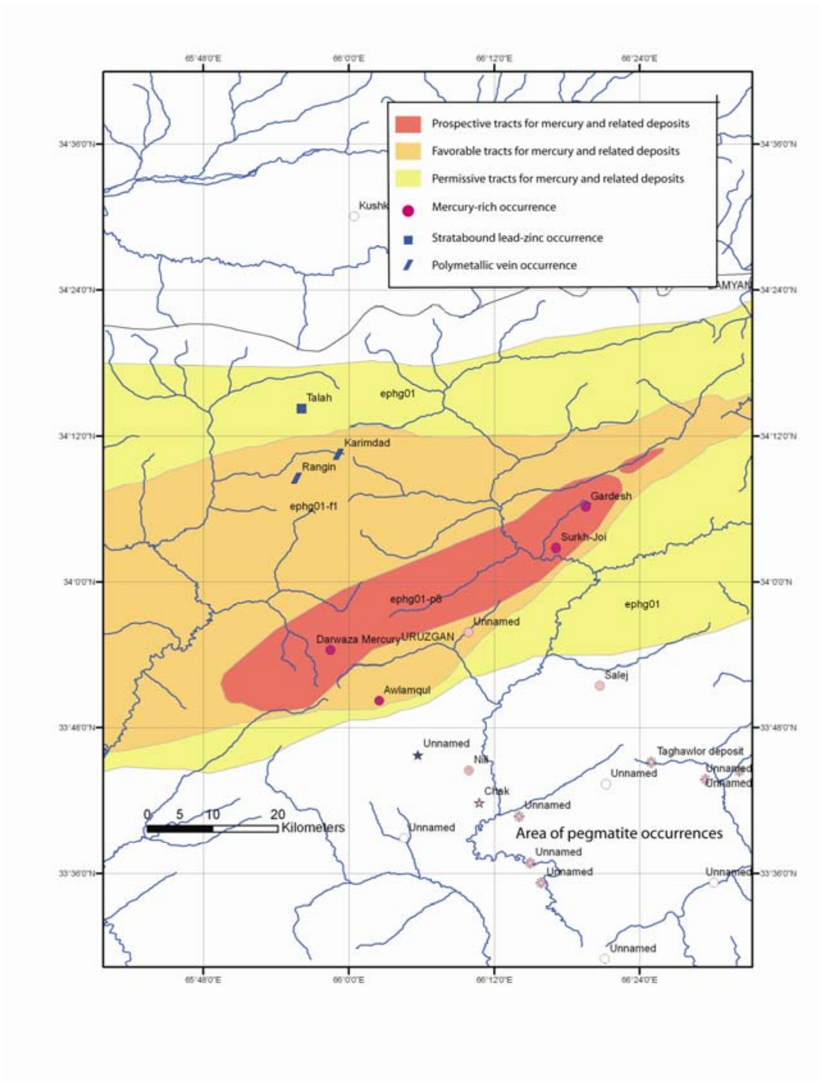

Figure 6.1-9. Map showing location of prospective tract ephg01-p8 containing the Darwaza mercury occurrence and two other occurrences. The tract lies at the northeastern tip of the favorable tract ephg01-f1.

Favorable tract ephg01-f2 Solghoi-Sewak

A favorable tract, ephg01-f2, was delineated in the eastern part of the Taywara ephg01 permissive tract in Bamyan Province (fig. 6.1-10). The tract was drawn along the grain of the Lower Cretaceous sedimentary rocks that also contain several elongated Cretaceous dunite bodies. Some of the characteristics described by Russian workers are similar to those in the Silica-carbonate Hg deposit model however the alteration is more consistent with hot spring type mercury mineralization present in the mercury mineral belt. Three mineral occurrences are known to be present in the central parts of the tract, the Solghoi, and Sewak mercury occurrence and the Waraz copper occurrence (fig. 6.1-10). The Solghoi occurrence is hosted in a 500–m-long and 300–m-wide zone in Lower Cretaceous pebble conglomerate grading between trace amounts and up to 0.7 wt. percent mercury (Kornev and Arvanitaki, 1974). The Sewak occurrence is smaller, has similar characteristics and is hematite rich (Orris and Bliss, 2002). The Waraz copper occurrence is hosted in a 300–m-long fracture zone that separates Lower Cretaceous ultramafic rocks from continental carbonate-bearing sedimentary rocks. Mineralization is in carbonated lenses, accompanied by copper oxide minerals.

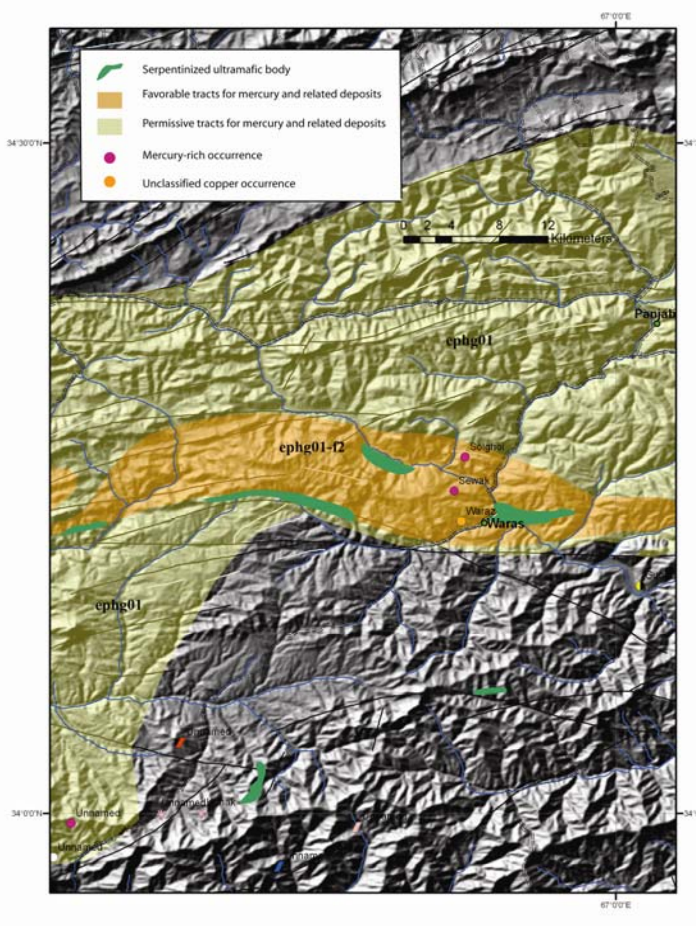

Figure 6.1-10. Map showing location of favorable mercury epithermal tract ephg01-f2 in Bamyan Province within permissive tract ephg01. The three mineral occurrences also lie proximal to elongate Cretaceous dunite bodies (green).

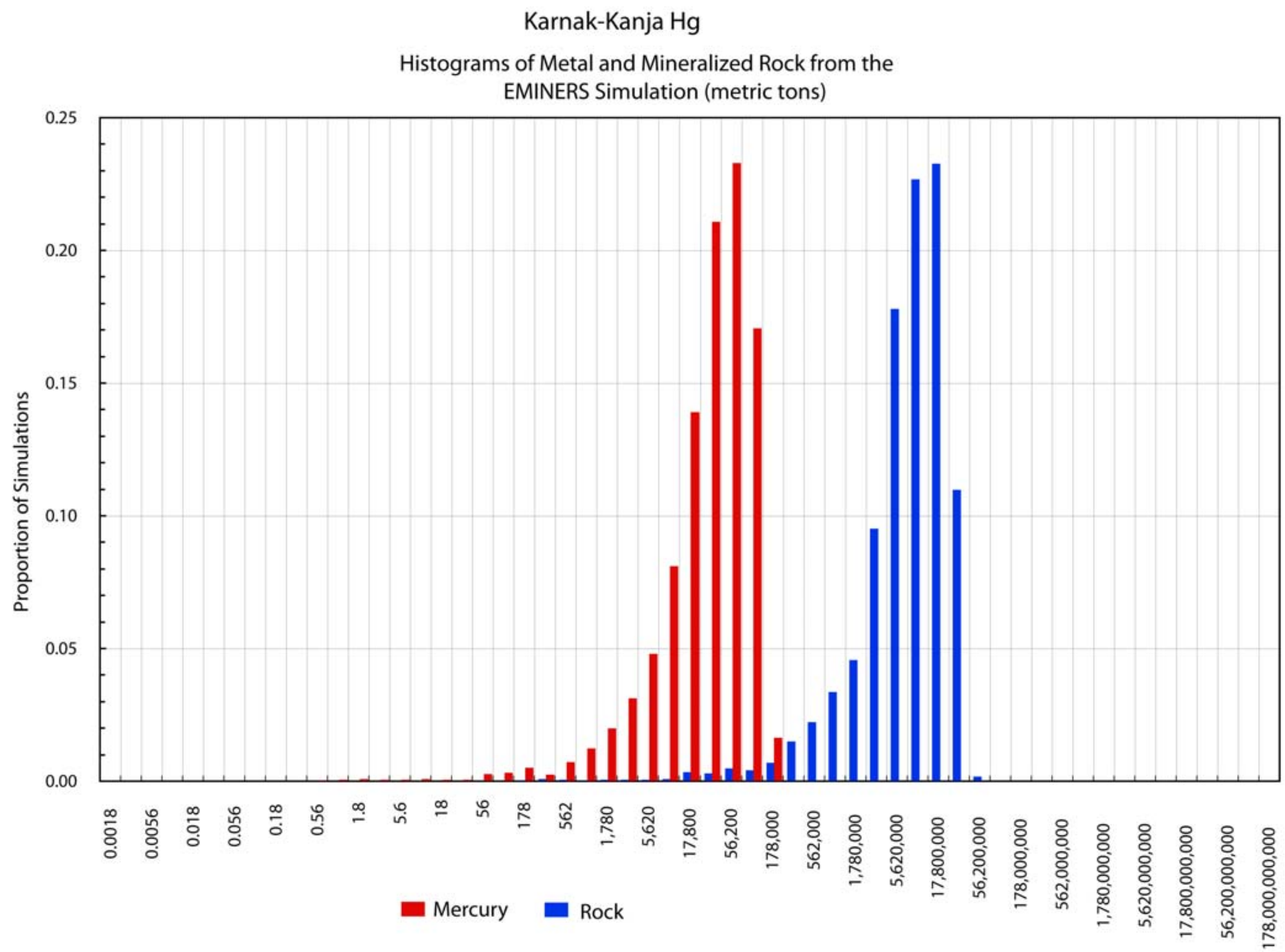

Figure 6.1-11. Histogram of estimated contained metal and mineralized rock in tract ephg01.

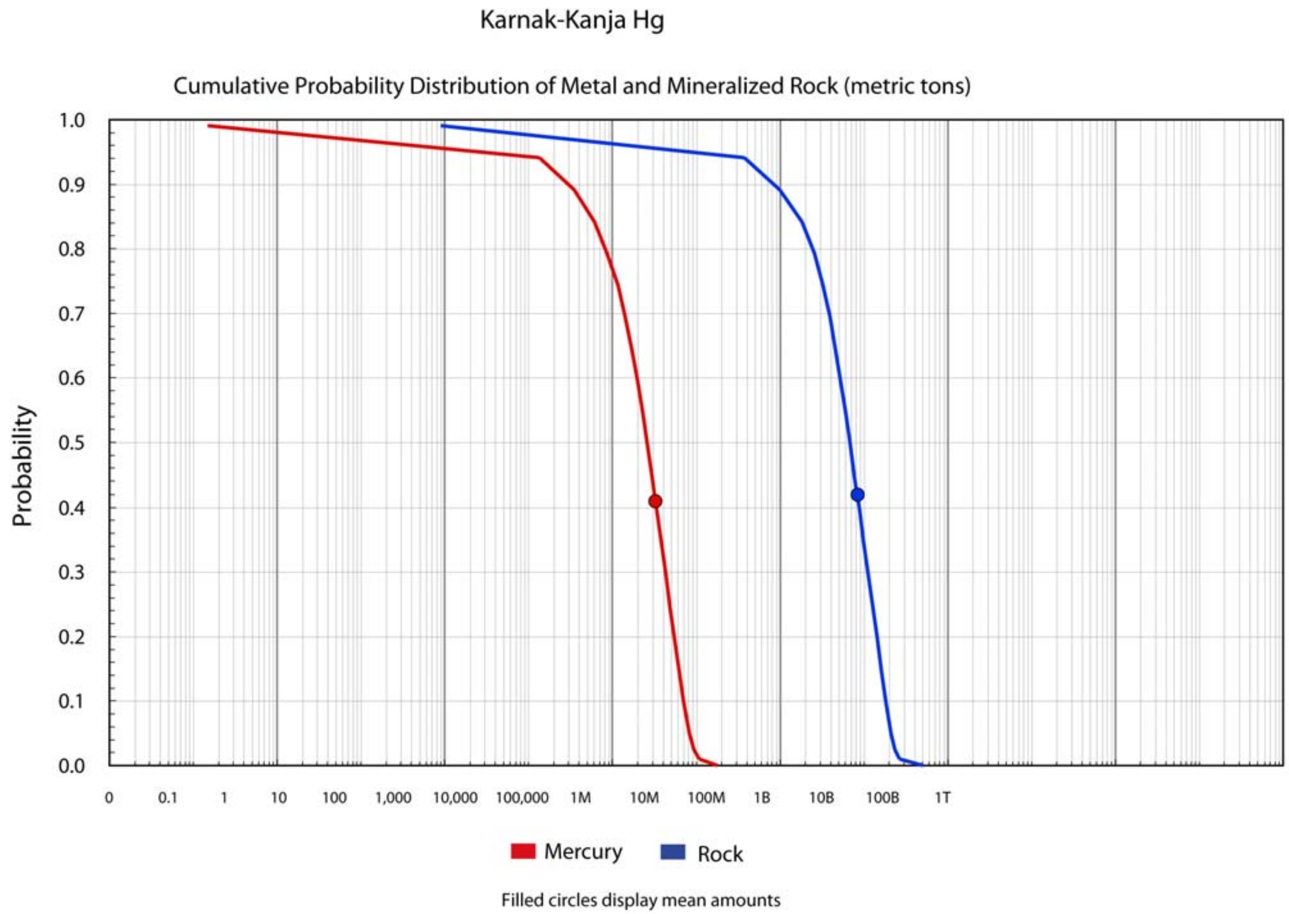

Figure 6.1-12. Cumulative distributions of estimated contained metal and mineralized rock in the Karnak-Kanja Hg tract ephg01.

Summary of Assessment Results

The tract ID is.................... Karnak-Kanja Hg
The EMINERS model is........ Hot Springs Hg(27a)

There is a 90% or greater chance of 11 or more deposits.
There is a 50% or greater chance of 28 or more deposits.
There is a 10% or greater chance of 78 or more deposits.

Mean Number of Deposits = 37.2

Estimated amounts of contained metal and mineralized rock (metric tons)

Quantile	Hg	Rock	0	0	0	Present Value
0.95	1,100	290,000	0	0	0	$0
0.90	3,200	890,000	0	0	0	$0
0.50	26,000	6,800,000	0	0	0	$0
0.10	71,000	18,000,000	0	0	0	$0
0.05	83,000	21,000,000	0	0	0	$0
Mean	32,000	8,400,000	0	0	0	$0
Probability of mean or more	0.41	0.42	0.00	0.00	0.00	0.00
Probability of zero	0.01	0.01	0.00	0.00	0.00	1.00

Table 6.1-2. Table showing probabilistic distribution of estimated contained metal and mineralized rock for undiscovered hot-spring mercury deposits permissive tract ephg01 Karnak-Kanja Hg.

In addition to permissive tract ephg01, four (4) additional permissive tracts were delineated in North Shaida, Tilak, Mayak and Katawaz areas. These tracts (fig. 6.1-1), however, did not contain enough information for quantitative estimates.

Permissive tract ephg02 North Shaida mercury

Deposit Type—Hot-spring mercury and epithermal vein precious-metal deposits.

Age of Mineralization—Eocene to Oligocene

Examples of Deposit Type—There are no known examples of the deposit type in the tract.

Exploration history—No known exploration has taken place within the tract other than regional stream geochemistry and geologic mapping by the Russians.

Tract boundary criteria—The tract was delineated around three mercury geochemical halo anomalies; it also includes part of a lead halo and Au anomaly. The north and south boundaries of the tract roughly follow the grain of the enclosing country rocks (fig. 6.1-12).

Most important data sources—Geochemical halo data, Geologic map and mineral occurrences of Afghanistan (Doebrich and Wahl, 2006; Abdullah and others, 1977).

Needs to improve assessment—The information that is most needed is intermediate-scale (1:100,000) geologic mapping and geochemical sampling. Local prospects should be resampled and mapped.

Optimistic factors—Three strong geochemical anomalies are present, including a geochemical halo anomaly for gold. The tract is located proximal to mercury deposits to the southeast.

Pessimistic factors for deposit numbers—No known mercury occurrences and Cenozoic plutonic rocks are not reported. Also, the area is isolated from most other mercury deposits.

Quantitative estimate—No quantitative estimate was made by the USGS AGS assessment team due to lack of information.

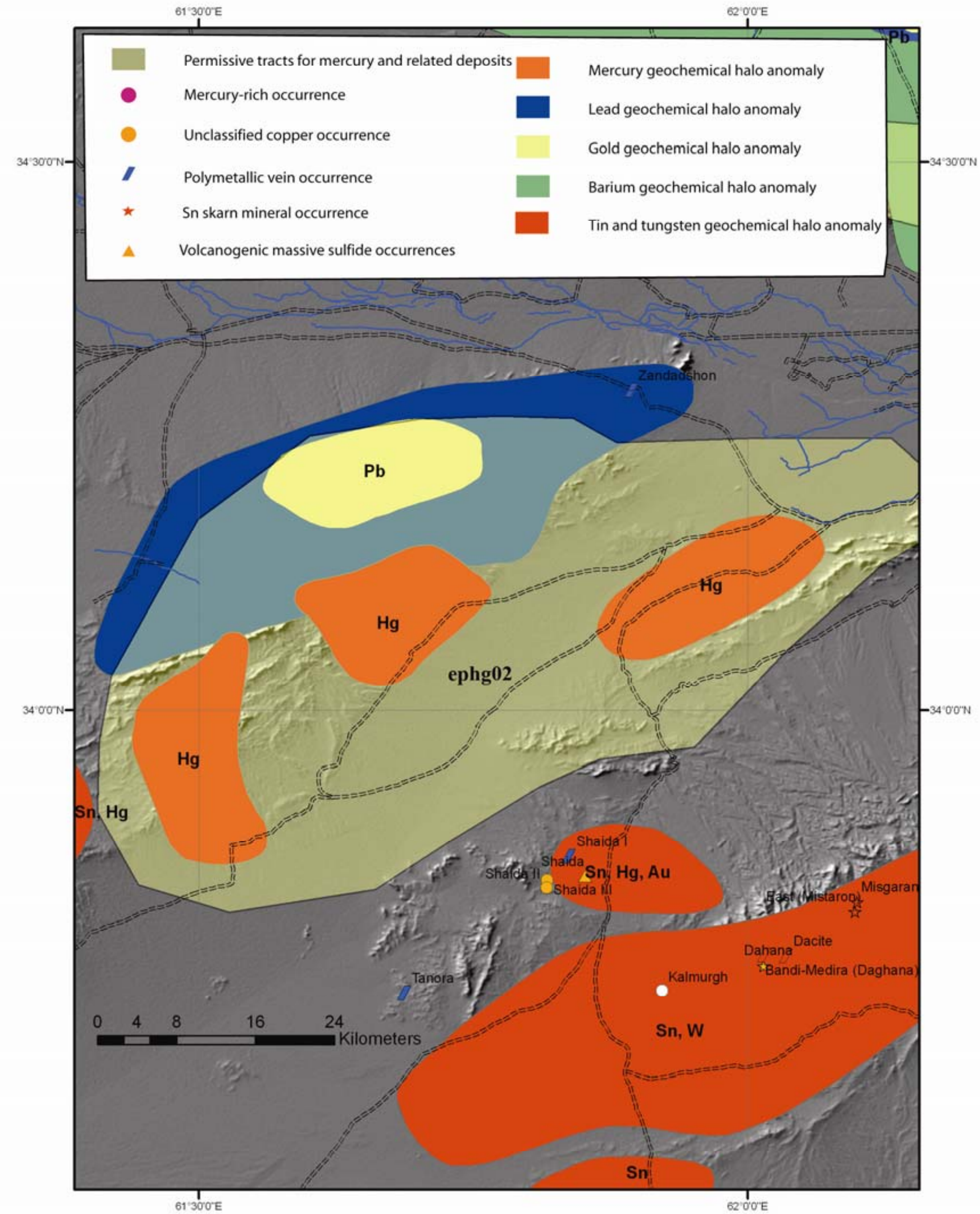

Figure 6.1-12. Location of permissive tract ephg02 for undiscovered mercury epithermal deposits and related precious-metal epithermal deposits in Herat Province. Mercury, lead-zinc, and gold (yellow) geochemical anomalous halos are also shown (see legend). See fig. 6.1-2 for location.

***Deposit Type*—**Hot-spring mercury and epithermal vein precious-metal deposits.

***Age of Mineralization*—**Eocene to Oligocene

***Examples of Deposit Type*—**The Tilak mercury occurrence lies in the central part of the tract (figs 6.1-2 and. 6.1-13). The Tilak occurrence lies within Oligocene red sandstone and siltstone in irregular 450–m-long and 0.1– to 4– and up to 15–m-wide bleached zones that contain disseminated cinnabar and grade between 0.05 and 0.06, and up to 0.13 wt. percent mercury (Kornev and others, 1975).

***Exploration history*—**No known exploration has taken place within the tract other than regional stream geochemistry by the Russians and prospecting near the known occurrences.

***Tract boundary criteria*—**The tract was delineated in Ghor and Herat Provinces around rocks containing the Tilak mercury occurrence, which consists of Oligocene sandstone, siltstone, clay, conglomerate, limestone, marl and felsic and mafic volcanic rocks. (Map unit P_3ssl, Doebrich and Wahl, 2006). The north and south boundaries of the tract roughly follow the grain of the enclosing country rocks (fig. 6.1-13). A mercury-lead geochemical halo anomaly lies to the south and within part of the central part of the tract.

***Most important data sources*—**Geochemical halo data, Geologic map. Mineral occurrence data base (Orris and bliss, 1977; Doebrich and others, 2006; Abdullah and others, 1977).

***Needs to improve assessment*—**The information that is most needed is intermediate-scale (1:100,000 and 1:25,000) geologic mapping and geochemical sampling. Local prospects should be visited and resampled and mapped in detail.

***Optimistic factors*—**The Tilak mercury occurrence, mercury geochemical halo anomaly and host rocks similar to the major tract to the south (ephg01) are present, including mafic volcanic rocks and Oligocene igneous rocks.

***Pessimistic factors*—**No known major occurrences are present and the area is isolated from most other mercury deposits and Oligocene plutonic rocks are not reported.

***Quantitative estimate*—**No quantitative estimate was made by the USGS AGS assessment team owing to lack of information.

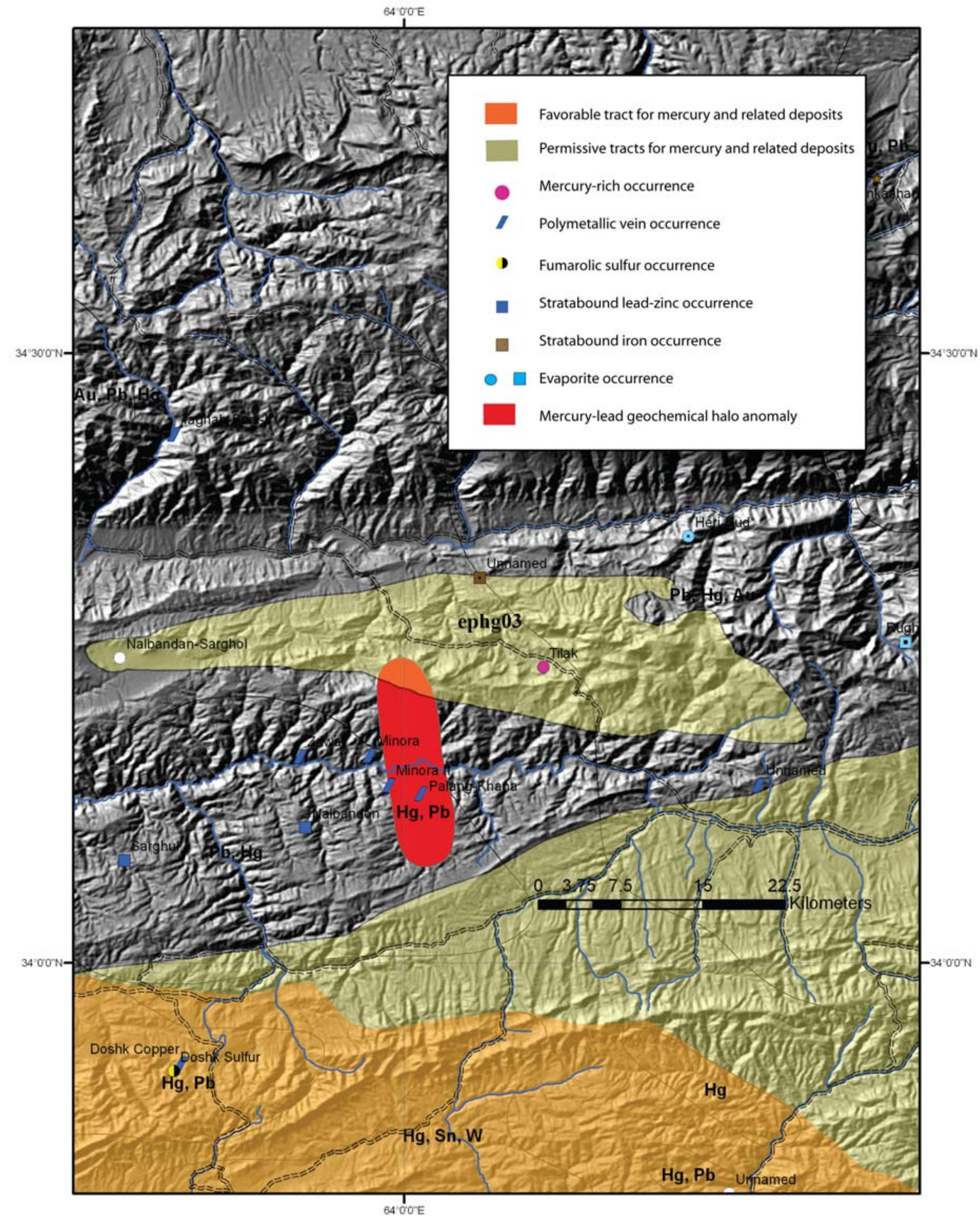

Figure 6.1-13. Location of the permissive tract ephg03 Tilak for hot-spring mercury deposits in Ghowr Province and location of known mercury mineral occurrences and geochemical anomalous halos.

***Deposit Type*—**Hot-spring mercury and epithermal vein precious-metal deposits.

***Age of Mineralization*—**Eocene to Oligocene

***Examples of Deposit Type*—**The Nayak mercury occurrence lies in the central part of the tract. The Nayak occurrence is in Eocene volcanic rocks containing thin hydrothermally altered zones composed of 30– to 35–m-wide sandstone and conglomerate beds that contain finely disseminated cinnabar. The mineralized intervals in the volcanic rocks are 0.3 to 1.0 by 1 to 6 m in size and assay a trace to up to 0.16 wt. percent mercury. There are also anomalous concentrations of copper throughout many zones in the volcanic rocks. Two 15– to 20–m-long, 1.5– to 3.0–m-thick hydrothermally altered zones grade 0.8 and 0.43 wt. percent copper respectively (Litvinenko and others, 1972; Kornev and others, 1975).

***Exploration history*—**No known exploration has taken place within the tract other than regional stream geochemistry by the Russians and prospecting near the known occurrence.

***Tract boundary criteria*—**The tract was delineated to encompass the Nayak mercury occurrence and the enclosing east-striking Eocene volcanic host rocks. In addition, two gold and one mercury geochemical halo anomalies also were included in the tract (fig. 6.1-14).

***Most important data sources*—**Geochemical halo anomaly data, Geologic map (Doebrich and others, 2006; Abdullah and others, 1977).

***Needs to improve assessment*—**The information that is most needed is intermediate-scale (1:100,000 and 1:25,000) geologic mapping and geochemical sampling. Local prospects should be visited and resampled and mapped in detail.

***Optimistic factors*—**The presence of a known mercury occurrence and geochemical anomalies and hydrothermal zones suggests that a mineralizing hydrothermal system was active within the tract.

***Pessimistic factors for deposit numbers*—**No major occurrences are present and the area is isolated from most other mercury deposits and Oligocene plutonic rocks are not reported.

***Quantitative estimate*—**No quantitative estimate was made by the USGS-AGS assessment team due to lack of information.

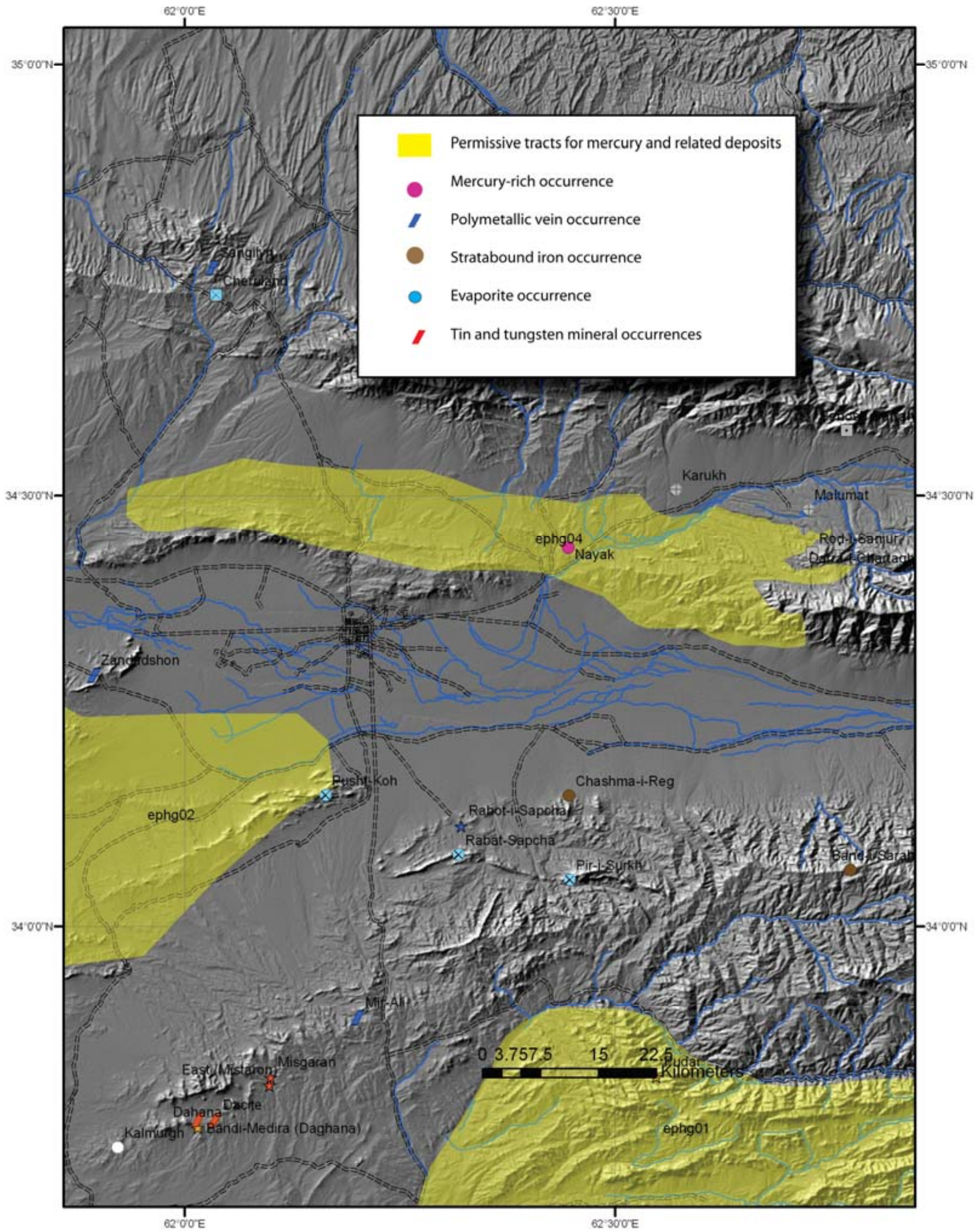

Figure 6.1-14. Permissive tract ephg04 Nayak for undiscovered epithermal mercury and precious-metal deposits in Herat Province. See figure 6.1-2 for location.

Tract ephg05 Katawaz-mercury

***Deposit Type*—**Hot-spring mercury and epithermal vein precious-metal deposits.

***Age of Mineralization*—**Oligocene or Miocene (?)

***Examples of Deposit Type*—**No known mineralized occurrences are present within the tract. There are indications, however of epithermal events within the tract. The Spira lead-zinc occurrence lies along the eastern, faulted boundary of the tract and the Zanda Gharay lead-zinc vein, in Khost Province. These mineralized occurrences are indications that Post-Eocene hydrothermal activity has taken place in or proximal to the tract.

The Spira lead-zinc occurrence is located in the faulted contact between Triassic sandstone, slate, and limestone and Paleocene conglomerate and sandstone; the occurrence is in a 40– to 60–m-wide, brecciated, hydrothermally altered zone. The mineralized area is 380 m long. 7 to 15 m wide, and 40 to 77 m deep and contains disseminated veinlets of massive sphalerite, galena, and pyrite assaying 1.12 wt. percent zinc, with traces of antimony, arsenic, nickel and silver. Estimated reserves are 11,900 metric tons combined lead and zinc (3,100 metric tons lead, 8,800 metric tons zinc) (Nikitin and others, 1973). The Zanda Gharay occurrence also lies along the north northeast-trending, brecciated, and hydrothermally altered fault zone separating Lower Carboniferous slate and Eocene conglomerate (fig. 6.1-16). Individual mineralized zones contain anomalous concentrations of copper. These two occurrences indicate that there has been post Eocene hydrothermal activity and the features in each are compatible with the epithermal mercury model and possible Oligocene epithermal activity within the ephg03 Katawaz-mercury permissive tract.

***Exploration history*—**No known exploration has taken place within the tract other than regional stream geochemistry by the Russians. The Spira lead-zinc mineral occurrence was mined in the past (Nikitin and others, 1973).

***Tract boundary criteria*—**The tract was constructed to encompass Oligocene sandstone, siltstone, clay, conglomerate, limestone, marl, and felsic and mafic volcanic rocks in the Katawaz Basin. In addition, 19 geochemical halo zones anomalous in mercury, tungsten, gold and or lead were included in the tract as favorable areas (fig 6.1-15). In the southwest part of the tract ASTER imagery has identified phyllic and argillic alteration zones spatially associated with Miocene plutons and stocks (map unit **N_1dig** Doebrich and Wahl, 2006). This altered area is designated separately as a permissive tract for porphyry copper deposits (ppycu07) (Mars and Rowan, 2006) (fig. 6.1-17). In addition, ASTER imagery also has identified a zone of illite, ferric iron and clay with local calcite and smectite along a northwest structure within a geochemical halo anomaly (fig. 6.1-18).

***Most important data sources*—**Geochemical halo data, Geologic map, ASTER data (Abdullah and others, 1977; Doebrich and others, 2006; Mars and Rowan, 2006).

***Needs to improve assessment*—**The information that is most needed is intermediate-scale (1:100,000) geologic mapping and geochemical sampling. Local lead-zinc prospects in the east part of the tract should be resampled and mapped in detail.

***Optimistic factors*—**The presence of geochemical anomalies of mercury and hydrothermal zones along the eastern margin of the tract suggests that a mineralizing hydrothermal system may have been active in the tract either during or after the deposition of the Katawaz Basin. The Miocene plutons and Oligocene sedimentary and volcanic sequence are also positive factors. An ASTER anomaly coincides with a northeast-striking linear zone that contains a mercury geochemical anomaly (fig. 6.1-18).

***Pessimistic factors*—**No major mineral occurrences are present in the tract and the area is isolated from most other mercury deposits, and Oligocene plutonic rocks are not reported.

***Quantitative estimate*—**No quantitative estimate was made by the USGS-AGS assessment team due to lack of information.

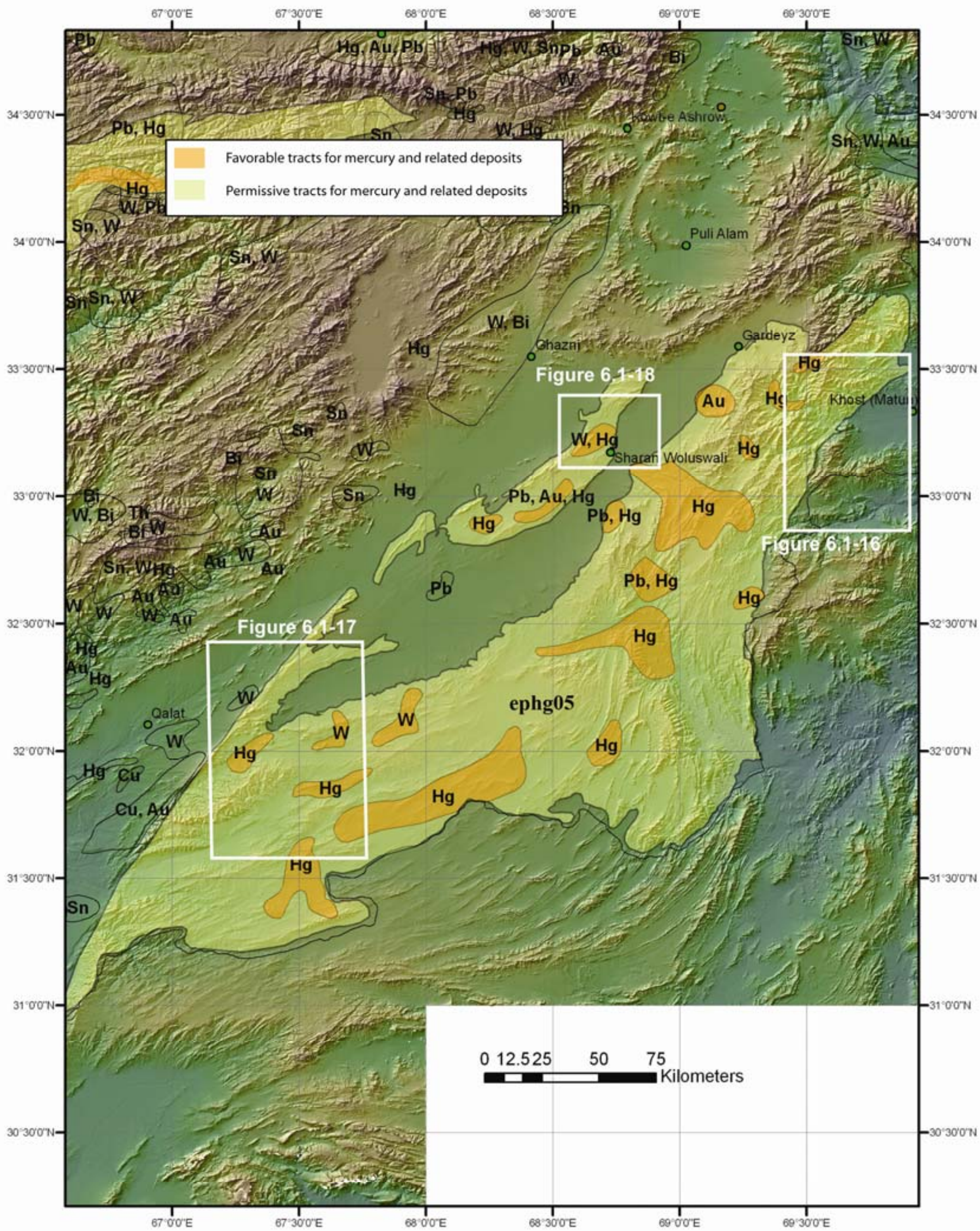

Figure 6.1-15. Permissive tract ephg05 Katawaz for undiscovered epithermal mercury deposits and precious-metal epithermal deposits in southeast Afghanistan. Orange mercury geochemical anomaly halos are designated as internal favorable tracts.

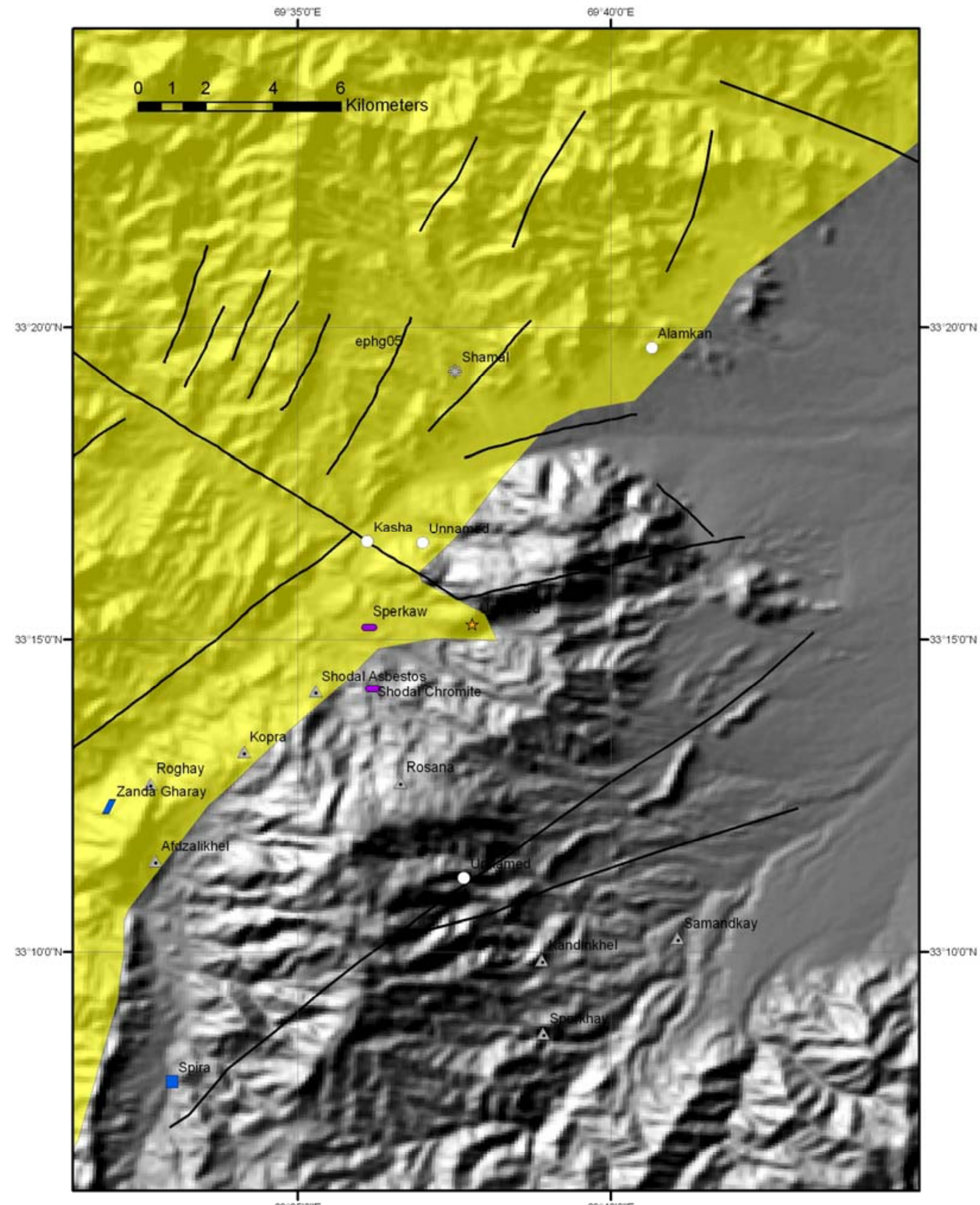

Figure 6.1-16. Map of Spira-Zanda Gharay area in eastern Paktika and western Khost Provinces on the faulted eastern margin of permissive tract ephg03 Katawaz mercury. The two mineral occurrences are evidence of hydrothermal activity that post dates the Eocene sedimentary rocks and is compatible with epithermal activity in the permissive tract as indicated by the abundant mercury anomalies.

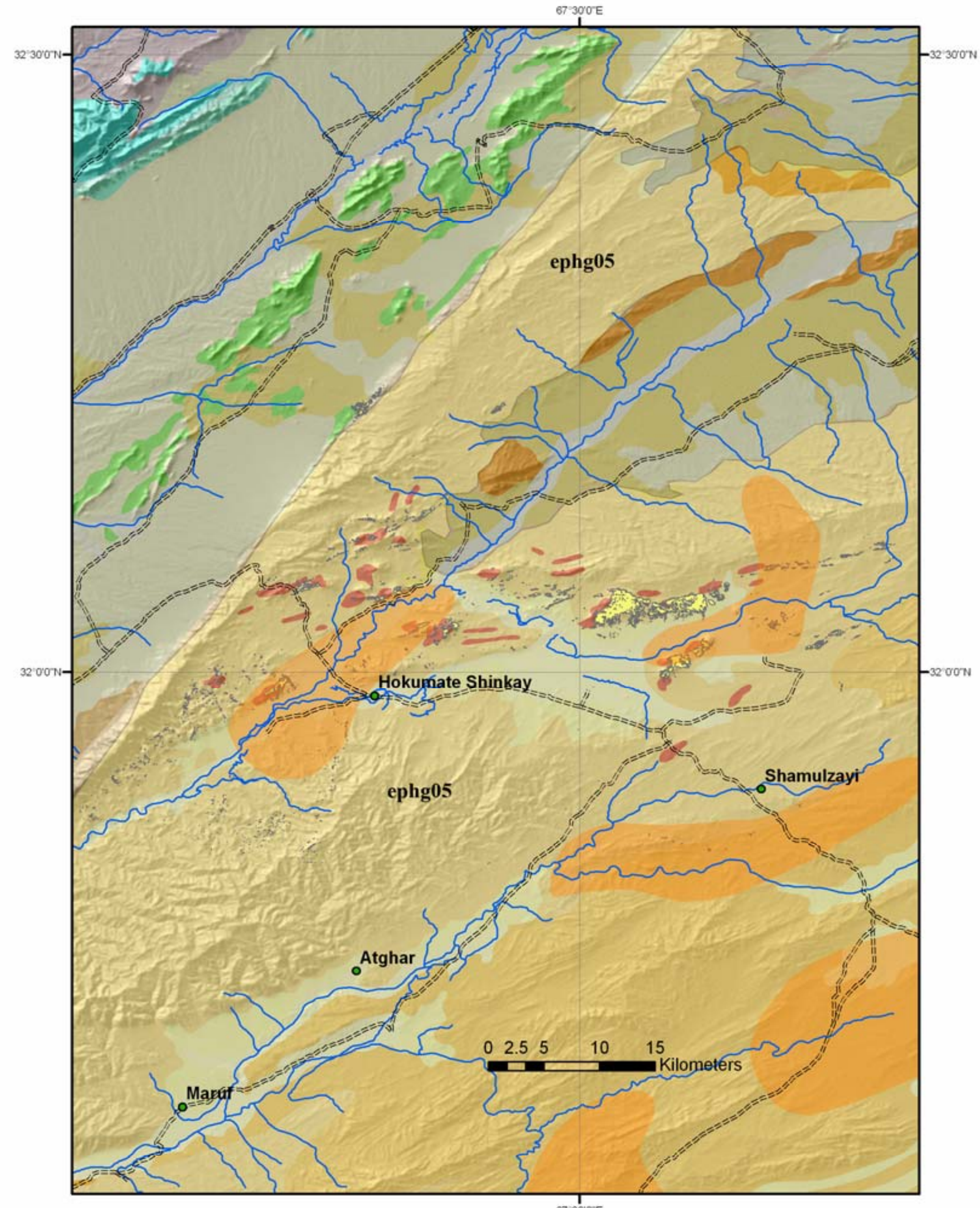

Figure 6.1-17. Area in west part of permissive tract ephg05 for undiscovered epithermal mercury deposits showing Miocene intrusive rocks (reddish color), and ASTER alteration patches from Mars and Rowan (2006). Darker orange are mercury geochemical anomaly halos and favorable tracts. Geology from Doebrich and Wahl (2006).

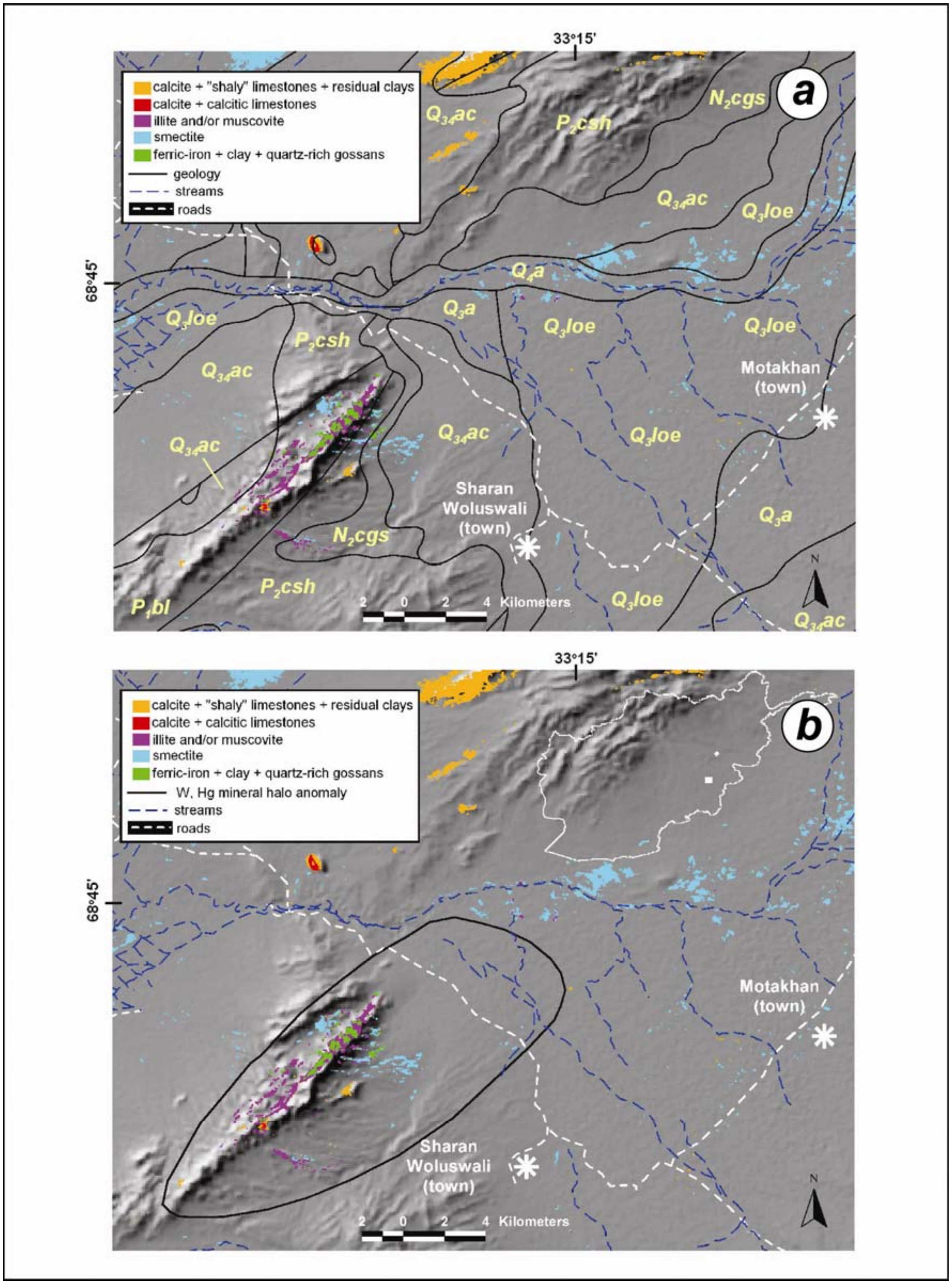

Figure 6.1-18. ASTER anomaly along northeast-striking linear zone coinciding with a mercury anomaly in part of tract ephg05 in the Katawaz Basin near Sharah Woluswal. The calcite, clay, and iron in the ASTER signature may indicate hydrothermal activity. ASTER analysis by Bernard Hubbard.

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6.2 Volcanogenic massive sulfide deposits

Contribution by Stephen G. Peters.

A number of poorly explored and partially described mineral occurrences in the northern and southwestern parts of Afghanistan have characteristics that may be compatible with volcanogenic massive sulfide deposits (Barrie and Harrington, 1999; Franklin and others, 2005; Mosier and others, 2007). Additionally, some of stratigraphic sequences are permissive for the occurrences of these deposits. The paucity of available information did not allow detailed assessment of this deposit type; however, additional work is warranted because this deposit type is known to contain significant amounts of base and precious metals elsewhere in the world.

6.2.1 Volcanogenic massive sulfide deposit models

Three large and rich volcanogenic massive sulfide (VMS) deposit sub models can be considered for assessment in Afghanistan. These are the copper-rich Cyprus massive sulfide deposits in pillow basalts, copper-lead-zinc Kuroko massive sulfide deposits in felsic to intermediate composition volcanic rocks, and copper-zinc Besshi massive sulfide deposits in mafic volcanic rocks and sediments. Mineral occurrences with many characteristics similar to one or all of these models are present in Afghanistan in the Upper Triassic rocks in Baghlan and Jowzjan, in Upper Jurassic to Lower Cretaceous rocks in Herat Province, and in Eocene to Oligocene rocks in Farah Province. In addition, Proterozoic stratigraphic sequences also may be permissive for undiscovered VMS deposits. The mineral occurrences in Afghanistan that may be of VMS type have not been well described. The following descriptive models are presented to aid in classification of the Afghanistan volcanogenic massive sulfide deposits.

Cyprus Massive Sulfide Deposits (model 24a, Singer, 1986a) are deposits of massive pyrite, chalcopyrite, and sphalerite hosted mainly in sheet flow and also in pillow basalts. They are common in ophiolite assemblages that contain tectonized dunite and harzburgite, gabbro, sheeted diabase dikes, pillow basalt, and fine-grained metasedimentary rocks such as chert and phyllite. Primary igneous features associated with these rocks are dikes, pillows, and in some cases, brecciated basalt. The range in age of Cyprus massive sulfide deposits is from Archean (?) to Tertiary; the majority are Ordovician or Cretaceous. The depositional environment contains submarine hot-springs that may have formed along axial grabens in oceanic or back-arc spreading ridges. Hot-springs related to submarine volcanoes that produced seamounts and may be adjacent to steep normal faults. They are associated with Mn– and Fe–rich cherts regionally.

Mineralogy consists of massive pyrite + chalcopyrite + sphalerite ± marcasite ± pyrrhotite. Stringer (stockwork): pyrite ± pyrrhotite, minor chalcopyrite and sphalerite (Cu, Au, and Ag are present in minor amounts). Ores comprise massive sulfides (>50 vol. percent sulfide minerals) generally with an underlying sulfide mineral stockwork or stringer zone. Sulfide-bearing minerals may be brecciated and recemented. Alteration in the stringer zone is characterized by feldspar destruction, abundant quartz, rare chalcedony, and chlorite, local muscovite and calcite. Some deposits are overlain by ochre (Mn–poor, Fe–rich bedded sediment containing goethite, maghemite, and quartz). Orebodies are associated with pillow basalt or mafic volcanic breccia, with diabase dikes stratigraphically below. Ores are rarely localized in sediments above pillows. There may be local faulting. Weathering produces massive limonite gossans. Gold is also present in streams and rivers that drain the deposits. Geochemical signature in the footwall rocks is a general loss of Ca and Na, and introduction and redistribution of Mg and Fe in the stringer zone.

Kuroko Massive Sulfide Deposits (model 28a, Singer, 1986b) or Noranda-type, VMS, or felsic to intermediate volcanic type deposits, are Cu– and Zn–bearing massive sulfide deposits in volcanic rocks of intermediate to felsic composition. The main associated rock types are submarine rhyolite, dacite, and subordinate basalt and associated sedimentary rocks, and local organic-rich mudstone or shale and pyritic, and siliceous shale. Rocks are present as flows, tuffs, pyroclastics, breccias, bedded sedimentary rocks, and in some cases felsic domes. Age range is Archean through Cenozoic. The depositional environment contains hot springs related to marine volcanism, probably under anoxic marine conditions. Lead-rich deposits are associated with abundant fine-grained volcanogenic sediments. Deposits are commonly located along island arcs with local extensional tectonic activity, or faults, or fractures, especially in Archean greenstone belts. Associated deposits are seafloor volcanogenic Mn, and Algoma-type Fe deposits.

Mineralogy in the upper stratiform massive zone (black ore) consists of pyrite + sphalerite + chalcopyrite ± pyrrhotite ± galena ± barite ± tetrahedrite - tennantite ± bornite. In the lower stratiform massive zone (yellow ore) common minerals include pyrite + chalcopyrite ± sphalerite ± pyrrhotite ± magnetite, and in the stringer (stockwork) zone minerals include pyrite + chalcopyrite (Au and Ag). Gahnite may be present in metamorphosed deposits. Gypsum and anhydrite are present in some deposits. Ore textures are massive (>50 volume percent sulfide minerals). An underlying zone contains stockwork, stringers or disseminated sulfide minerals or sulfide-matrix breccia is locally present. Slumped and redeposited ore with graded bedding can also occur. Altered rocks may be adjacent to and blanket massive sulfides in some deposits. Alteration minerals consist of zeolites, montmorillonite and chlorite; stringer (stockwork) zone—silica, chlorite, and sericite; below stringer—chlorite and albite. Cordierite and anthophyllite are present in the footwall of strongly metamorphosed deposits, and graphitic schist may be present in the hanging wall.

The Kuroko massive sulfide deposits form toward the more felsic tops of volcanic or volcanic-sedimentary sequences. Deposits tend to occur near centers of felsic volcanism and may be locally brecciated or have felsic domes nearby. Pyritic siliceous rock (exhalite) may mark horizons where the deposits are present. Proximity to deposits may be indicated by sulfide clasts in volcanic breccias. Some deposits may be gravity-transported and deposited in paleo depressions on the seafloor. Weathering produces red and brown gossans. Gahnite can be present in stream sediments near some metamorphosed deposits. Geochemical signatures in gossan may be high values of Pb, and Au typically is present. Adjacent to the deposit there is enrichment in Mg and Zn, and depletion in Na. Within deposits the ores typically contain high Cu, Zn, and in some cases associated Pb, Ba, As, Ag, Au, Se, Sn, and or Bi.

Besshi Massive Sulfide Deposits (model 24b, Cox, 1986a) are thin, sheet-like bodies of massive to layered pyrite (or pyrrhotite), and chalcopyrite within thinly laminated clastic sediments and mafic tuffs. They are contained in clastic terrigenous sedimentary rocks and in tholeiitic to andesitic tuff and breccia and locally in black shale, oxide-facies iron formation, and red chert. All known examples are in strongly deformed metamorphic terranes. Rocks are quartzose and mafic schist that are present mainly in Paleozoic and Mesozoic rocks. The depositional environment may involve submarine hot springs related to basaltic volcanism. Ores may be localized within permeable sediments and fractured volcanic rocks in anoxic marine basins. Tectonic setting may be rifted basins in island arc or back-arc settings, or possibly spreading ridges underlying terrigenous sediments at continental margins.

Mineralogy consists of pyrite + pyrrhotite + chalcopyrite + sphalerite ± magnetite ± vallerite ± galena ± bornite ± tetrahedrite ± cobaltite ± cubanite ± stannite ± molybdenite. Alteration minerals include quartz, carbonate, albite, white mica, chlorite, amphibole, and tourmaline. Ores are massive to layered. Breccia or stringer ore consists of cross-cutting veins that contain chalcopyrite, pyrite, calcite, and/or galena and sphalerite. Altered rocks are difficult to recognize because of metamorphism. Chloritization of adjacent rocks is noted in some deposits. Deposits are thin, but laterally extensive and tend to cluster in en echelon patterns. Weathering produces significant gossan. Geochemical signature in the rocks is Cu, Zn, Co, Ag, Ni, Cr, Co/Ni >1.0, Au up to 4 ppm, Ag up to 60 ppm.

6.2.2 Volcanogenic massive sulfide deposit tract descriptions

Permissive tracts were constructed in Afghanistan for undiscovered volcanic massive sulfide deposits in stratigraphic sequences that contain known mineral occurrences with characteristics similar to those of volcanogenic massive sulfide deposits (fig. 6.2-1). These sequences are Upper Triassic volcanic and associated rocks (VMS-01), Upper Jurassic to Lower Cretaceous volcanic and associated rocks (VMS-02), and Eocene to Oligocene volcanic and associated rocks (VMS-03). In addition, a permissive tract for all Precambrian rocks (VMS-04) was delineated, although no known volcanogenic massive sulfide occurrences are known in Afghanistan in these older rocks.

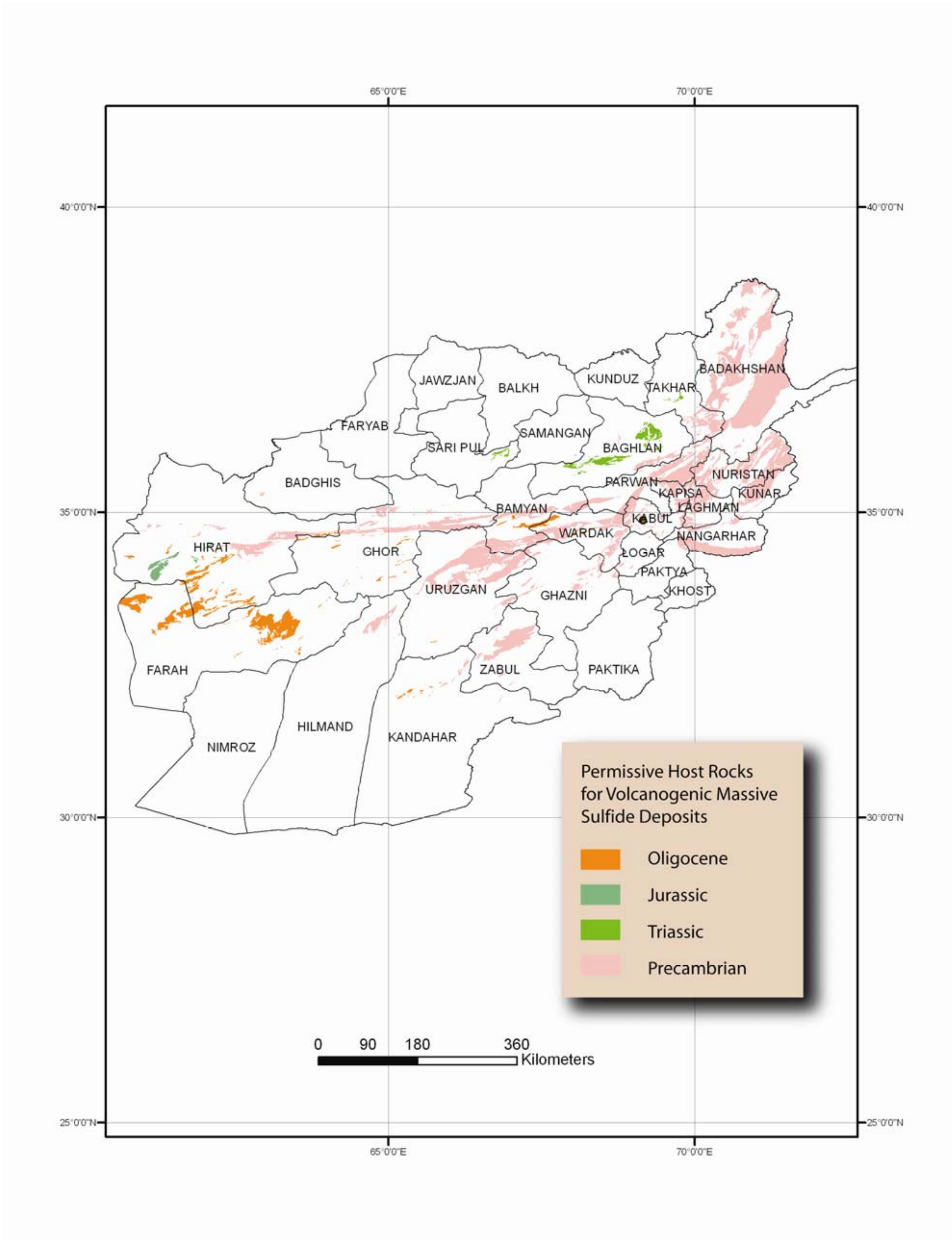

Figure 6.2-1. Map showing permissive tracts for volcanogenic massive sulfide deposits in Afghanistan.

Permissive Tract VMS-01 Late Triassic Balkhab-Gazoghel

***Deposit Type*—**Volcanogenic massive sulfide

***Age of Mineralization*—**Late Triassic

***Examples of Deposit Type*—**Balkhab in Sari Pul Province, Gazoghel volcanic-hosted sulfide occurrences in central Baghlan Province, volcanic-hosted sulfide occurrences and unnamed volcanic-hosted deposits in eastern Baghlan Province.

***Exploration history*—**There is only limited previous exploration in this part of Afghanistan, although discovery and description of the mineral occurrences in the western and east-central part of the tract indicate some ground prospecting. Geochemical stream sediment exploration has taken place throughout the tract. The U.S. Geological Survey team has not visited areas in the tract. Some mining has probably taken place at Balkhab.

Tract boundary criteria*—**The permissive trace VMS-01 Late Triassic (Balkhav and Gazoghel area) was delineated to encompass Upper Triassic (Rhaetian) rhyolite, andesite, and basalt including sandstone, mudstone, conglomerate (map unit ***T_3ral), and overlying hypabyssal andesite porphyry (map unit and ***T_3agp***), both of which lie unconformably above Ordovician sandstone, siltstone and shale. The tract also includes three known copper- and lead-bearing volcanic-hosted mineral occurrences within these rocks. The tract has four main discontinuous parts, one in Sari Pul, two in Baghlan, and one in western Takhar Provinces (fig. 6.2-2).

The Balkhab volcanogenic massive sulfide mineral occurrence is in an eroded exposure of Triassic and Ordovician rocks in Sari Pul Province in a western part of permissive tract VMS01 (fig. 6.2-3), and is along the unconformity contact between Ordovician sandy slate and Upper Triassic subvolcanic andesite porphyry (fig. 6.2-4). Mineralization consists of a silicified, limonite-bearing 4,000– to 5,000–m-long by 300– to 400–m-wide faulted zone containing four (4) areas of strong jointing containing malachite, pyrite, and disseminated galena grading 0.25 to 1.34 wt. percent copper; an old slag sample contains 1.66 wt. percent copper (Kafarskiy and others, 1972).

The Gozoghel mineral occurrence lies within Upper Triassic, strongly limonitic, bleached, gypsum-bearing felsic volcanic rocks that crops out 5,000 and 8,000 m along strike and are 500 to 600 m thick, and have general grades of 0.02 wt. percent copper. The Gazoghel I occurrence is in similar rocks to the south (fig. 6.2-5), and also is hosted in slate as well as volcanic rocks, occupying a 500–m-long and 150– to 300-m-wide zone that grades 0.7 wt. percent copper (Kafarskiy and others, 1972).

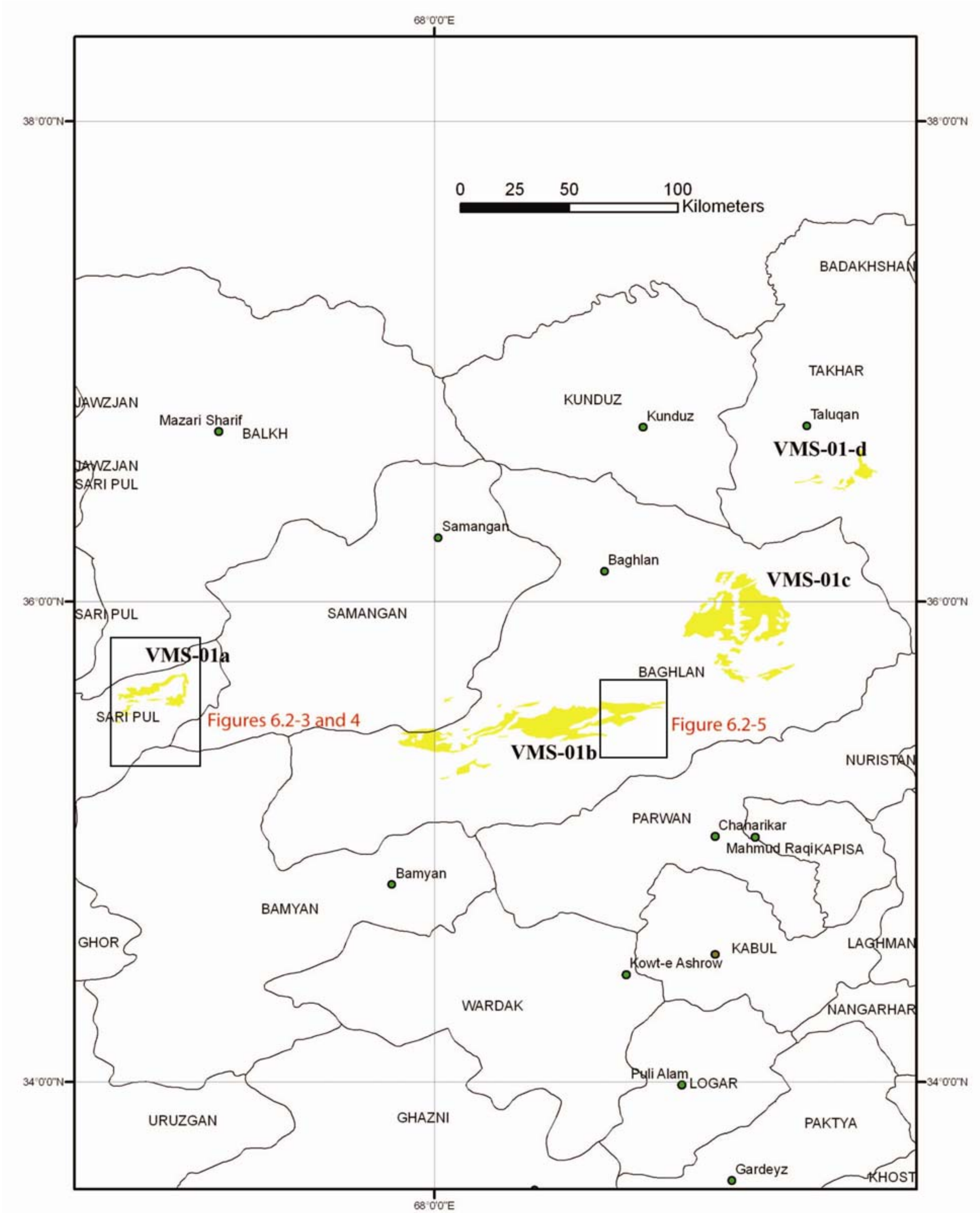

Figure 6.2-2. Map showing location of the four (4) parts of permissive tract VMS-01 Late Triassic Balkhab-Gazoghel (yellow) for undiscovered volcanogenic massive sulfide deposits.

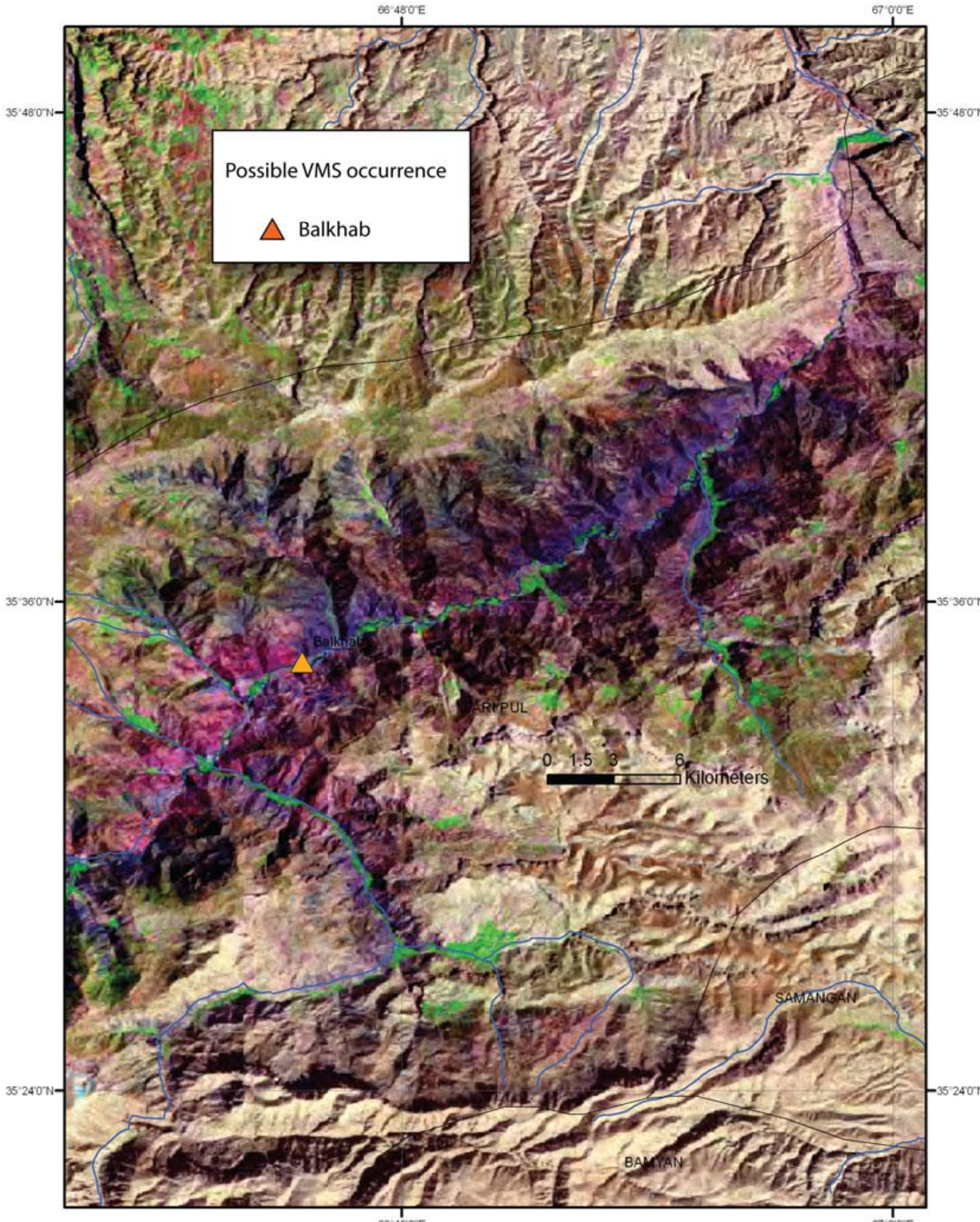

Figure 6.2-3. Landsat imagery showing the location of the Balkhab volcanogenic massive sulfide occurrence in Sari Pul Province (VMS01a). The darker, redder colors represent the eroded pre-Jurassic rocks that include Upper Triassic volcanic and sedimentary rocks unconformably overlying Ordovician and older sedimentary rocks.

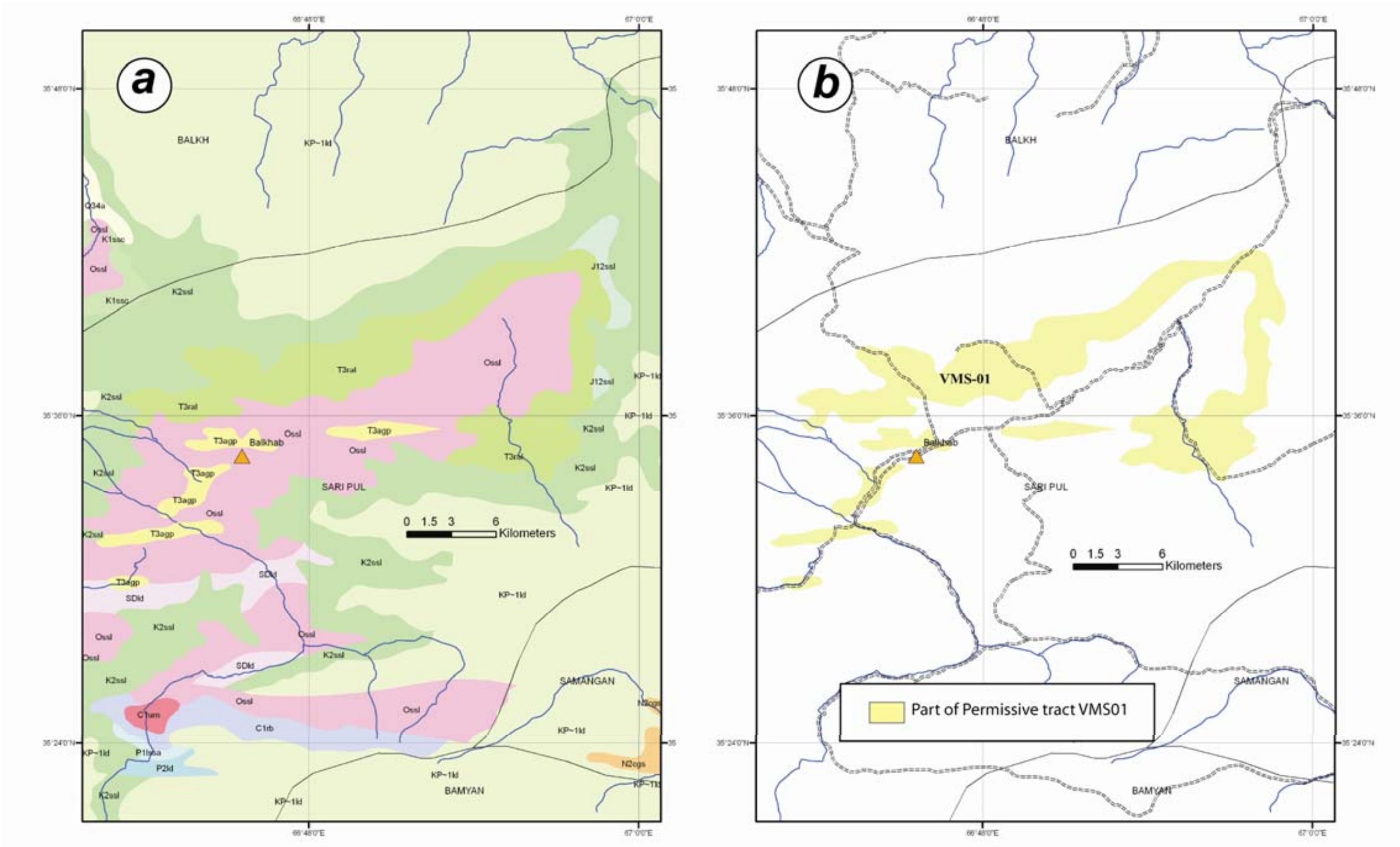

Figure 6.2-4. Map showing geology and location of western part of permissive tract VMS-01-Triassic Balkhab-Gazoghel for undiscovered volcanogenic massive sulfide deposits and the location of the Balkhab mineral occurrence. (a) Geologic map (from Doebrich and Wahl, 2006) showing eroded parts of the surrounding Jurassic and Cretaceous sedimentary rocks revealing Upper Triassic volcanic host rocks. SDld = Silurian-Devonian limestone, dolomite, schist, and sandstone, Ossl = Ordovician sandstone, siltstone, limestone, and shale, T_3agp = Upper Triassic andesite and granite porphyry, T_3ral = Upper Triassic felsic and mafic volcanic rocks, sandstone, mudstone, and conglomerate, J_{12}ssl = Lower to Middle Jurassic sandstone, siltstone, claystone, conglomerate, and coal, K_2ssl = Upper Cretaceous sandstone, siltstone, limestone, conglomerate and gypsum, KP_1ld = Upper Cretaceous to Paleocene limestone, dolomite, sandstone siltstone, gypsum, and conglomerate. (*b*) Location of western part of permissive tract VMS-01.

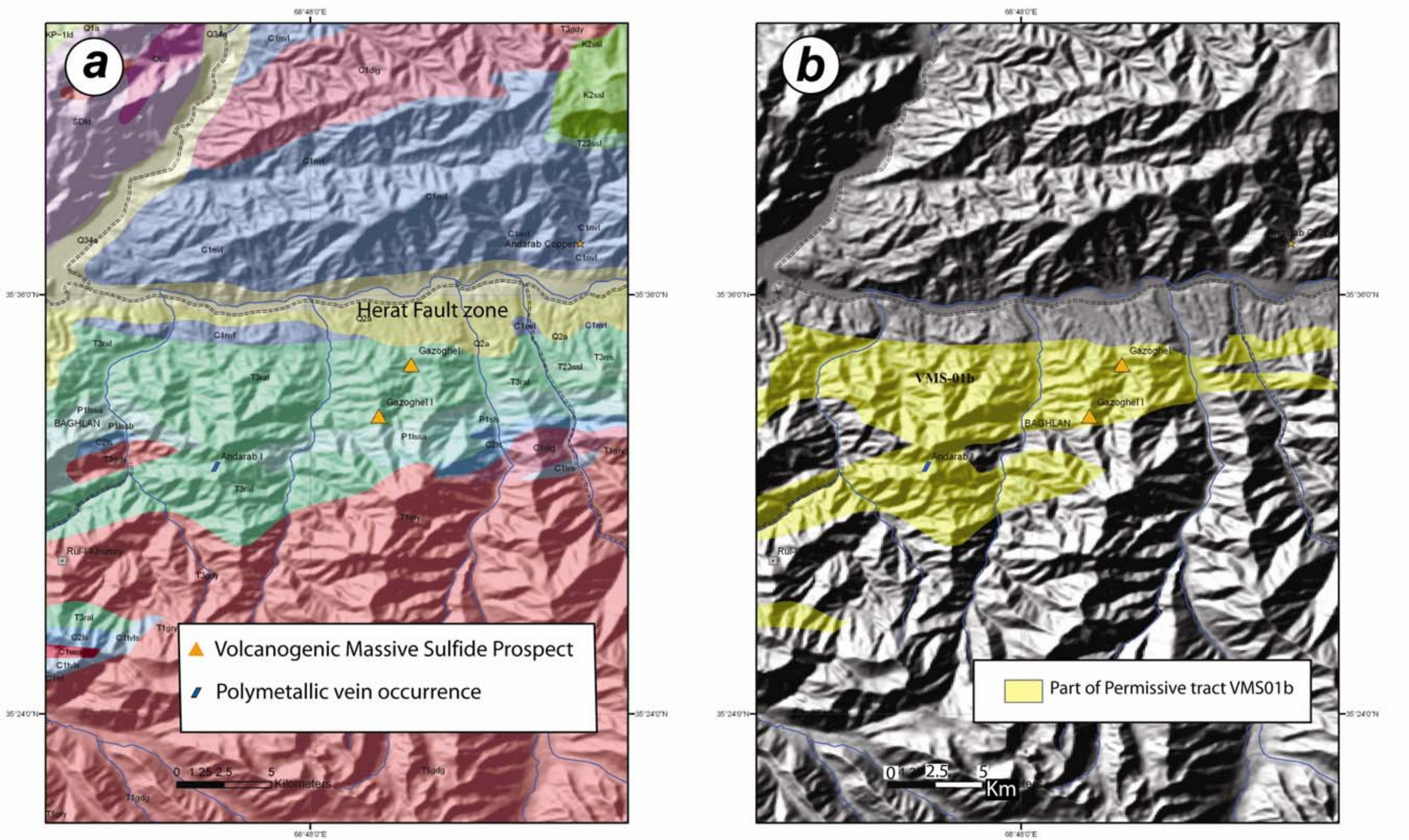

Figure 6.2-5. Map showing location of two volcanogenic massive sulfide occurrences Gazoghel and Gazoghel I in central Baghlan Province in the eastern part of a central part of permissive tract VMS-01 Late Triassic Balkhab-Gazghel (VMS-01b) for undiscovered volcanogenic massive sulfide deposits.

***Important data sources*—**Geologic map, LANDSAT imagery, mineral deposit database (Doebrich and Wahl, 2006).

***Most important data sources*—**Mineral occurrence data base, Geochemical halo data, Geologic map (Abdullah and others, 1977; Orris and Bliss, 2002; Doebrich and Wahl, 2006).

***Needs to improve assessment*—**The information that is most needed is intermediate-scale (1:100,000 and 1:25,000) geologic mapping and geochemical sampling. Local prospects should be visited and resampled and mapped in detail, especially for establishing the sequence stratigraphy associated with the mineralization. Both would require site visits.

***Optimistic factors*—**The three known deposits have some geologic, mineral logic, and geochemical characteristics like those of volcanogenic massive sulfide deposits. Geochemical halos anomalous in lead and copper cover parts of the tract.

***Pessimistic factors*—**None of the known mineral occurrences has definitive characteristics of volcanogenic sulfide deposits and none is of large size.

***Numerical estimate*—**No numerical estimate was made due to the lack of adequate data and poor fit with the descriptive model characteristics.

Permissive Tract VMS-02- Late Jurassic-Early Cretaceous

***Deposit Type*—**Volcanogenic massive sulfide

***Age of Mineralization*—**Late Jurassic-Early Cretaceous

***Examples of Deposit Type*—**The Dusar and Shaida volcanic-hosted base-metal mineral occurrences within the tract have characteristics similar to those of volcanogenic massive sulfide deposits. In addition, a number of base-metal vein deposits are spatially associated with these occurrences.

***Exploration history*—**There is only limited previous exploration in this area of Afghanistan, although discovery and description of the mineral occurrences in the central and southeastern parts of the tract indicate some ground prospecting. Geochemical stream sediment exploration has taken place throughout the tract. Diamond drilling was done at the Dusar and Shaida prospects; the Shaida area was the scene of former mining. The U.S. Geological Survey team has not visited the area.

***Tract boundary criteria*—**The VMS-02 Late Jurassic-Early Cretaceous tract was delineated in southwest and central Herat Province to enclose Late Jurassic to Early Cretaceous rhyolite and mafic volcanic rocks, as well as shale, siltstone, sandstone, conglomerate, chert, limestone (map unit J_3k1rl), and also a number of volcanic-hosted base-metal mineral occurrences (fig. 6.2-6). The tract is made up of three separate parts, the largest is the Dusar area in the west, the Shaida part is located in the central part of the tract and a small eastern part was also delineated.

The Dusar volcanic-hosted mineral occurrence is associated with numerous diabase and gabbro diabase intrusive bodies within Upper Jurassic to Lower Cretaceous intermediate to mafic faulted volcanic rocks. Within the 2,200–m-long 30– to 250–m-wide and 2.0– to 7.2–m-thick mineralized zone are massive, ochreous, and siliceous limonitic gossans. Diamond drilling below a gossan intersected a siliceous and sericitic limonitic rock underlain by quartz keratophyre with disseminated pyrite. Mineralized sections grade 0.06 wt. percent copper and up to 0.05 wt. percent zinc (Abdullah and others, 1977 referring to a report by Tarasenko and others written in 1973). Additional mineral occurrences within this part of the tract contain geologically similar mineralized zones with anomalous concentrations of copper, zinc, and gold. The vein-like occurrences some of which are up to 1.5 km long are silicified and are associated with diabase dikes that locally contain chalcopyrite and secondary copper minerals (fig. 6.2-7).

The Shaida I volcanogenic massive sulfide mineral occurrences consist of the Shaida and Shaida I occurrences and are both hosted within Mesozoic volcanic rocks. These are distinct from the Shaida II and Shaida II occurrences, which lie to the west in Cenozoic sedimentary and volcanic rocks and have porphyry copper characteristics associated with Oligocene plutonic rocks (fig. 6.2-8). The Shaida I volcanic-hosted occurrence is strongly jointed, silicified, and contains limonite zones up to 100 m long and 3 to 8 m thick. The zones contain quartz veinlets with secondary copper minerals and disseminated chalcopyrite. These zones grade 0.01 to 0.30 wt. percent copper and up to 0.7 wt. percent lead and have anomalous concentrations of zinc, molybdenum, and arsenic.

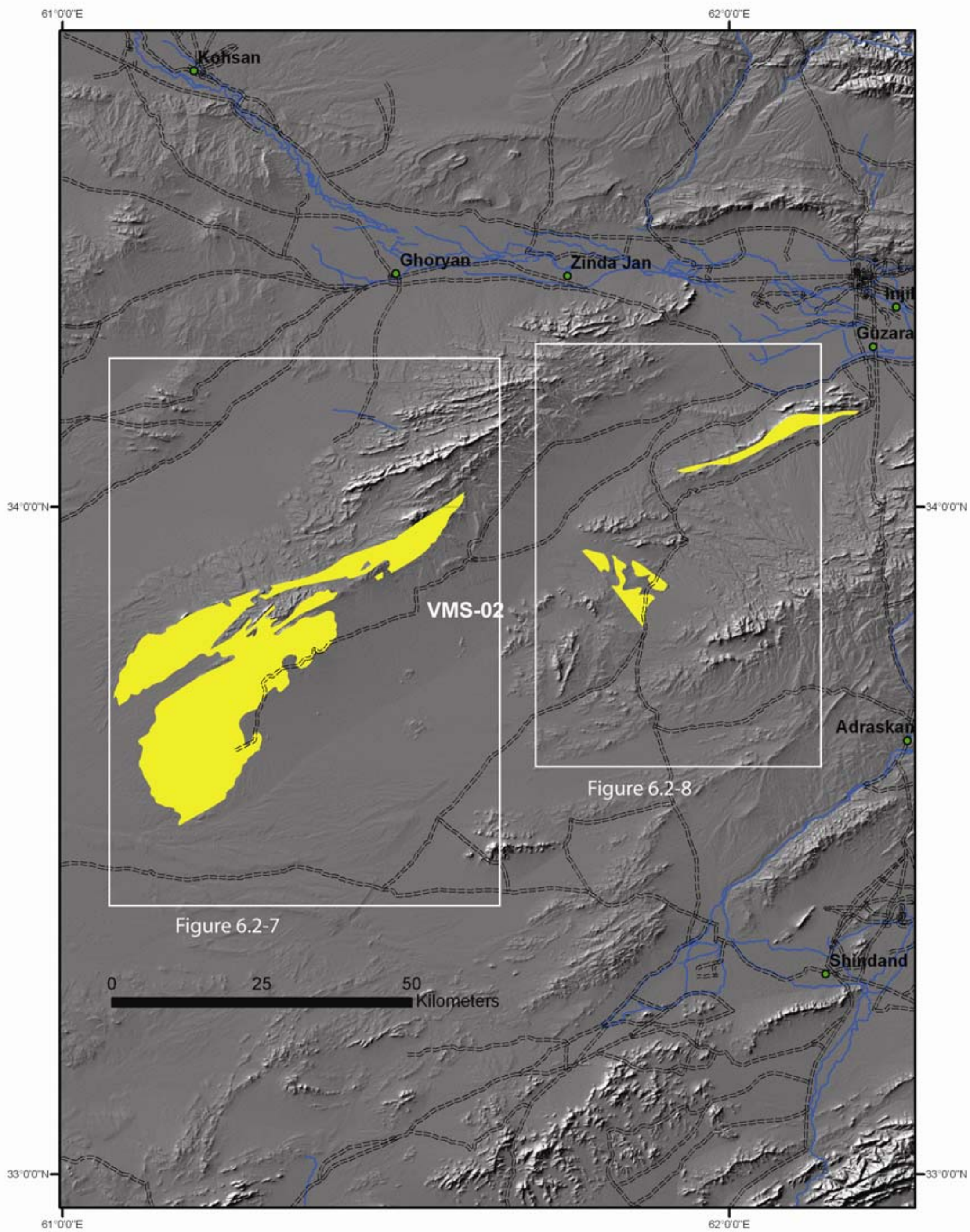

Figure 6.2-6. Map showing location and three parts of permissive tract VMS-02 Late Jurassic-Early Cretaceous for undiscovered volcanogenic massive sulfide deposits. See figure 6.2-1 for location.

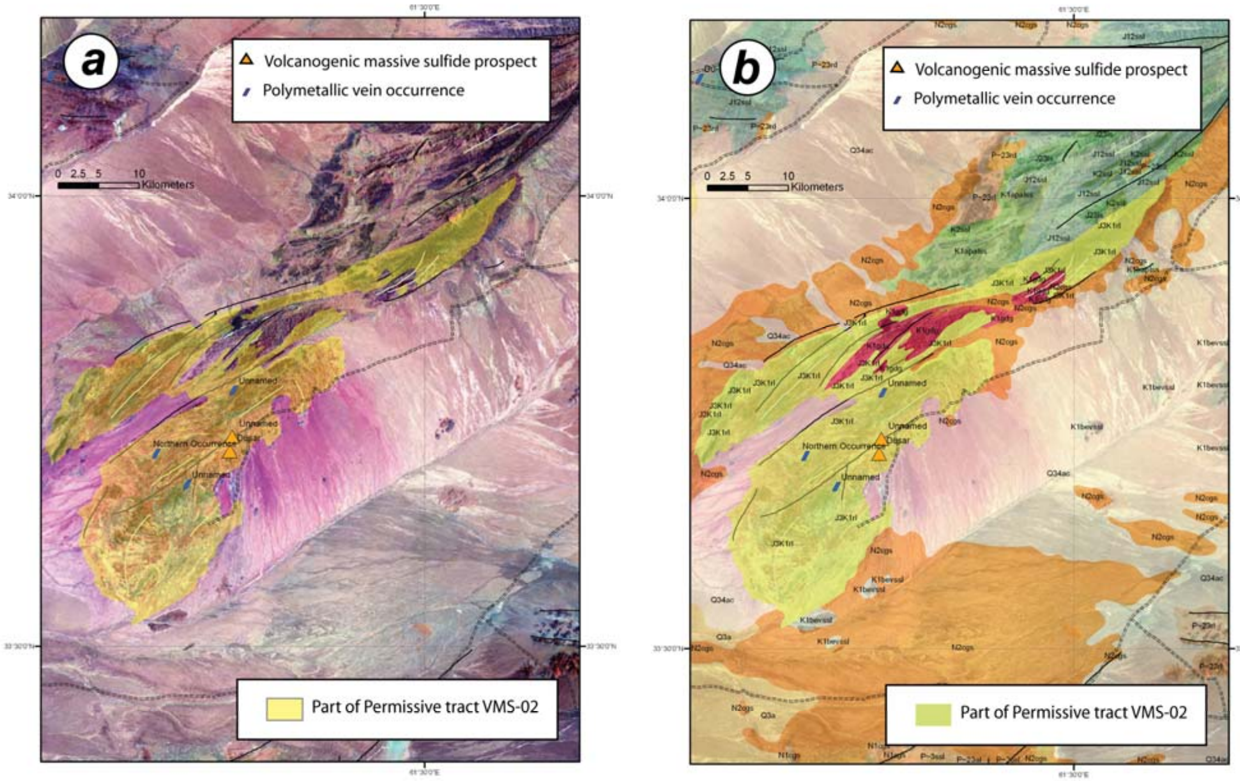

Figure 6.2-7. Maps showing the western most part of the permissive tract VMS-02 Late Jurassic-Early Cretaceous for undiscovered volcanogenic massive sulfide deposits in Herat Province. (*a*) Western part of tract VMS-02 and faults over Landsat imagery, showing outline of volcanic rocks and the Dusar and associated VMS occurrences. (*b*) Same view as (*a*), but with geology superimposed. Rocks within or adjacent to tract include K_1gdg = Lower Cretaceous granodiorite and granite, J_{12}ssl = Lower to Middle Jurassic sandstone, siltstone, clay, coal, and felsic volcanic rocks, J_3k1rl = Upper Jurassic to Lower Cretaceous shale, siltstone, sandstone, chert, limestone and felsic and mafic volcanic rocks.

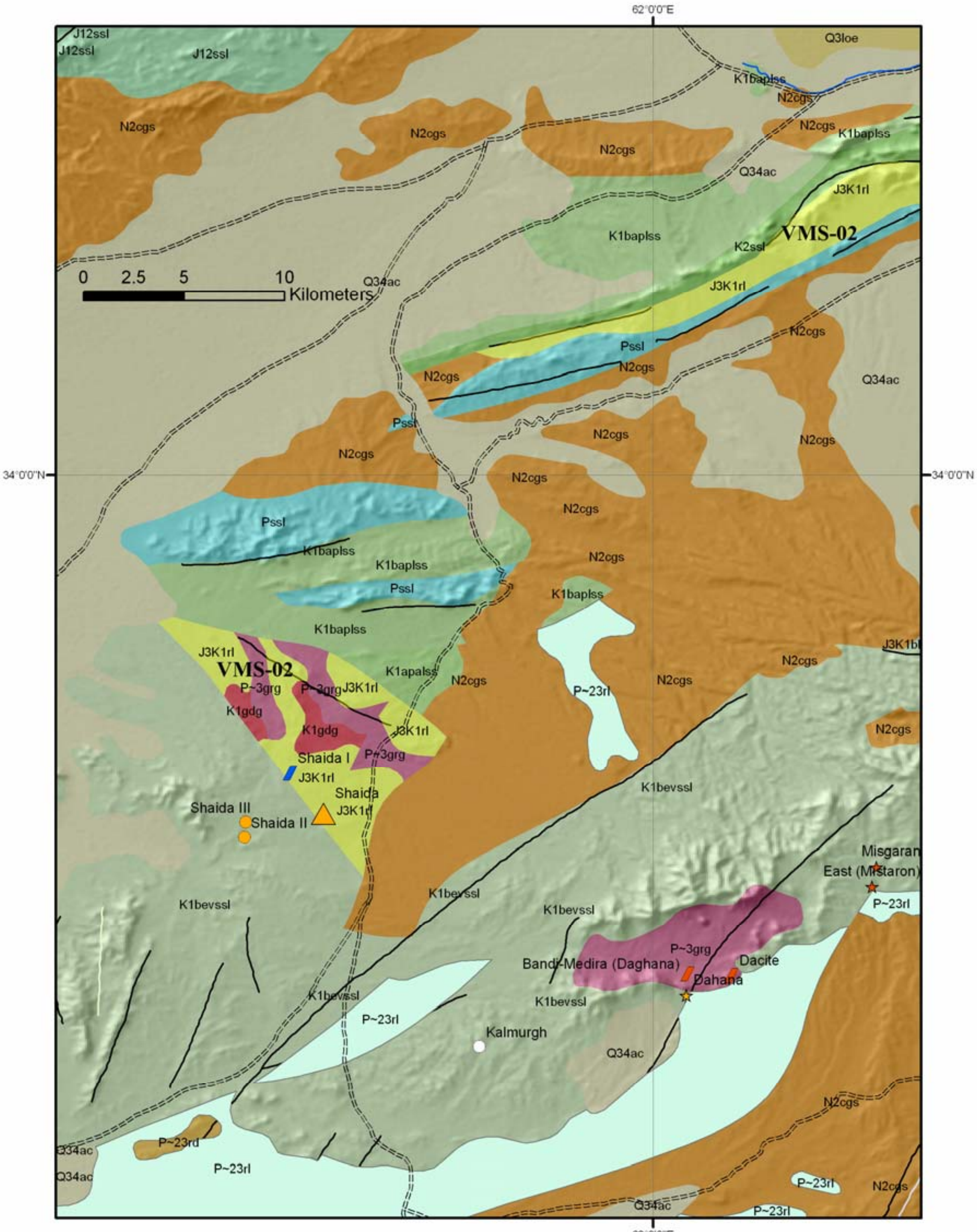

Figure 6.2-8. Map showing the central part of permissive tract VMS-02 Upper Jurassic-Lower Cretaceous containing the Shaida VMS occurrence and also showing the eastern parts of the tract. Tract consists of K_3K_1rl = Upper Jurassic to Lower Cretaceous shale, siltstone, sandstone, conglomerate, chert, limestone, and felsic and mafic volcanic rocks. Intrusive rocks are K_1gdg = Lower Cretaceous granodiorite, and P_3grg = Oligocene granite, granite porphyry, and "granosyenite" (Doebrich and Wahl, 2006).

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

Needs to improve assessment—The information that is most needed is intermediate-scale (1:100,000 and 1:25,000) geologic mapping and geochemical sampling. Local prospects should be visited and resampled and mapped in detail, especially noting the sequence stratigraphy associated with mineralization. Both would require site visits.

Optimistic factors—Mineralization at the Dusar and at the eastern Shaida occurrences has characteristics that are compatible with the descriptive VMS models. Most of the occurrence descriptions indicate significant gossanous zones.

Pessimistic factors—There are no substantial or rich intercepts or assays known from prospecting in the deposits. The overprint of Oligocene granites at Shaida of and Cretaceous granites at Dusar obscure the classification and modeling of the occurrences. No significant anomalous base-metal geochemical halos are present over the tracts.

Numerical estimate—No numerical estimate was made due to the lack of adequate information and lack of definitive features that fit and allow classification of the tract into one of the descriptive VMS sub models.

Permissive Tract VMS-03 Eocene-Oligocene

Deposit Type—Volcanogenic massive sulfide

Age of Mineralization—Eocene to Oligocene

Examples of Deposit Type—Durbas and Rode-Duzd volcanic-hosted base-metal mineral occurrences. Although adjacent to the tract, the volcanic-associated Gologha I mineral occurrence in Farah Province (fig. 6.2-9) may have similar characteristics.

Exploration history—There is only limited previous exploration in this area of Afghanistan, although discover and description of the occurrences in the central and southeastern part of the tract indicate some ground prospecting. Geochemical stream sediment exploration has taken place throughout the tract. The U.S. Geological Survey team has not visited the area.

Tract boundary criteria—The VMS-03 Eocene-Oligocene permissive tract for undiscovered volcanogenic massive sulfide deposits was delineated in northern Farah, southern Herat, and parts of Ghor, Kandahar, and Bamyan and Wardak Provinces (fig. 6.2-9) to encompass Eocene and Oligocene volcanic rocks that include rhyolite, andesitic basalt, basalt, trachyte, dacite, ignimbrite, tuff, as well as conglomerate, sandstone, siltstone, and limestone (map unit $\boldsymbol{P_{23}rl}$). Additional Tertiary volcanic and sedimentary units near the tract not included but some of these units may be permissive. The tract is comprised of a large number of discontinuous polygons. Also, within the tract are the Durbas II and Rode-Duzd volcanic-hosted base-metal occurrences and the Siab and Ghurma polymetallic vein occurrences in Farah Province (figs. 6.2-10 and 11).

Parts of the tract were identified as also being permissive for undiscovered porphyry copper deposits (see section 5.0). The Rhode-Duzd occurrence lies in ferruginous and chloritized Eocene to Oligocene andesite in a 10– to 20–m-wide zone grading 0.1 to 0.28 wt. percent copper. The Durbas II volcanogenic massive sulfide occurrence is hosted within Oligocene altered subvolcanic dacite porphyry in a 3,000– to 5,000–m-long, 20– to 200–m-wide zone grading 0.01 to 0.3 wt percent copper with anomalous concentrations of zinc (Dronov and others, 1970). The Siab polymetallic vein occurrence lies in Lower Cretaceous volcanic sedimentary rocks along a 800–m-long and 120– to 130–m-wide fault zone containing a number of 15– to 30–m-long, 1–m-wide quartz veins. These veins contain copper sulfide minerals and galena and grade 2.98 wt. percent copper with up to 4.55 wt. percent zinc and 1.0 wt. percent lead. The Ghurma volcanic-hosted base-metal occurrence is a large mineralized area that consists of two zones. The first zone is 1,000 m long and 100 to 200 m wide, and grades 0.02 to 0.05 wt percent copper. The second zone contains quartz-calcite veins in a 40–m-wide area with abundant chalcopyrite, pyrite, and siderite in irregular veinlets grading 0.01 to 9.68 wt percent copper with anomalous concentrations of zinc and lead.

***Important data sources*—**Geologic map, aeromagnetic map, LANDSAT imagery, mineral deposit database (Doebrich and Wahl, 2006; Sweeney and others, 2006).

***Needs to improve assessment*—**The information that is most needed is intermediate-scale (1:100,000and 1:25,000) geologic mapping and geochemical sampling. Local prospects should be visited and resampled and mapped in detail. In addition, other rock units in the region need to be investigated to see if they correlate with those in the tract, because they may also be permissive. Specifically, the volcanic-associated Gologha I mineral occurrence, Farah Province, should be investigated. Both would require site visits.

***Optimistic factors*—**Known volcanic-hosted mineral occurrences with characteristics similar to volcanogenic massive sulfide deposits are present within the permissive tract; some parts of the tract are anomalous in base metals and mercury.

***Pessimistic factors*—**Much of the permissive tract is not known to contained mineralized rock, nor it is anomalous in base or precious metals.

***Numerical estimate*—**No numerical estimate was made because the characteristics of the known mineral occurrences were not adequately known to equate them with a specific VMS sub model.

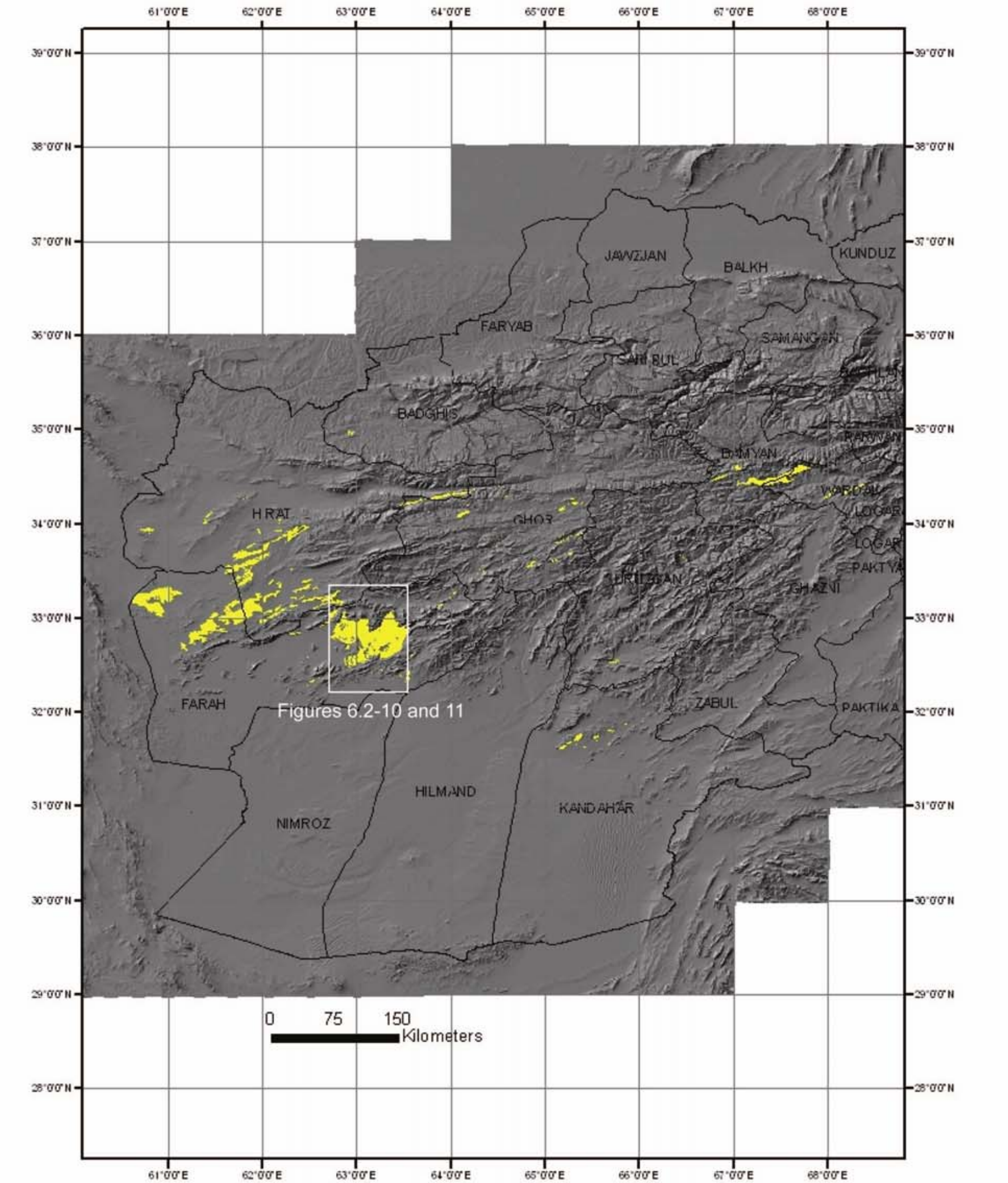

Figure 6.2-9. Map showing location of parts of permissive tract VMS-03 Eocene-Oligocene for undiscovered volcanogenic massive sulfide deposits. The tract is based on the distribution of map unit P23rl, which is known to contain deposits with characteristics similar to those of volcanogenic massive sulfide deposits. Inset shows locations of figures 6.2-10 and 6.2-11.

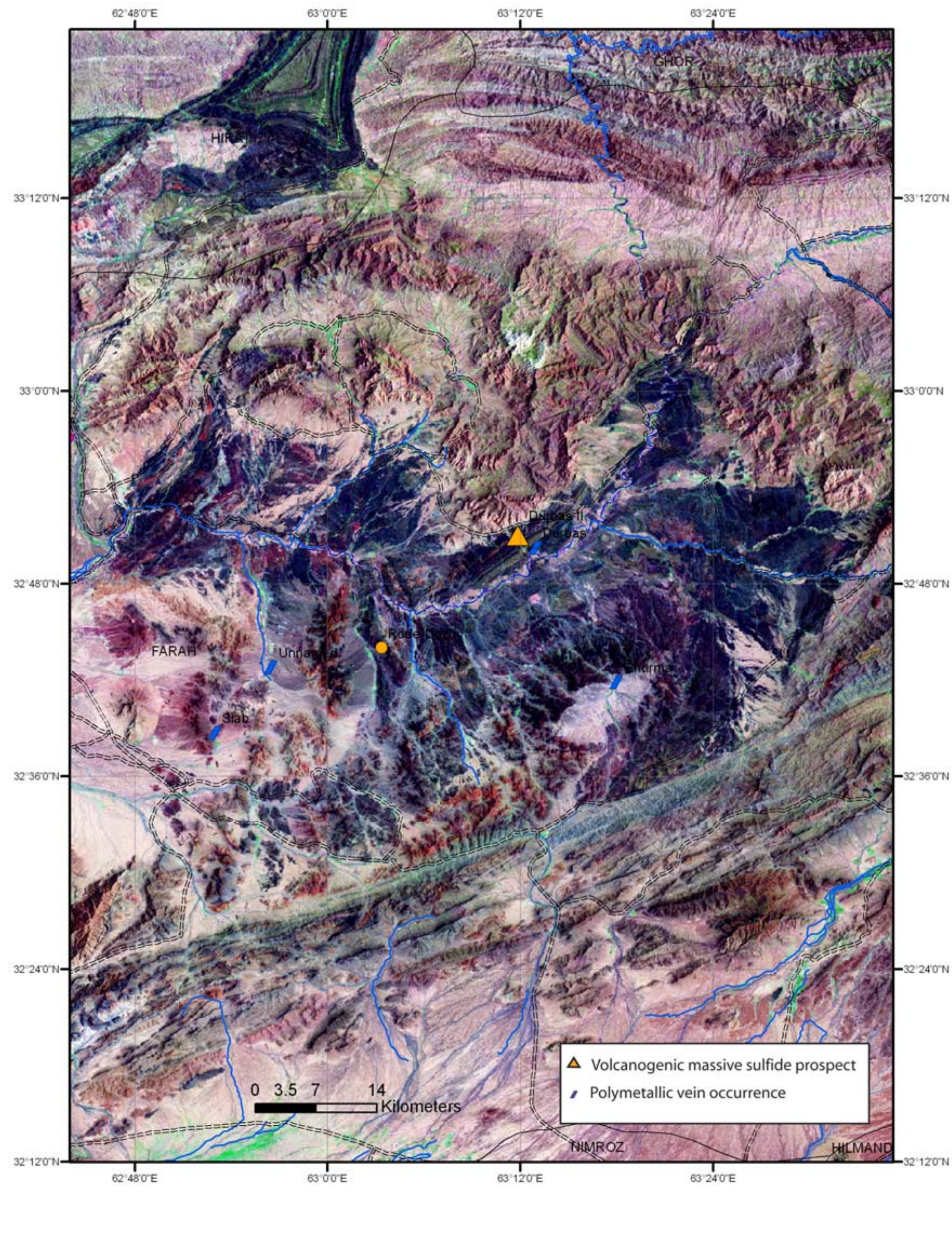

Figure 6.2-10. LANDSAT image of the Durbas area in Farah Province within permissive tract VMS-03. The Eocene-Oligocene permissive volcanic rocks are the darker colors and contain the mineral occurrences.

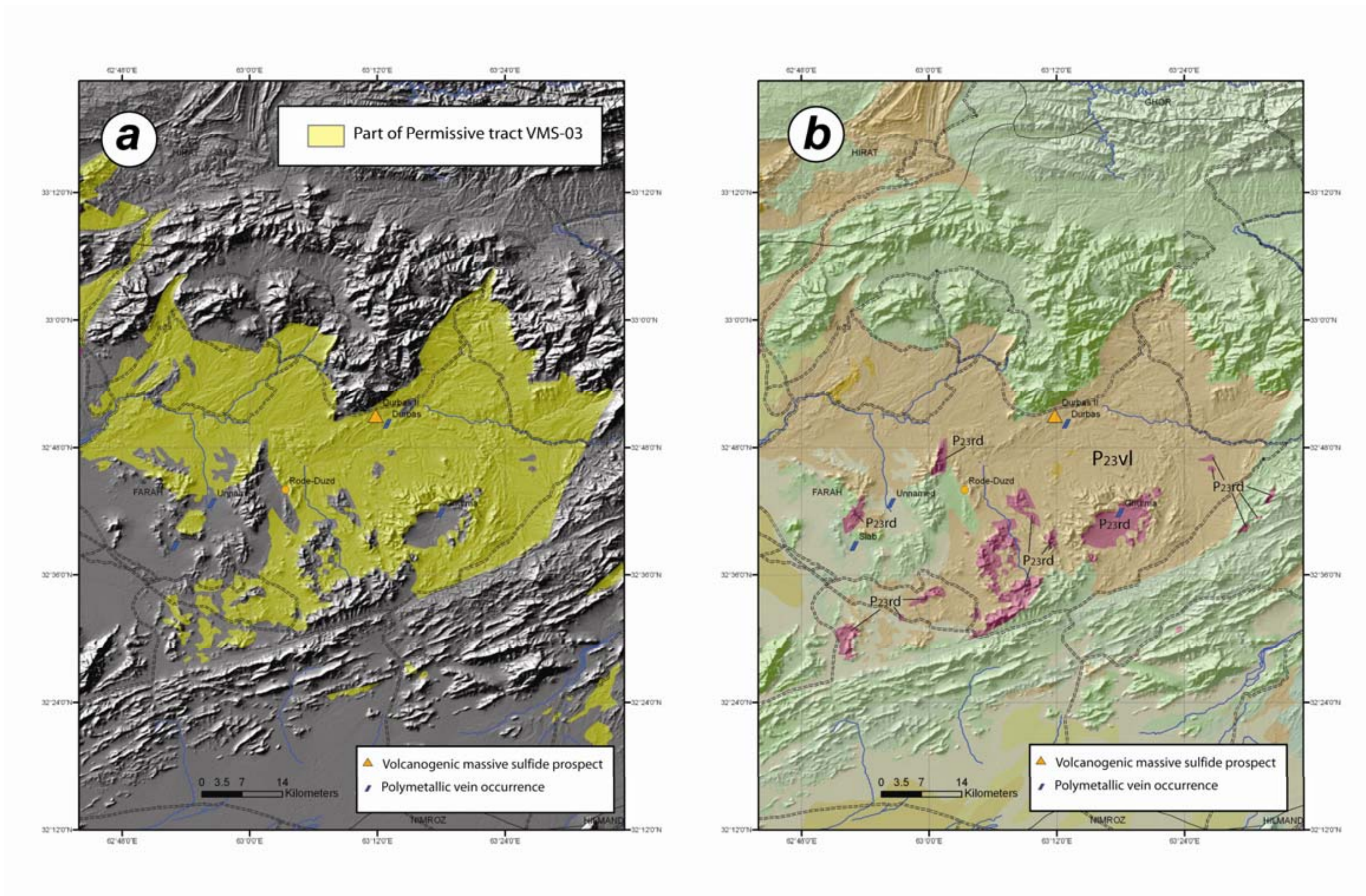

Figure 6.2-11. Distribution of the part of tract VMS-03 Eocene-Oligocene in Farah Province in the Durbas area. (*a*) distribution of tract and mineral occurrences in relation to shaded relief. (*b*) Distribution of geologic units and mineral occurrences in the Durbas area. Rock types in the tract are P_{23}vl = Eocene to Oligocene andesitic basalt, basalt, trachyte, dacite, rhyolite, tuff, conglomerate, sandstone, siltstone, and limestone (tan color), P_{23}rd = Eocene to Oligocene rhyolite, dacite, and granite porphyry, and Oligocene granite, granite porphyry, granodiorite, quartz syenite, and “granosyenite” (light purple) (from Doebrich and Wahl, 2006).

Permissive Tract VMS-04 Precambrian

***Deposit Type*—**Volcanogenic massive sulfide

***Age of Mineralization*—**Precambrian

***Examples of Deposit Type*—**No known mineral occurrences of the volcanogenic massive sulfide type are known in the tract.

***Exploration history*—**There is no known previous exploration for volcanogenic massive sulfide deposits in Afghanistan within Precambrian rocks. Geochemical stream sediment exploration has taken place throughout most of the tract. The U.S. Geological Survey team has not visited the area.

***Tract boundary criteria*—**The permissive tract VMS04 Precambrian was delineated to include all of the known Precambrian units including 8,000– to 10,000–m-thick Archean, 3,000– to 7,000–m-thick Paleoproterozoic, 3,000– to 5,500–m-thick Mesoproterozoic, and 9,000–m-thick Neoproterozoic sections. These sections include gneiss, amphibolite, as well as metasedimentary and metavolcanic sequences (fig. 6.2-12).

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

***Needs to improve assessment*—**The information that is most needed is intermediate-scale (1:100,000) geologic mapping that classifies the Precambrian sections in terms of permissive volcanic protolith. Any areas within the tract that are mineralogically (geochemically) anomalous in base metals should be visited and sampled.

***Optimistic factors*—** Precambrian rocks are common hosts for volcanogenic massive sulfide deposits elsewhere in the world. Extensive relatively unexplored areas of Precambrian rocks exist in Afghanistan.

***Pessimistic factors*—**Much of the permissive tract is not known to contained mineralized rock, nor Precambrian is it anomalous in base or precious metals.

***Numerical estimate*—**No numerical estimate was made because the characteristics of the known mineral occurrences were not well known enough to equate them with a specific model.

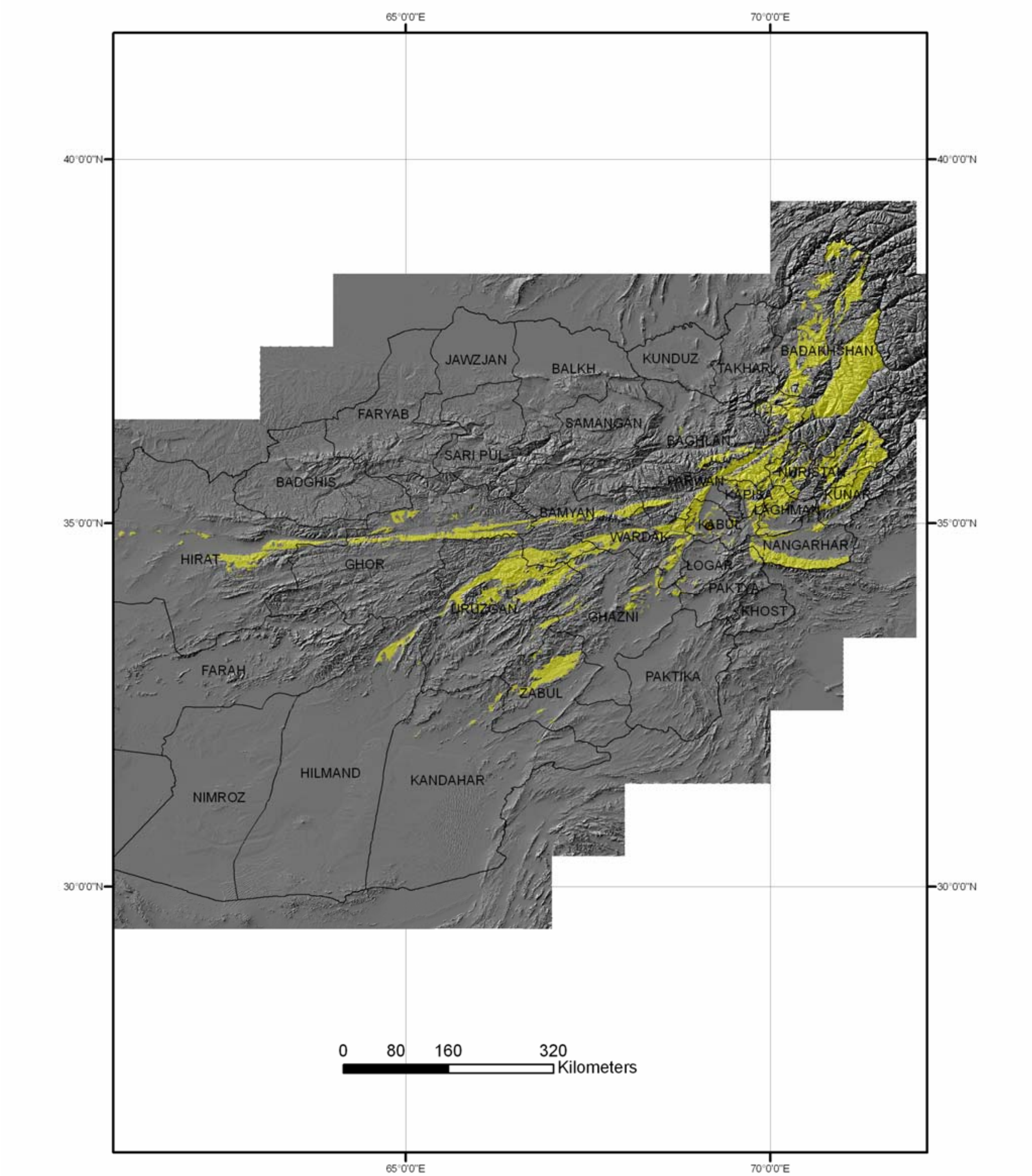

Figure 6.2-12. Map showing distribution of permissive tract VMS-04 Precambrian for undiscovered volcanogenic massive sulfide deposits in Afghanistan.

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