Prepared in Cooperation with the Afghanistan Geological Survey

Preliminary Mineral Resource Assessment of Selected Mineral Deposit Types in Afghanistan

By

Steve Ludington, Greta J. Orris, Karen S. Bolm, and Stephen G. Peters, and the U.S. Geological Survey-Afghanistan Ministry of Mines and Industry Joint Mineral Resource Assessment Team

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Introduction

Wise decision-making and management of natural resources depend upon credible and reliable scientific information about the occurrence, distribution, quantity and quality of a country's resource base. Economic development decisions by governments require such information to be part of a Mineral Resource Assessment. Such Mineral Assessments are also useful to private citizens and international investors, consultants, and companies prior to entry and investment in a country. Assessments can also be used to help evaluate the economic risks and impact on the natural environment associated with development of resources.

In February 2002, at the request of the Department of State and the then U.S. Ambassador to Afghanistan (Robert P. Finn), the U.S. Geological Survey (USGS) prepared a detailed proposal addressing natural resources issues critical to the reconstruction of Afghanistan. The proposal was refined and updated in December 2003 and was presented as a 5-year work plan to USAID-Kabul in February 2004. USAID-Kabul currently funds this plan and this report presents a part of the preliminary results obligated for fiscal year 2006. A final Preliminary Assessment of the Non Fuel Mineral Resource of Afghanistan will be completed and delivered at the end of fiscal year 2007.

Afghanistan has abundant metallic and non-metallic resources, but the potential resources have never been systematically assessed using modern methods. Much of the existing mineral information for Afghanistan was gathered during the 1950s and continued in the late 1980s until the departure of the geologic advisors from the Soviet Union. During this period, there were many mineral-related activities centered on systematic geologic mapping of the country, collection of geochemical and rock samples, implementation of airborne geophysical surveys, and exploration focused on the discovery of large mineral deposits. Many reports, maps, charts, and tables were produced at that time. Some of this information remains in the libraries of the Afghanistan Ministry of Mines and Industry (MMI) and the Afghanistan Geological Survey (AGS), but much of these data and materials were shipped to the Soviet Union, Eastern European countries, or elsewhere. These materials have been acquired within Afghanistan and outside the country and compiled to form the foundation for this Preliminary Assessment of Non Fuel Mineral Resources.

Methods

The assessment was conducted by a team of scientists from the U.S. Geological Survey. To begin the assessment, the team reviewed the geology of Afghanistan and selected appropriate deposit models. They then delineated permissive tracts for each type of deposit. The permissive tracts were defined by the environments of formation described in the deposit model such that the probability of deposits of the type delineated occurring outside the tract is negligible (i.e., less than 0.00001 to 0.000001) (Singer, 1993). Geologic maps and location maps showing the distribution and types of existing mineral deposits and occurrences were used in outlining these permissive tracts. Geophysical and geochemical maps, as well as knowledge about the exploration history, were used in tract delineation and estimation. More details and the theoretical basis for these procedures can be found in Singer (1993).

As a general rule, current methods of estimating undiscovered resources are made to a depth of 1 km beneath the surface of the Earth. Thus, if an area of permissive rock is covered by more than 1 km of rock known to be barren or by younger sediment, it was excluded from the tract. This rationale is consistent with mining practice; direct exploration is seldom conducted at depths greater than 1 km, although extensions of deposits may be explored and developed deeper (up to 3 km) once they have been discovered at shallower depths. The international boundary line, provincial boundaries, town and city locations (indicated by yellow squares), and the spelling of names were acquired from the Afghanistan Information Management Service (AIMS) website (http://www.aims.org.af).

The result of the estimation process is a probability distribution of numbers of undiscovered deposits. These estimated deposits should be consistent with the grade and tonnage model. That is, if 10 deposits are estimated, 5 of them are considered to be larger than the median tonnage, and 5 of them are considered to have a higher grade than the median grade. There are many geologic, geochemical, and geophysical guides to estimating undiscovered deposits. Estimates can be guided by counting mineral occurrences, geochemical anomalies, or exploration "plays" and assigning to each a probability of its being a member of the grade and tonnage distributions. Estimates can also be guided by analogy with well-explored areas that contain known numbers of deposits and that are geologically similar to the study area. One important factor in assessment of a particular tract is the degree of previous and current exploration activity. Exploration intensity may have two opposing influences. First, because many types of ore deposits tend to occur in clusters, success in finding one deposit stimulates the search for others. When that search is not yet exhaustive, additional deposits are likely. On the other hand (and more rarely), exploration activity may be so thorough that the probability of an undiscovered deposit is minimal.

The team reviewed the descriptive characteristics and grade and tonnage data for known deposits in all defined tracts, and decided which deposit type and grade and tonnage models were appropriate for the tract. Reasoning by analogy to other parts of the world where similar deposits are present, the undiscovered deposits estimated in the area should be similar in grade and tonnage to known examples. Whenever possible, the team then estimated the number of undiscovered deposits in the permissive tract. These estimates are subjective, and are expressed in terms of least numbers of deposits for specified cumulative probabilities. Commonly, estimators were asked for the least number of deposits at a specified cumulative probability, and the answer is a specific number of deposits. A series of these questions for several quantiles (generally 0.9, 0.5, 0.1, and 0.05) was used to develop a cumulative probability distribution. Teams used a variety of methods to arrive at a consensus. The most common method was simply to continue the discussion until all agreed. However, many tools, including deposit density estimates and assumptions about exploration adequacy, and were used to guide the final estimates (Singer, 1993).

The most important data sources used for this assessment were the digital geologic map of Afghanistan (Doebrich and Wahl, 2006), the mineral deposit database for Afghanistan (Doebrich and Wahl, 2006) based on the earlier studies of Abdullah and others (1977) and Economic and Social Commission for

Asia and the Pacific (1995), along with new geophysical data collected by the U.S. Geological Survey that is in the process of publication.

Assessments

Permissive tracts were created for porphyry copper deposits, sediment-hosted copper deposits, limestone deposits, bedded halite deposits, potash-bearing bedded halite deposits, and bedded gypsum deposits enabling the assessment of copper, limestone, halite, potash, and gypsum resources. In addition, an assessment for sand and gravel deposits has been prepared, but is being published separately (Bliss and Bolm, in press).

The assessments for porphyry copper and sediment-hosted copper deposits were done in Denver, Colorado, in August 2006 by a team that consisted of Jeff Doebrich, John Mars, Bob Eppinger, Doug Stoeser, Carol Finn, Larry Snee, Steve Ludington, and Paul Schruben. The assessments for limestone deposits, bedded halite deposits, potash-bearing bedded halite deposits, and bedded gypsum deposits were done in August 2006 by a team that consisted of Greta Orris, Karen Bolm, Jim Bliss, and Steve Ludington.

Porphyry Copper Deposits

Igneous rocks typical of geologic provinces containing porphyry copper deposits are common in Afghanistan. Most of the country is part of the Tethyan geodynamic belt, which contains porphyry copper deposits in the Carpathian Mountains, of southern and eastern Europe, and in the Himalayas in central Asia. Relatively little is known about specific characteristics of the known porphyry copper prospects in Afghanistan and there are no known deposits. We therefore assessed this deposit type using the general porphyry copper deposit model as described by Singer and others (2005). We delineated 12 permissive tracts for porphyry copper deposits (fig. 1). In some cases, the tract is also permissive for copper skarn deposits, but we did not make estimates of numbers of undiscovered deposits of this type. We created a distinct tract for each combination of characteristics, primarily age or presumed age.

Tracts ppycu02, ppycu05, and ppycu07 have the highest predicted deposit densities and they are the most attractive areas for exploration.

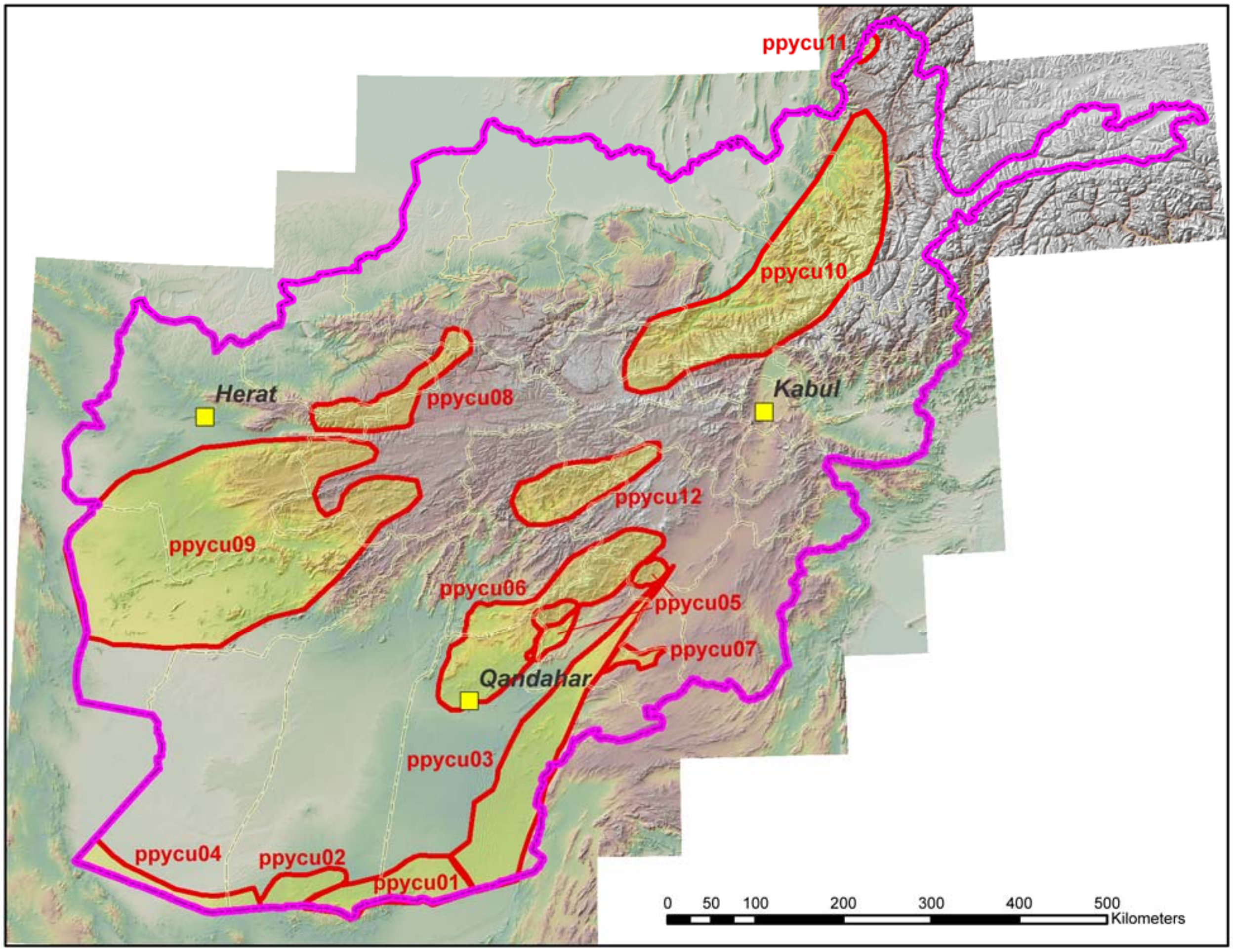

Figure 1. Map of Afghanistan, showing the location of mineral resource assessment tracts for porphyry copper deposits. Major Cities shown by yellow squares.

Porphyry Copper Tract Descriptions

***Tract ID*—ppycu01 (fig. 2)**

Deposit types—Porphyry copper and skarn copper

Age of mineralization—22 to 12 Ma

Examples of deposit type—Dasht-e-Kain, Ziarat Pir Sultan, Saindak, Koh-i-Dalil, Reko Diq (nearby in Pakistan) (Sillitoe and Khan, 1977; Spector and others, 1987; Ahmad, 1992)

Exploration history—There is no known exploration in this part of Afghanistan. The U.S. Geological Survey team did not visit the area.

Tract boundary criteria—The tract is based on a group of mapped Tertiary intrusive rocks (map unit P_3grg from Doebrich and Wahl, 2006) that may be related to porphyry-style mineralization. The boundary was refined by using aeromagnetic data, as the intrusions are characterized by linear positive anomalies that trend east-west (Sweeney and others, 2006). The eastern boundary with tract ppycu03 is dependent on certainty and amount of knowledge; less is known about tract ppycu03.

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

Needs to improve assessment—The information that is most needed is intermediate-scale (1:100,000) geologic mapping and geochemical sampling. Both would require site visits.

Optimistic factors—The presence of two well-explored deposits nearby in Pakistan, as well as at least two other prospects, is a positive indication. The geologic environment of those deposits and prospects can be extrapolated into this area.

Pessimistic factors—There are no known prospects in the tract. Based on satellite imagery, the area appears to be relatively deeply eroded.

Quantitative assessment—There is a 90 percent chance of 0 or more undiscovered porphyry copper deposits, a 50 percent chance of 1 or more, and a 10 percent chance of 3 or more (table 1).

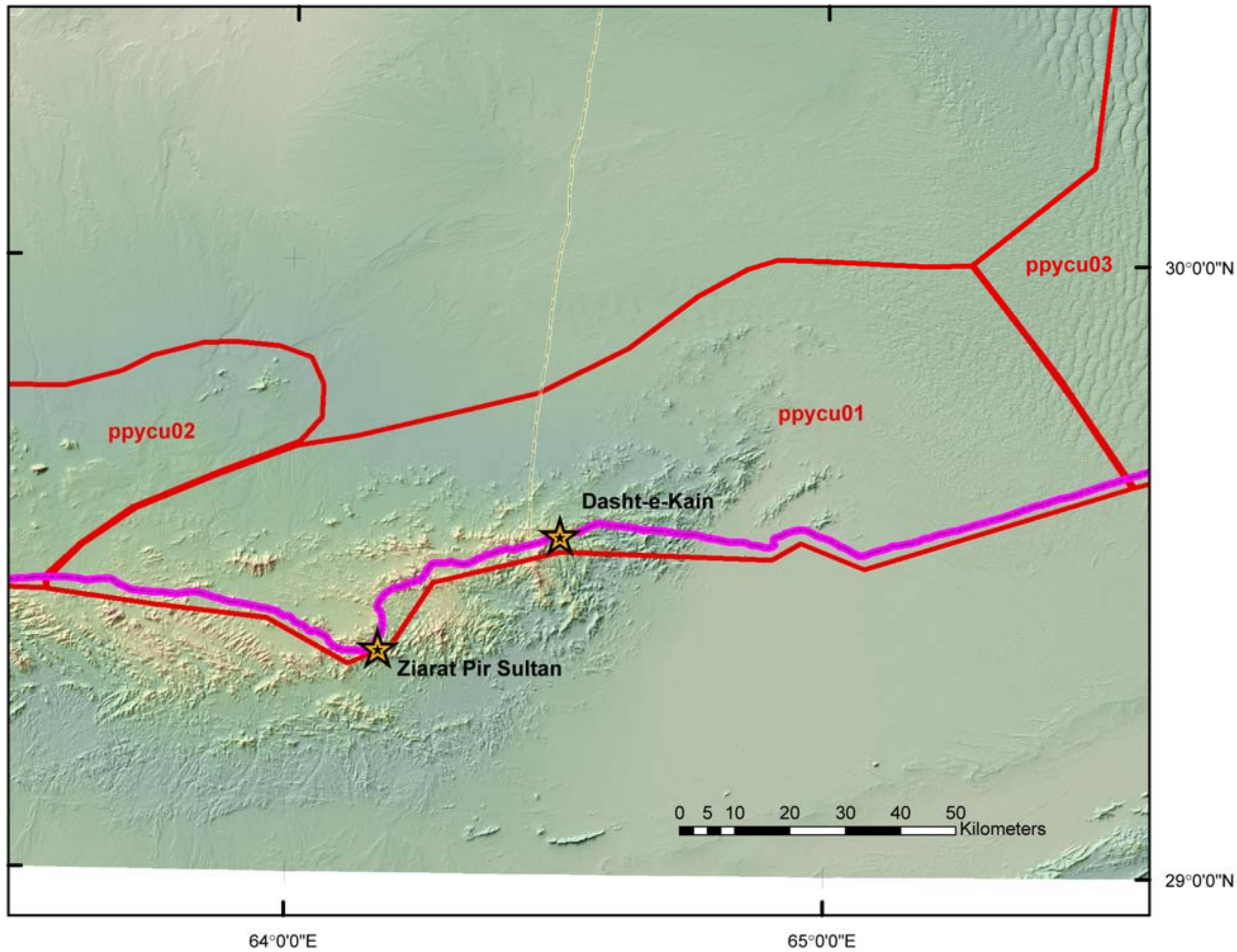

Figure 2. Map showing tract ppycu01 and porphyry copper prospects in Pakistan (orange stars).

***Tract ID*—ppycu02 (fig. 3)**

Deposit types—Porphyry copper and skarn copper

Age of mineralization—22 Ma to present (geologic map indicates Quaternary age)

Examples of deposit type—Dasht-e-Kain, Ziarat Pir Sultan, Saindak, Koh-i-Dalil, Reko Diq (nearby in Pakistan) (Sillitoe and Khan, 1977; Spector and others, 1987; Ahmad, 1992)

Exploration history—There is no known exploration in this part of Afghanistan. The U.S. Geological Survey team has not visited the area.

Tract boundary criteria—The tract is based on a group of mapped Tertiary intrusive rocks (map unit Q_3rd from Doebrich and Wahl, 2006) that may contain porphyry-style mineralization. The boundary was refined using aeromagnetic data, as the intrusions were characterized by linear positive anomalies that trend east-west. The eastern boundary with tract ppycu01 is dependent on certainty and amount of knowledge; less is known about tract ppycu01 (Sweeney and others, 2006).

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

Needs to improve assessment—The information that is most needed would be gained by intermediate-scale (1:100,000) geologic mapping and geochemical sampling. Both would require site visits.

Optimistic factors—The presence of two well-explored deposits nearby in Pakistan, along with at least two other prospects, is a positive indication. The geologic environment of those deposits and prospects could be extrapolated into this area. Satellite imagery shows abundant hydrothermally altered rocks described as rhyodacites, but which appear to be intrusions on imagery. There is a high proportion of altered rock to the total outcrop area.

Pessimistic factors—There are no known prospects in the tract. Based on satellite imagery, the intensity of the hydrothermal alteration is less than what might be expected at classic porphyry copper deposits.

Quantitative assessment—There is a 90 percent chance of 0 or more undiscovered porphyry copper deposits, a 50 percent chance of 1 or more, and a 10 percent chance of 2 or more (table 1).

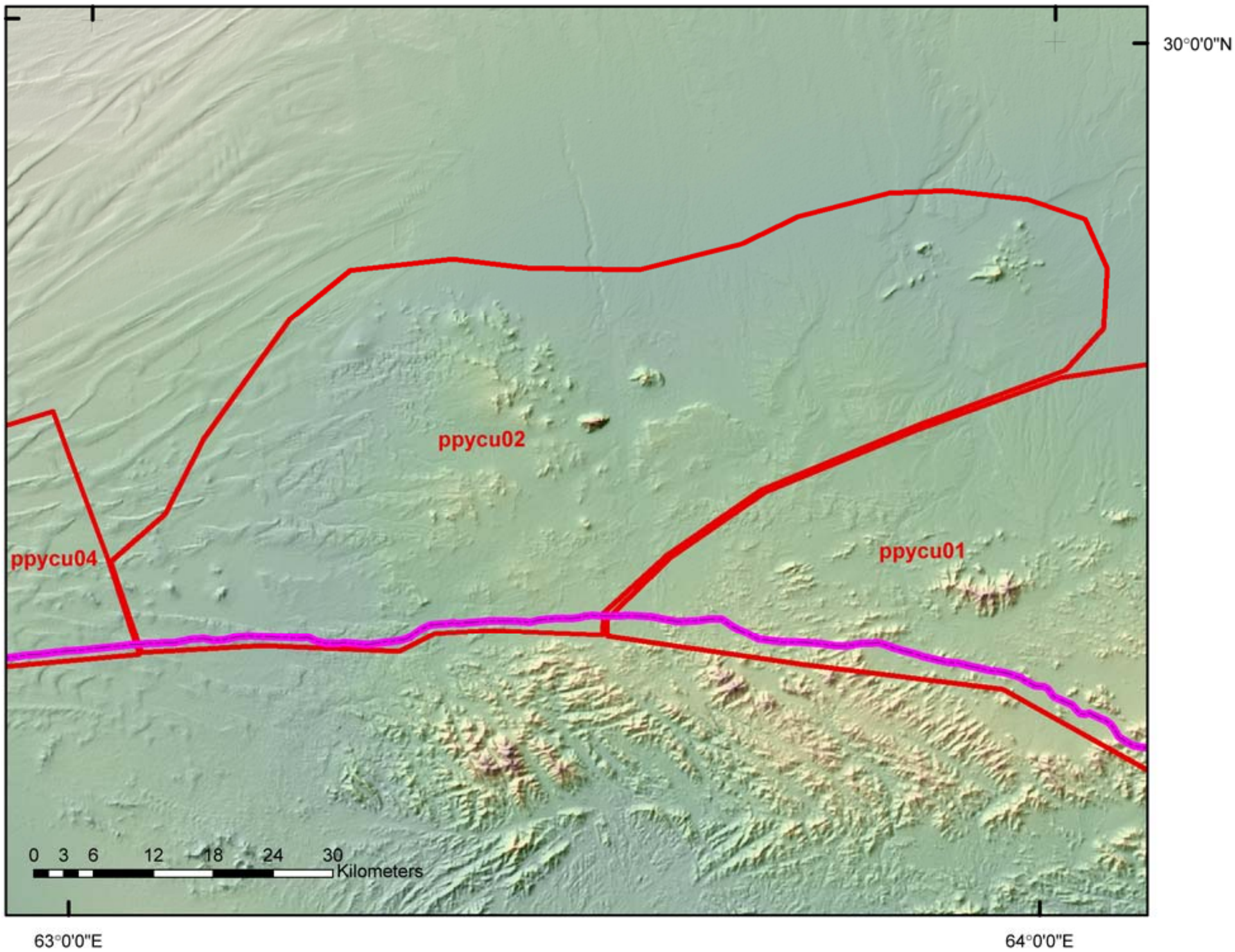

Figure 3. Map showing tract ppycu02.

Tract ID—ppycu03 (fig. 4)

Deposit types—Porphyry copper and skarn copper

Age of mineralization—Tertiary

Examples of deposit type—There are two small skarn copper prospects in the hills northwest of Spin Bodak, in the central part of the tract.

Exploration history—There was only limited previous exploration in this part of Afghanistan. The U.S. Geological Survey team has not visited the area.

Tract boundary criteria—The tract is based on the presence of a few prospects in a fault-bounded discrete crustal block. The boundaries of the crustal block are also delineated by the presence of positive aeromagnetic anomalies within the tract (Sweeney and others, 2006).

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 would be gained by intermediate-scale (1:100,000) geologic mapping and geochemical sampling. Both would require site visits.

Optimistic factors—The presence of two copper prospects demonstrates that mineralizing processes have been active within the tract. The few intrusive rocks present (map unit P_3grg) are of an appropriate age, size, and level of exposure to host porphyry copper deposits.

Pessimistic factors—Based on LANDSAT satellite imagery, there is little evidence of widespread hydrothermal alteration near intrusive rock outcrops. Prospects and other signs of mineralization are not numerous or widespread.

Quantitative assessment—There is a 90 percent chance of 0 or more undiscovered porphyry copper deposits, a 50 percent chance of 0 or more, and a 10 percent chance of 2 or more (table 1).

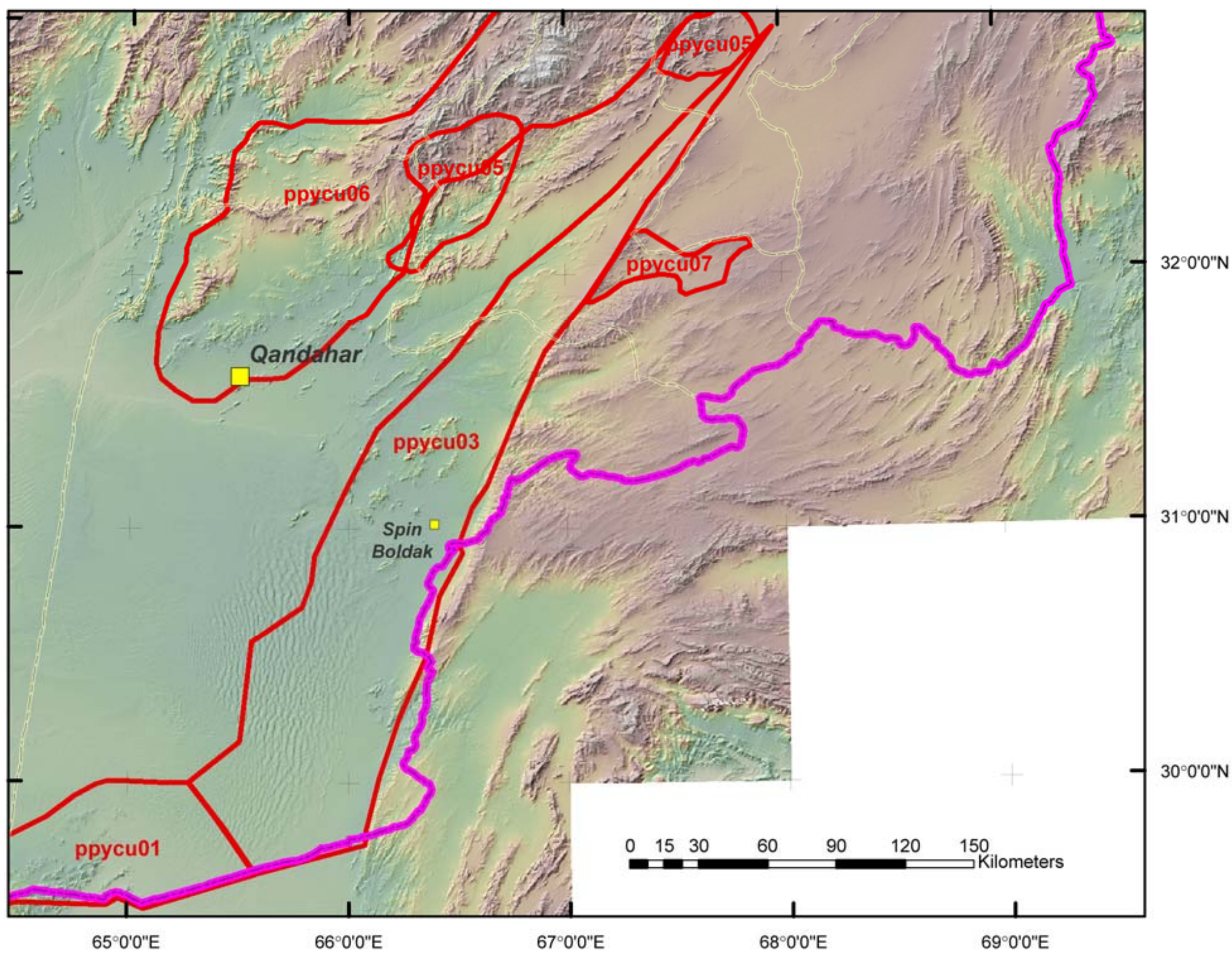

Figure 4. Map showing tract ppycu03.

***Tract ID*—ppycu04 (fig. 5)**

Deposit types—Porphyry copper and skarn copper

Age of mineralization—Miocene (?)

Examples of deposit type—There are no mineral deposits or prospects in the tract. Saindak and Reko Diq are nearby in Pakistan (Sillitoe and Khan, 1977; Spector and others, 1987; Ahmad, 1992).

Exploration history—There was no known exploration in this part of Afghanistan. The U.S. Geological Survey team has not visited the area.

Tract boundary criteria—The tract is based on the continuation into Afghanistan of the aeromagnetic signature that characterizes the area to the south in Pakistan that contains porphyry copper deposits. The tract is entirely covered by Quaternary deposits and bedrock is not exposed (Sweeney and others, 2006).

Important data sources—aeromagnetic data (Sweeney and others, 2006).

Needs to improve assessment—The information that is most needed is the complete, interpreted, aeromagnetic data set (Sweeney and others, 2006). Any further exploration would require a site visit and drilling.

Optimistic factors—The proximity to the Pakistani deposits and the probability of a positive aeromagnetic signature are favorable indications (Sweeney and others, 2006).

Pessimistic factors—There are no known prospects in the tract and it is completely covered to an unknown depth.

Quantitative assessment—There is a 90 percent chance of 0 or more undiscovered porphyry copper deposits, a 50 percent chance of 0 or more, and a 10 percent chance of 3 or more (table 1).

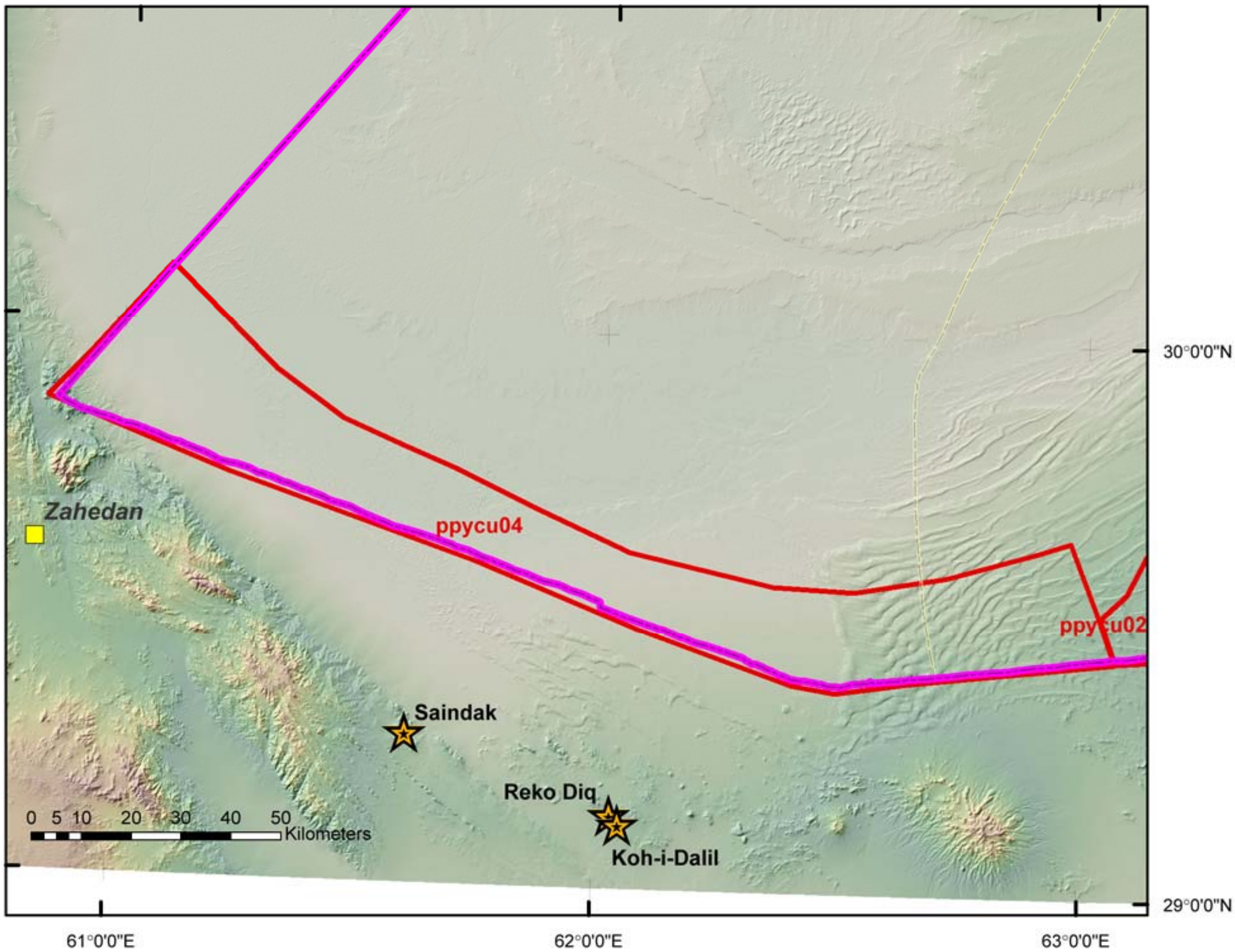

Figure 5. Map showing tract ppycu04 and porphyry copper prospects in Pakistan (orange stars).

Tract ID—ppycu05 (fig. 6)

Deposit types—Porphyry copper and skarn copper

Age of mineralization—Cretaceous

Examples of deposit type—Kundalyan and Zarkashan are both areas that contain a group of partially-explored skarn copper deposits.

Exploration history—Both the Kundalyan and Zarkashan areas were explored by trenches, tunnels, and diamond drilling by Soviet and Afghanistan geologists. The U.S. Geological Survey team paid a brief (10 minute) visit to one dump at Kundalyan and overflew the Zarkashan area.

Tract boundary criteria—The tract is based on a distinctive group of mapped Cretaceous intrusive rocks (map unit KP_1gbm from Doebrich and Wahl, 2006) that are spatially related to the known copper skarn deposits and prospects. The boundary was refined using data, as each of the two polygons of this tract contain strong positive magnetic anomalies (Sweeney and others, 2006). The intrusive rocks are alkaline in nature, and relatively oxidized.

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

Needs to improve assessment—This area requires field examination and detailed mapping to determine if there is porphyry-style mineralized rock in addition to the skarn deposits. Several man-months in each of the two areas would be needed. In addition, the mineralization age should be determined, to confirm that it is related to the Cretaceous plutons exposed in the area.

Optimistic factors—The presence of relatively well-explored deposits (Kundalyan and Zarkashan) is the most important positive indication. The petrologic characteristics of the associated intrusive rocks suggest that copper deposits found here might be gold-bearing.

Pessimistic factors—The previous exploration did not reveal economically important deposits.

Quantitative assessment—There is a 90 percent chance of 0 or more undiscovered porphyry copper deposits, a 50 percent chance of 1 or more, and a 10 percent chance of 2 or more (table 1).

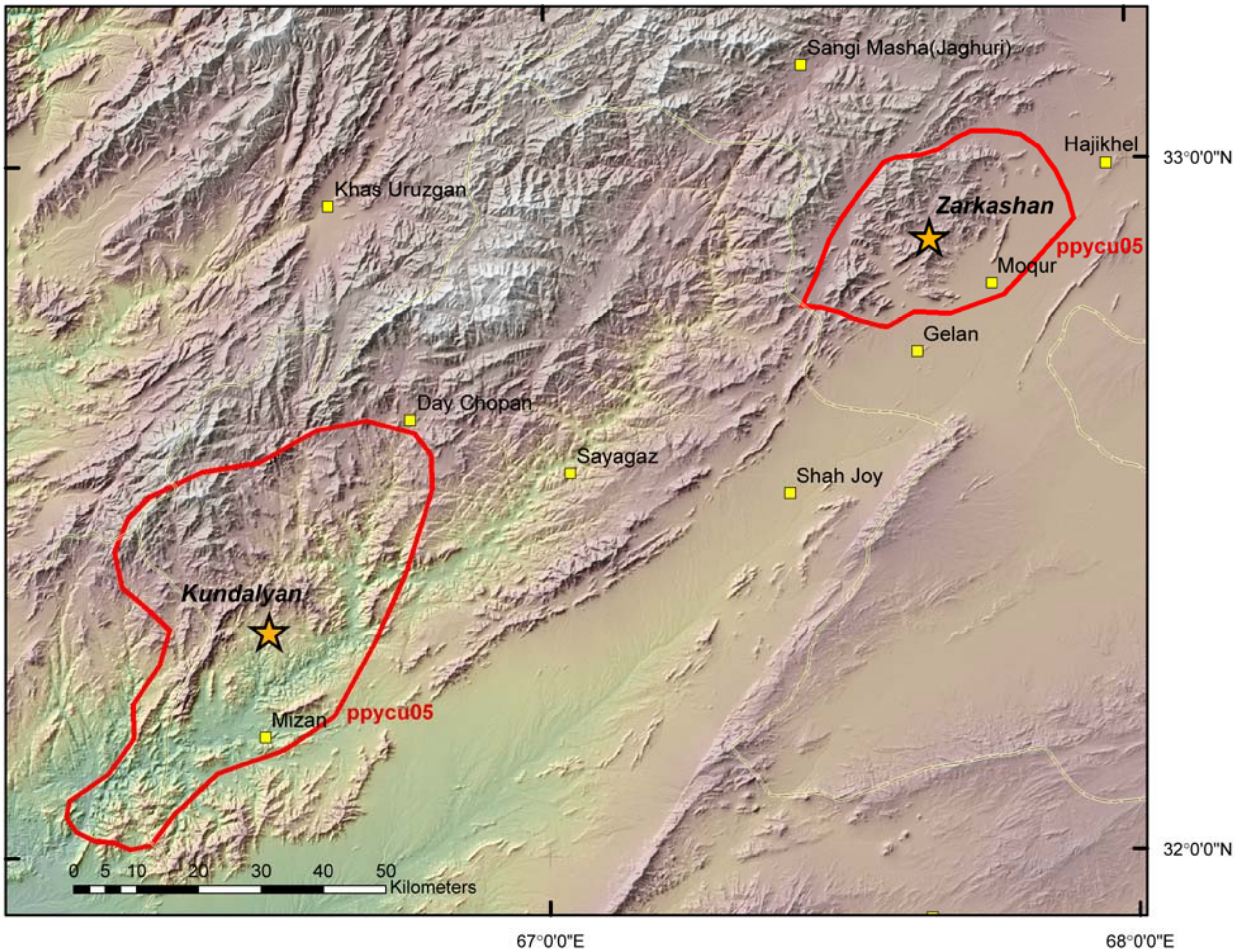

Figure 6. Map showing tract ppycu05 and copper skarn prospects (orange stars).

***Tract ID*—ppycu06 (fig. 7)**

Deposit types—Porphyry copper and skarn copper

Age of mineralization—Oligocene

Examples of deposit type—The tract contains no porphyry deposits, but numerous small deposits and prospects of precious and base metals, iron, and tungsten are present. The most common deposit type is polymetallic veins.

Exploration history—There was limited exploration in the past. The U.S. Geological Survey team flew over the area.

Tract boundary criteria—The tract is based on the outcrop area of a large Oligocene composite batholith, combined with the distribution of precious- and base-metal vein deposits and prospects. Aeromagnetic data help indicate the extent of hidden intrusive rocks, and were used to refine the tract boundaries (Sweeney and others, 2006). The northeastern tip of the area is fault-bounded.

Important data sources—geologic map, aeromagnetic map, lithogeochemical data, mineral deposit database, ASTER imagery (Doebrich and Wahl, 2006; Mars and Rowan, 2006; Sweeney and others, 2006).

Needs to improve assessment—The information that is most needed is intermediate-scale (1:100,000) geologic mapping, geochemical sampling, and examination of known prospects. All would require site visits.

Optimistic factors—The presence of widespread prospects of pluton-related deposits is a positive indicator, as is the presence of widespread phyllic and argillic alteration.

Pessimistic factors—The alteration patterns appear to be related to regional fractures within the batholith, and don't correlate well spatially with the distribution of mineral prospects. The composition of the batholithic rocks is not highly favorable; there are many peraluminous rocks and a lack of mafic rocks (diorites), both somewhat atypical of porphyry-bearing terranes. The widespread exposure of mesozonal(?) batholithic rocks suggests that the area is relatively deeply eroded, and much of the porphyry environment that may have once been present has been removed by erosion.

Quantitative assessment—There is a 90 percent chance of 0 or more undiscovered porphyry copper deposits, a 50 percent chance of 0 or more, and a 10 percent chance of 2 or more (table 1).

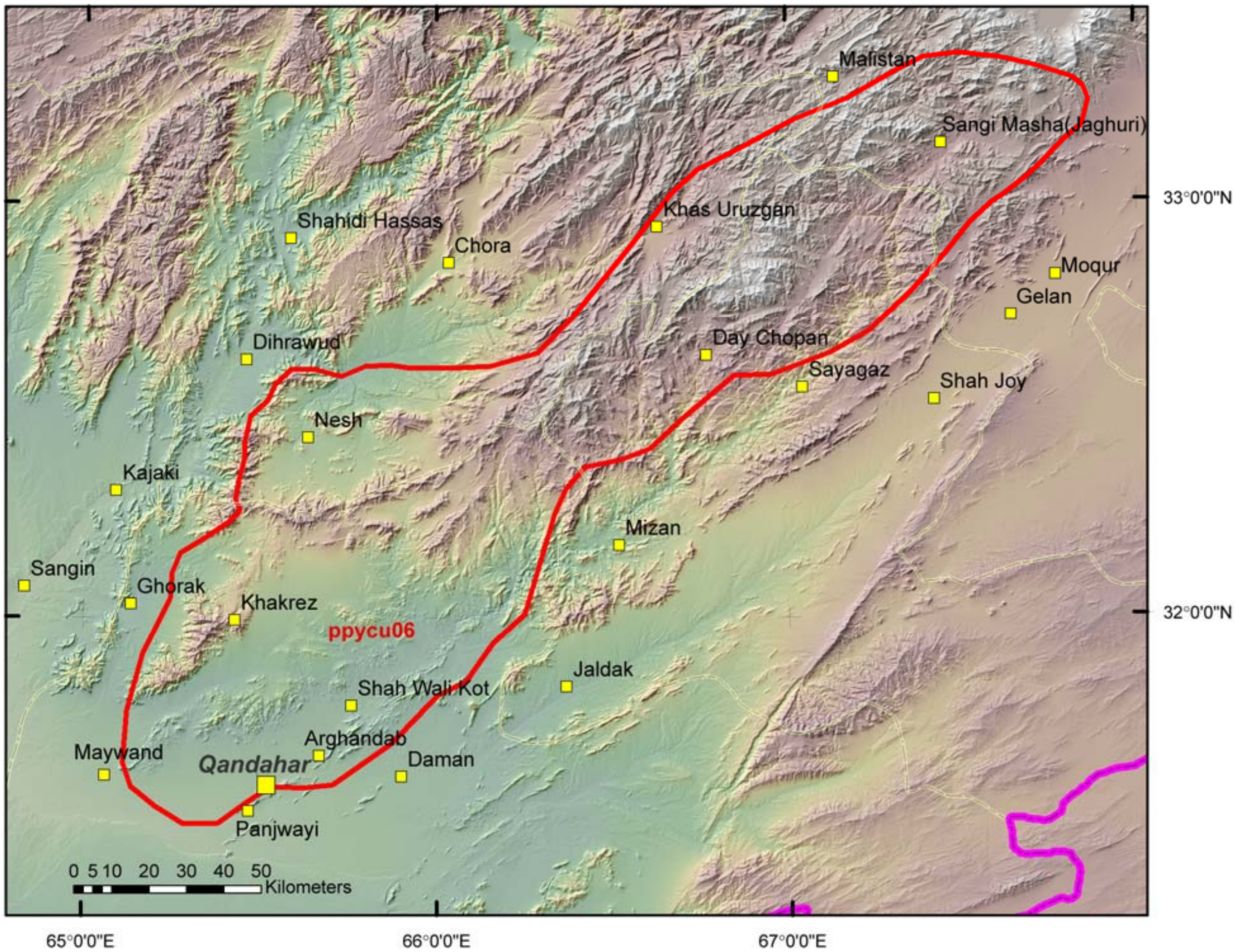

Figure 7. Map showing tract ppycu06.

Tract ID—ppycu07 (fig. 8)

Deposit types—Porphyry copper and skarn copper

Age of mineralization—Miocene

Examples of deposit type—There are no mineral deposits or prospects within the tract.

Exploration history—There is no known exploration in this part of Afghanistan. The U.S. Geological Survey team has not visited the area.

Tract boundary criteria—The tract is based on a group of mapped Miocene intrusive rocks (map unit N_1dig from Doebrich and Wahl, 2006) that may be related to porphyry-style mineralization. These rocks consist of diorite, granodiorite, monzonite, syenite, and nepheline syenite porphyry. In addition, ASTER imagery reveals widespread phyllic and lesser argillic alteration in the area (Mars and Rowan, 2006). The alteration patterns are linear, and correspond spatially with the distribution of the alkaline Miocene intrusive rocks. The intrusive rocks have no apparent magnetic signature and may be ilmenite-series rocks.

Important data sources—Geologic map, ASTER imagery (Doebrich and Wahl, 2006; Mars and Rowan, 2006), lithogeochemical data.

Needs to improve assessment—The information that is most needed would be gained by intermediate-scale (1:100,000) geologic mapping and geochemical sampling in order to determine if metals are associated with the hydrothermal alteration. Both would require site visits.

Optimistic factors—The intense hydrothermal alteration patterns are typical of regions that contain porphyry copper deposits.

Pessimistic factors—There are no known deposits or prospects in the tract.

Quantitative assessment—There is a 90 percent chance of 0 or more undiscovered porphyry copper deposits, a 50 percent chance of 0 or more, and a 10 percent chance of 2 or more (table 1).

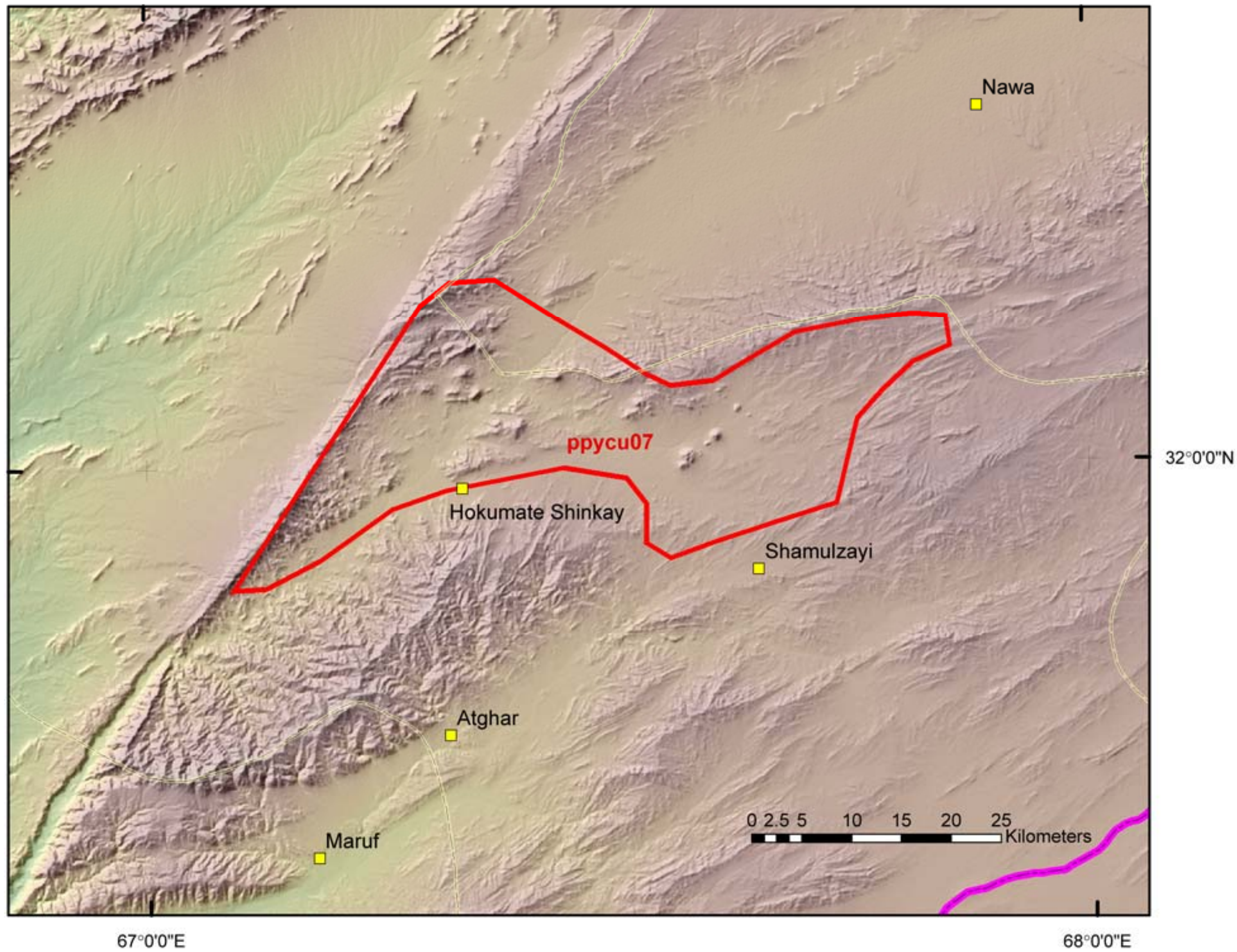

Figure 8. Map showing tract ppycu07.

***Tract ID*—ppycu08 (fig. 9)**

Deposit types—Porphyry copper and skarn copper

Age of mineralization—Miocene

Examples of deposit type— The tract contains no porphyry deposits, but there is one skarn copper prospect, Ahankashan, however, the AGS fact sheet APPEARS to place this prospect about 110 km to the northeast). There are also a few polymetallic vein occurrences and an iron skarn prospect.

Exploration history—There was only limited previous exploration in this part of Afghanistan. The U.S. Geological Survey team has not visited the area.

Tract boundary criteria— The tract is based on a group of mapped Miocene intrusive rocks (map unit N_1dig from Doebrich and Wahl, 2006) that may be related to porphyry-style mineralization. These rocks consist of diorite, granodiorite, monzonite, syenite, and nepheline syenite porphyry. These intrusive rocks have no apparent magnetic signature and may be ilmenite-series rocks.

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

Needs to improve assessment—The information that is most needed would be gained by intermediate-scale (1:100,000) geologic mapping and geochemical sampling. Both would require site visits.

Optimistic factors—The description of the prospect at Ahankashan includes mention of stockwork and veinlet mineralization, which characterizes porphyry copper deposits.

Pessimistic factors—There are very few prospects in the tract. No study has been made using satellite imagery, but there is no apparent widespread hydrothermal alteration like that in tract ppycu07. The erosion level here may be above the porphyry environment and any deposits may be hidden.

Quantitative assessment—There is a 90 percent chance of 0 or more undiscovered porphyry copper deposits, a 50 percent chance of 0 or more, and a 10 percent chance of 2 or more (table 1).

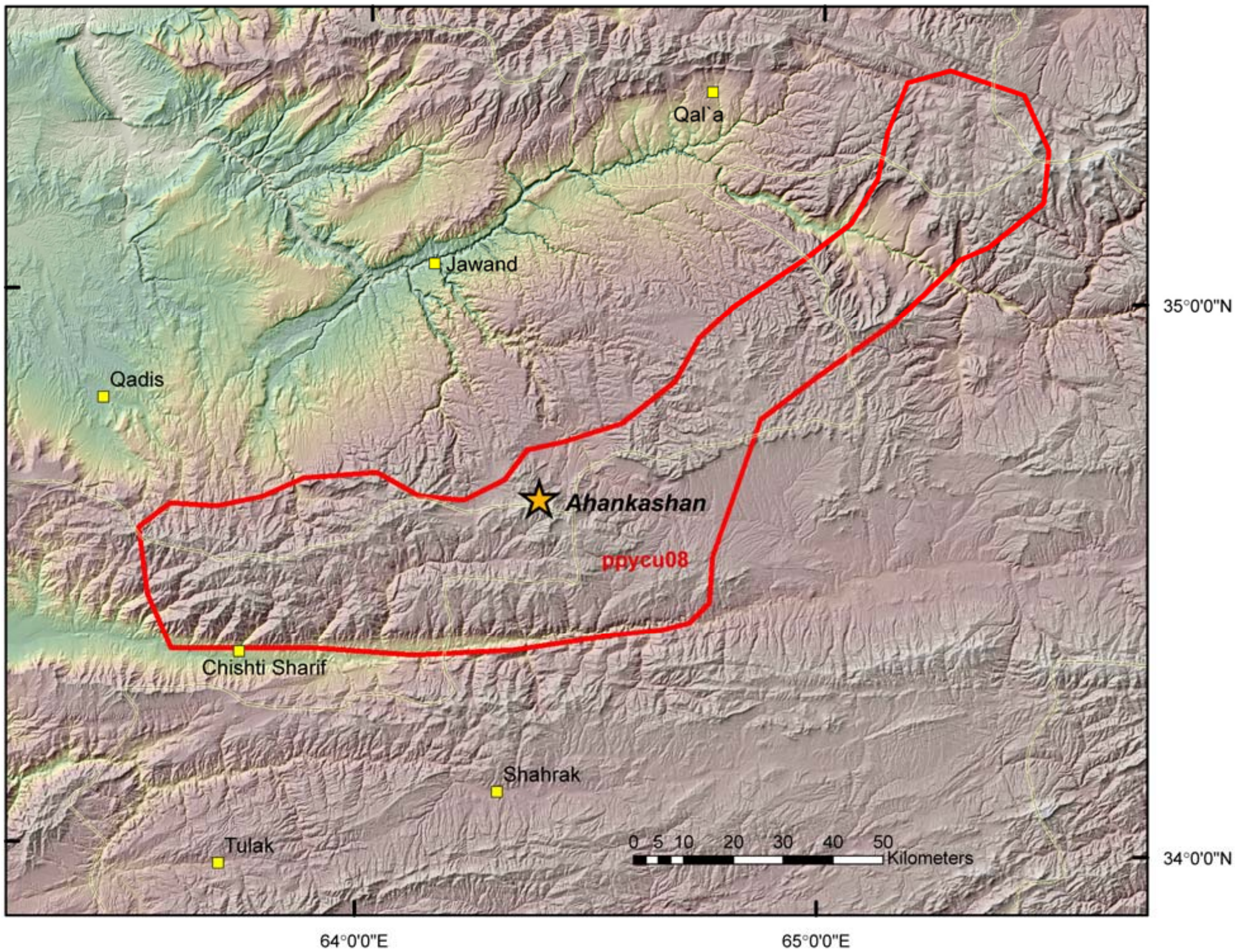

Figure 9. Map showing tract ppycu08 and location of Ahankashan skarn copper prospect (orange star).

***Tract ID*—ppycu09 (fig. 10)**

Deposit types—Porphyry copper and skarn copper

Age of mineralization—Tertiary

Examples of deposit type—Shaida, in the north-central part of the tract, was described as a porphyry copper deposit (Daud Saba, Kabul, Afghanistan, personal comm., 2005, 2006). Soviet geologists, however, did not classify it as such. There are numerous mineral prospects and occurrences in the tract, including a number of polymetallic veins and copper skarns. There are also several tin deposits, both skarns and stockwork veins. A few prospects have also been classified as volcanogenic massive sulfide deposits.

Exploration history—This area received a moderate amount of attention in the past, as evidenced by the numerous identified deposits and prospects. The U.S. Geological Survey team has not visited the area.

Tract boundary criteria—The tract is based on a group of mapped Oligocene intrusive rocks (map unit P_3grg from Doebrich and Wahl, 2006) that may be related to porphyry-style mineralization. The intrusive rocks consist of granite, granodiorite, quartz syenite, and granosyenite. Some volcanic rocks of equivalent age are also present. The tract was extended to include the hydrothermal mineral prospects that were suspected to be related to this same igneous event. The boundary was refined using aeromagnetic data; where high resolution data are available, the signature is typical of volcanic terranes and shows many short wavelength (high frequency) anomalies (Sweeney and others, 2006).

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

Needs to improve assessment—The information that is most needed would be gained by intermediate-scale (1:100,000) geologic mapping and geochemical sampling. Both would require site visits.

Optimistic factors—The presence of at least one prospect (Shaida) that has been interpreted to be a porphyry copper prospect is a positive indication. The geologic environment is appropriate and the presence of associated volcanic rocks suggests that the level of exposure is favorable. Copper is prominent in the metallogenic signature of many of the deposits and prospects. Limestone is relatively scarce in the tract, meaning that skarn deposits are less likely than porphyry deposits.

Pessimistic factors—The presence of numerous tin-bearing deposits may be a negative factor. In other parts of the world, some types of tin-copper deposits exist, but tin is not known to be an important element in the geochemical signature of porphyry copper deposits. It has been suggested that Shaida is Cretaceous in age, and not related to the Oligocene rocks used to delineate the tract. Shaida has also been interpreted to be a simple vein deposit.

Quantitative assessment—There is a 90 percent chance of 0 or more undiscovered porphyry copper deposits, a 50 percent chance of 1 or more, and a 10 percent chance of 3 or more (table 1).

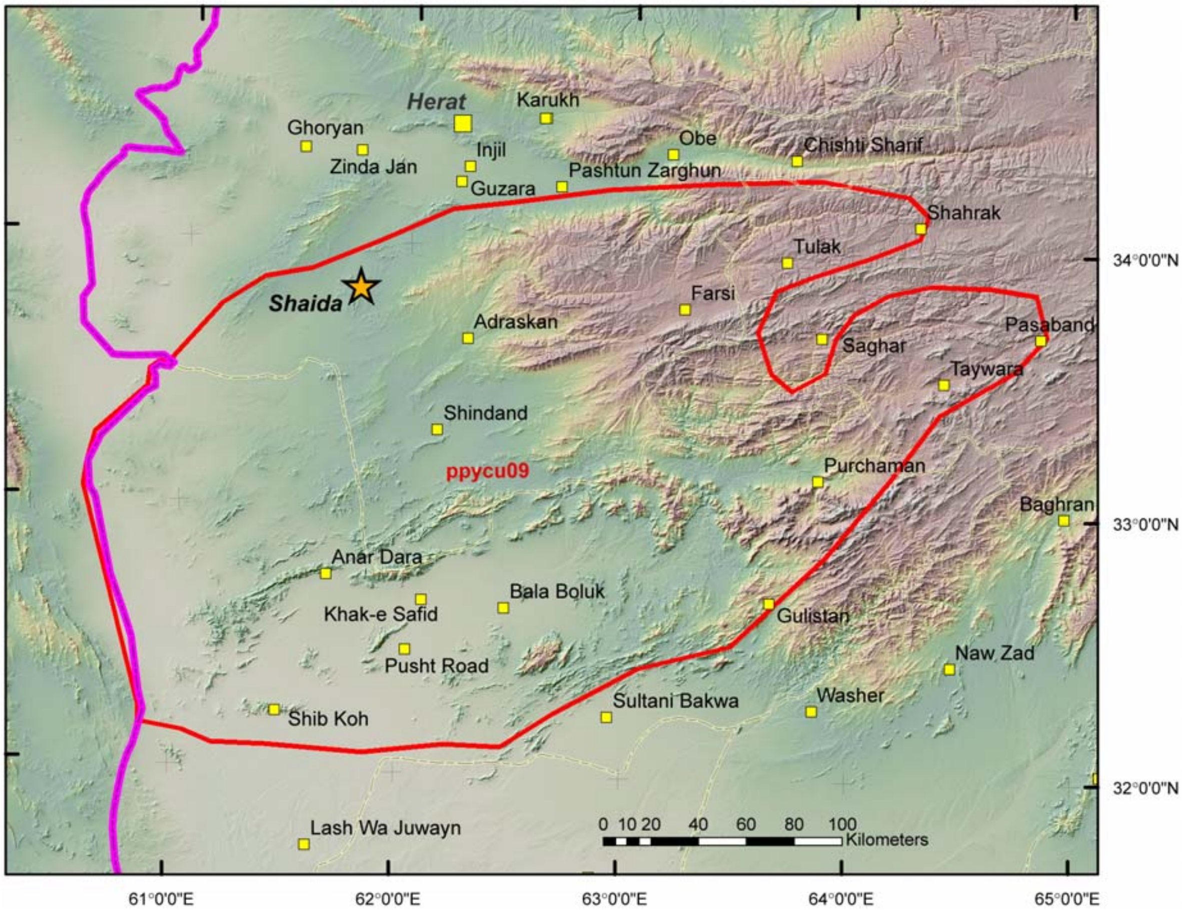

Figure 10. Map showing tract ppycu09 and location of Shaida porphyry copper prospect (orange star).

Tract ID—ppycu10 (fig. 11)

Deposit types—Porphyry copper

Age of mineralization—Triassic (?)

Examples of deposit type—There are scattered mineral deposits and prospects in the tract, including at least one copper skarn (Darra Alasang) and several polymetallic veins. There are no porphyry copper prospects.

Exploration history— This area received some attention in the past, as evidenced by the presence of identified deposits and prospects. The U.S. Geological Survey team has not visited the area.

Tract boundary criteria—The tract is based on mapped Triassic intrusive rocks (map unit T_1gdg from Doebrich and Wahl, 2006) that could contain porphyry-style mineralization. The tract was extended to include the hydrothermal mineral prospects that could be related to this igneous event.

Important data sources—geologic map, mineral deposit database

Needs to improve assessment—Very little is known about the hydrothermal mineral prospects in this area. The first step would be to visit copper-bearing mineral sites to determine if they could be related to porphyry copper deposits.

Optimistic factors—This tract is no more than permissive for the occurrence of porphyry copper deposits.

Pessimistic factors—There are relatively few mineral prospects in this large area.

Quantitative assessment—There is a 90 percent chance of 0 or more undiscovered porphyry copper deposits, a 50 percent chance of 0 or more, and a 10 percent chance of 1 or more (table 1).

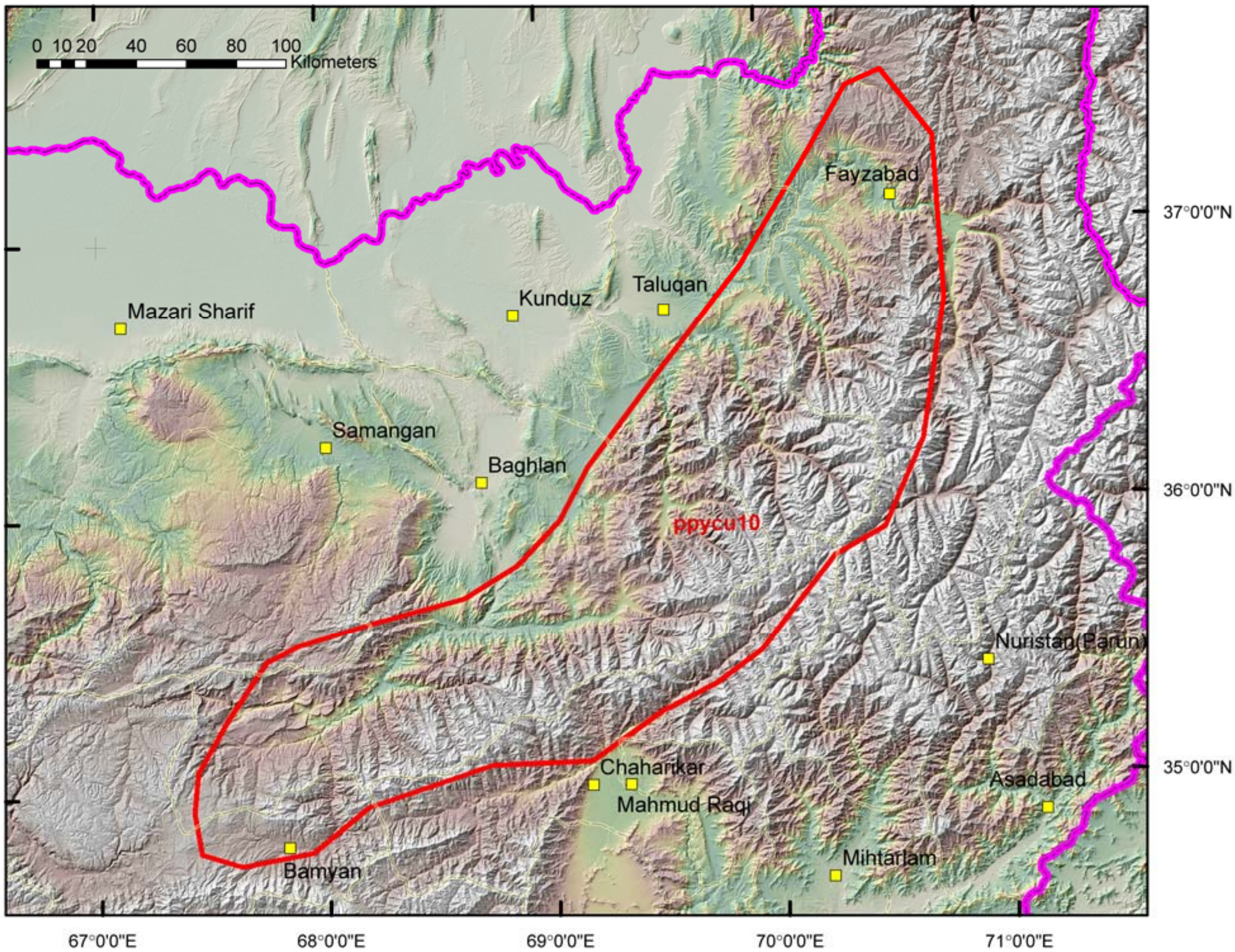

Figure 11. Map showing tract ppycu10.

***Tract ID*—ppycu11 (fig. 12)**

Deposit types—Porphyry copper

Age of mineralization—Miocene (?)

Examples of deposit type—There is mention of Miocene copper porphyry-style mineralization in Badakhshan Province (Afghanistan Geological Survey, 2006b). We have no further information on prospects in this tract that would indicate porphyry copper deposits.

Exploration history—This area received some attention in the past, as evidenced by the presence of a few identified deposits and prospects. The U.S. Geological Survey team has not visited the area.

Tract boundary criteria—The tract is based on the locations of three unnamed copper occurrences in Badakhshan Province. We are not certain this is the location of the porphyry-style mineralization reported in Afghanistan Geological Survey (2006a and b).

Important data sources—Afghanistan Geological Survey (2006a and b), mineral deposit database

Needs to improve assessment—More information must be obtained from the authors of Afghanistan Geological Survey (2006).

Pessimistic factors—There is very little documented information about copper mineralization in the area.

Quantitative assessment—Because of the lack of information, a quantitative assessment was not made.

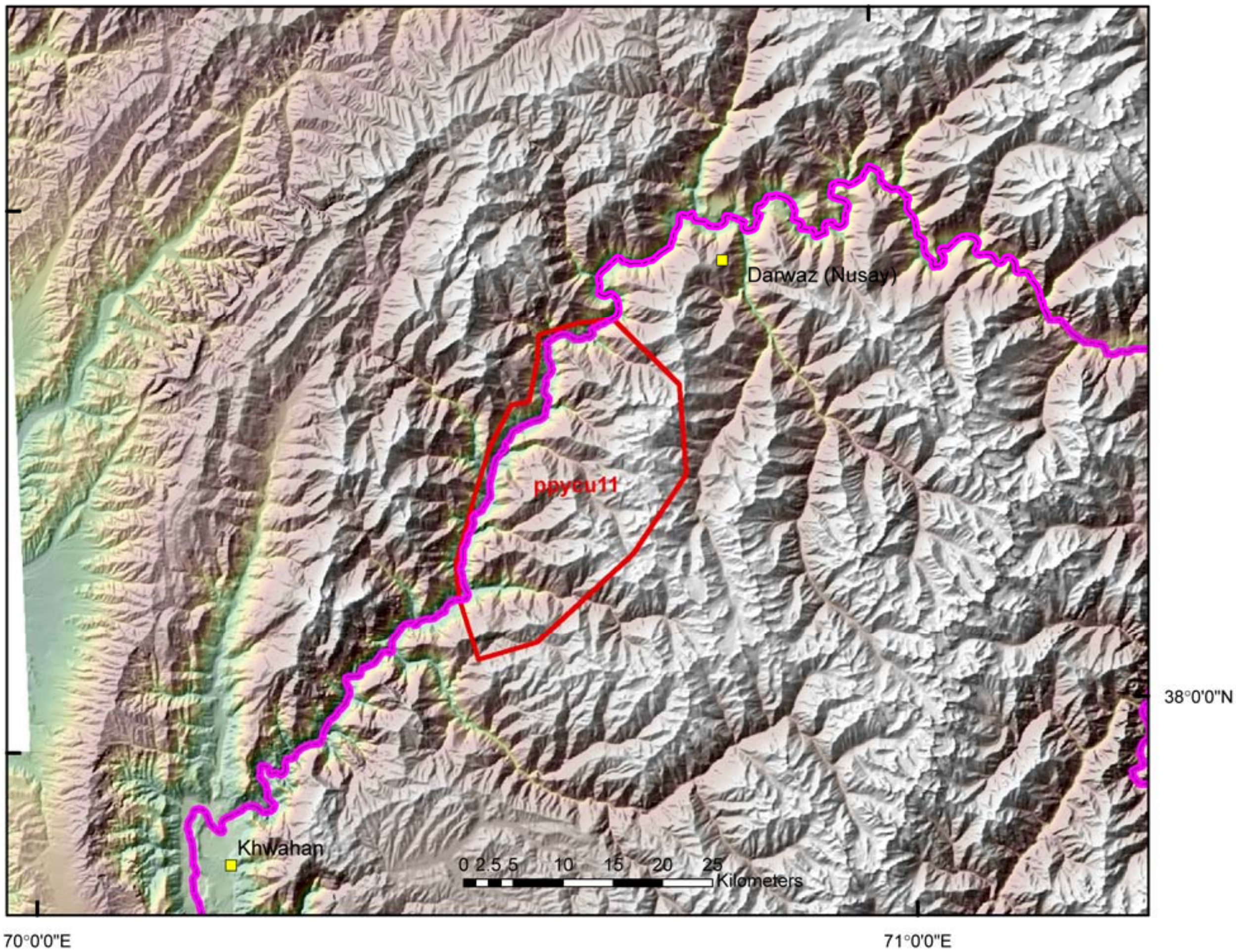

Figure 12. Map showing tract ppycu11.

Tract ID—ppycu12 (fig. 13)

Deposit types—Porphyry copper and copper skarn

Age of mineralization—Tertiary

Examples of deposit type—There are no porphyry copper prospects in this tract. There are a few polymetallic veins and base metal skarn prospects.

Exploration history—This area received some attention in the past, as evidenced by the presence of a few identified deposits and prospects. The U.S. Geological Survey team has not visited the area.

Tract boundary criteria—The tract is based on the outcrop area of Oligocene intrusive rocks similar in age and composition to those in tract ppycu06 (map units P_3gd and P_3gdy; granodiorite, granosyenite, and granite from Doebrich and Wahl, 2006), combined with the distribution of a few base-metal vein deposits and prospects.

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

Needs to improve assessment—The information that is most needed would be gained by intermediate-scale (1:100,000) geologic mapping and geochemical sampling. Both would require site visits.

Optimistic factors—The petrochemistry of the intrusive rocks is similar to tract ppycu06.

Pessimistic factors—There are very few prospects in this relatively large area.

Quantitative assessment—There is a 90 percent chance of 0 or more undiscovered porphyry copper deposits, a 50 percent chance of 0 or more, and a 10 percent chance of 1 or more (table 1).

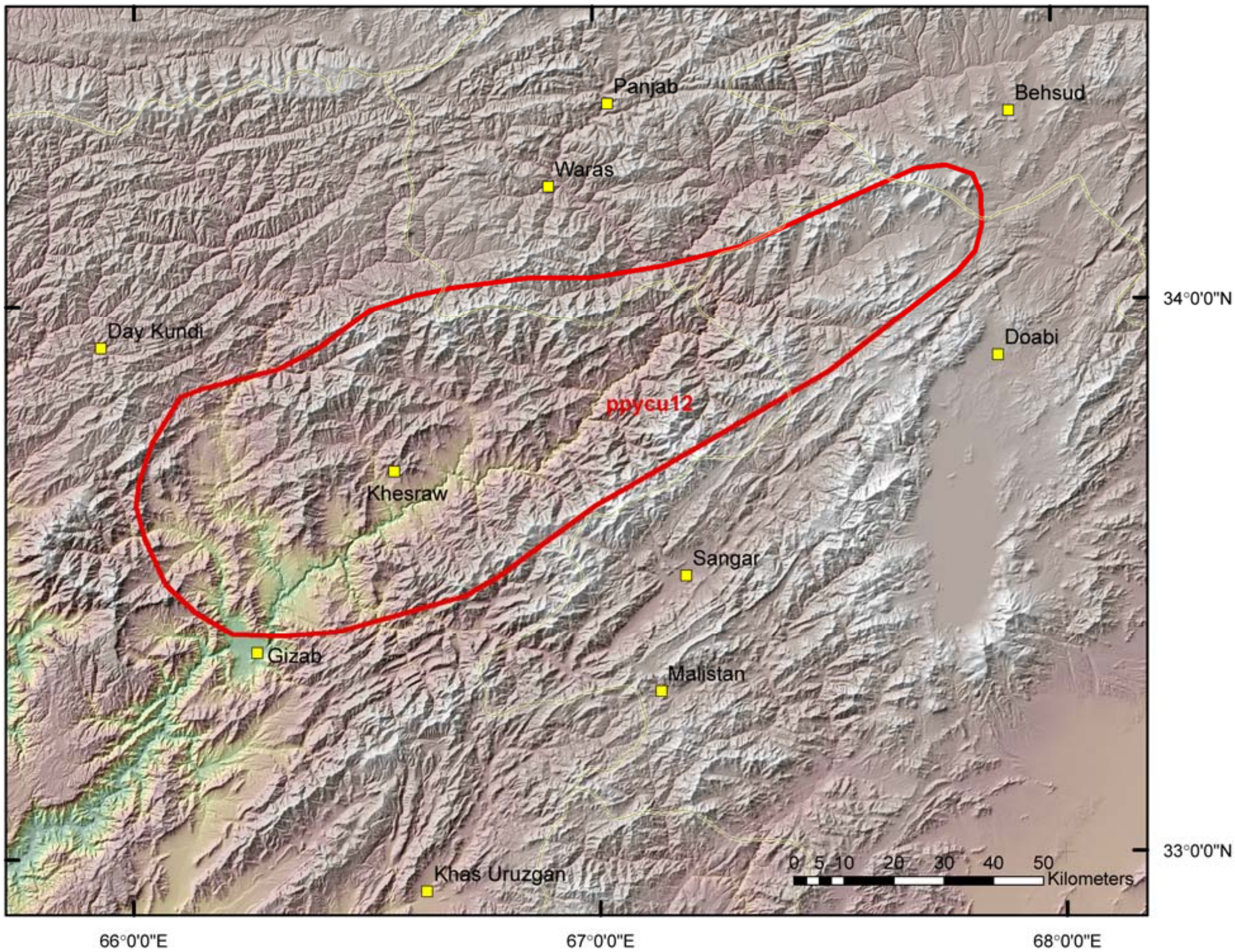

Figure 13. Map showing tract ppycu12.

Sediment-Hosted Copper Deposits

Aynak is a world-class copper deposit located about 30 km southeast of Kabul. The copper mineralization is stratabound and consists primarily of chalcopyrite and bornite disseminated in dolomite marble and quartz-biotite-dolomite schist of the Loy Khwar Formation. It has been explored by more than 150 boreholes.

The deposit can be classified generally as a sediment-hosted copper deposit. It is believed to have been formed by reactions between evaporitic brines and seawater circulating through underlying volcanic rocks that could have supplied the copper in the deposit. Some of the limestones and marls in the Loy Khwar Formation contain abundant carbon, probably the result of former organic material, that could have reacted with ascending solutions to fix copper sulfide minerals. It is not clear whether this deposit should be classified as a reduced-facies subtype of the sediment-hosted copper model (Cox and others, 2003), so the team assessed the tract for deposits like Aynak.

Sediment-Hosted Copper Tract Description

Tract ID—sedcu01 (fig. 14)

Deposit types—Sediment-hosted copper

Age of mineralization—Neoproterozoic to Early Cambrian

Examples of deposit type—Aynak, Darband, Jawkhar

Exploration history—The Aynak deposit and the surrounding areas were explored primarily in the 1960s and 1970s. More than 30,000 m of drilling was used to delineate two major ore zones at Aynak Central and Aynak West. During the same time period, about 40 prospects having similar characteristics were identified and a few of them contain small measured or estimated reserves (Afghanistan Geological Survey, 2006a).

Tract boundary criteria—The tract is an attempt to outline the areas within the Kabul tectonic block where map unit Z_eЄld might be present at shallow depth as well as at the surface. This map unit consists of marble, quartzite, metasandstone, and mica schist, and is the host rock for the Aynak deposits. On the south, the tract terminates against a large Oligocene granodiorite intrusion. Small bodies of ultramafic rock and ophiolite bodies are included in the tract because they are thought to be without deep vertical extensions. Some small areas where older Proterozoic metamorphic rocks crop out are excluded from the tract. Four small sedimentary-rock-hosted copper prospects are outside the tract to the west. Although these prospects are reported to occur in Ediacaran (formerly Vendian; i.e. Paleoproterozoic) rocks, the outcrop areas are extremely restricted in thickness and extent and do not appear on the geologic map.

Important data sources—Geologic map, aeromagnetic and gravity data (Sweeney and others, 2006), mineral deposit database (Doebrich and Wahl, 2006), Aynak information CD (British Geological Survey, 2005)

Needs to improve assessment—The information that is most needed is an intermediate-scale (1:100,000) geologic map of the parts of the tract distant from the Aynak deposit (particularly in the north). The rock mapped as Z_eꞒld (from Doebrich and Wahl, 2006) northeast of Kabul should be visited and described, in an effort to understand why there are no apparent copper prospects in that region. The descriptions of the Aynak deposit should be studied and evaluated to permit proper classification of the deposit.

Optimistic factors—There are large discovered copper resources in the tract, and a large number of prospects.

Pessimistic factors—Part of the tract is relatively well explored, and further discoveries there are less likely. The classification of the deposits is uncertain, and this leads to uncertainty in how to evaluate the importance of understanding the depositional environment of similar rocks distant from the Aynak deposit.

Quantitative assessment—The estimate we made is actually for "Aynak-type" deposits, as the team is uncertain of the correct classification of the Aynak deposit. There is a 90 percent chance of 1 or more undiscovered Aynak-type copper deposits, a 50 percent chance of 3 or more, and a 10 percent chance of 8 or more (table 1).

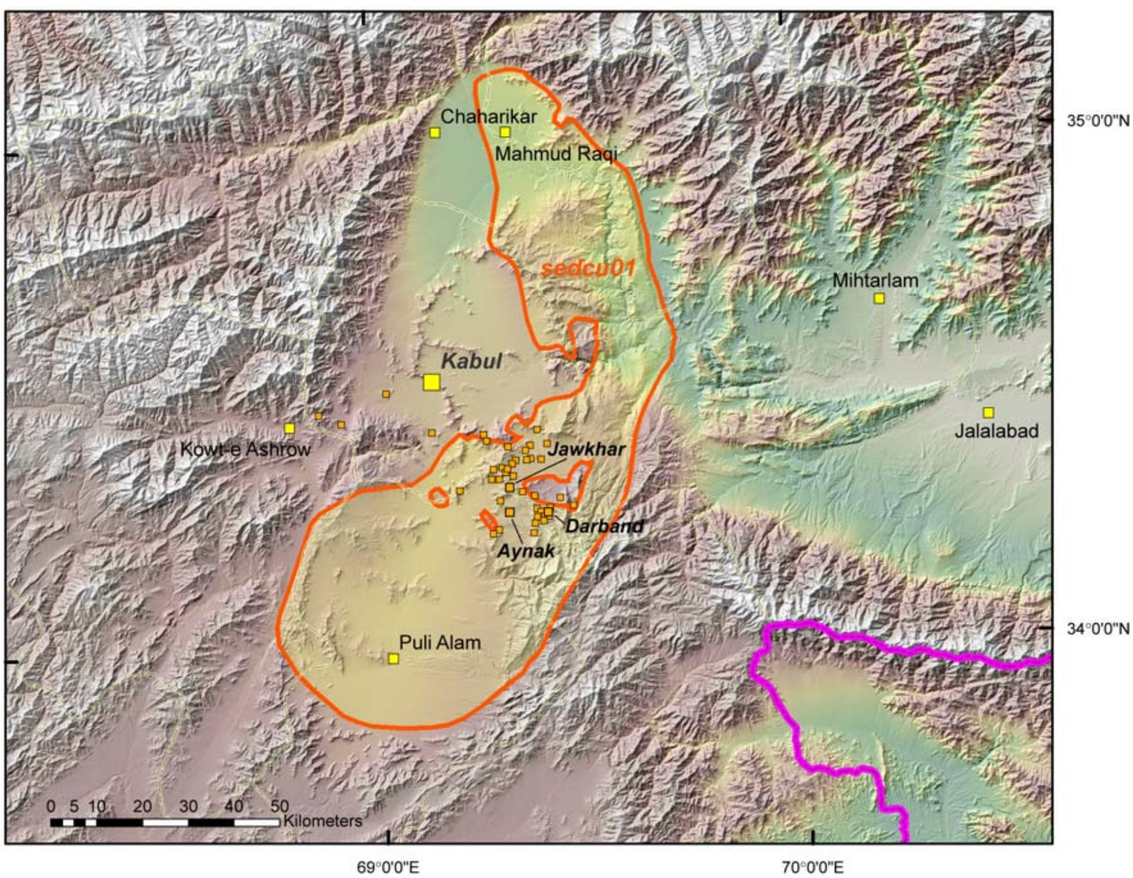

Figure 14. Map showing tract sedcu01 and locations of known deposits and prospects (orange squares).

Gypsum Tract Description

***Tract ID*—gyp01 (fig. 15)**

Deposit types—Gypsum

Age of mineralization—Late Jurassic to Paleocene, Eocene, and Neogene (fig. 16)

Examples of deposit type—Dudkash (Late Jurassic, Baghlan Province), Sary-Assya (Late Cretaceous to Pliocene, Samangan Province), Surkh-Rod (Neogene, Nangarhar Province)

Exploration history—Soviet and Afghanistan geologists identified several gypsum deposits during geological surveys in the 1970s, but there was no known exploration specifically for gypsum deposits.

Importance of deposits—Gypsum is a key component in the manufacture of wallboard, a cost-effective building material, and there are additional uses in cement and agriculture. Most currently active gypsum quarries are mined on a small scale and the specific utilization of the mined material is not known. Larger operations would use standard open-pit mining methods. The demand for gypsum normally increases with an increasing national gross domestic product (GDP).

Tract boundary criteria—The tract was delineated using the digital geologic map of Afghanistan (Doebrich and others, 2006). The tract consists of those map units that have gypsum identified as a major or dominant component. Gypsum-bearing rocks of all ages are combined in this tract because we lack information to develop criteria for differing probabilities of occurrence in rocks of different ages. Units in which limestone is a minor component could be considered to have lower potential.

Important data sources—geologic map, mineral deposit database, and data from oil and gas assessment.

Needs to improve assessment—Information about consistency of chemical and physical properties of gypsum within known deposits would be particularly helpful, along with confirmation of the age and mode of occurrence of different gypsum deposits. All of these would require site visits.

Optimistic factors—Some of the known deposits are quite large (thousands of meters long and from 5 to more than 30 m thick). Reported grades range from 89 percent to as much as 99 percent gypsum.

Pessimistic factors—Very few data about gypsum quality are available. There is no information about the consistency of chemical or physical properties of gypsum within known deposits.

Quantitative assessment—Available information is not sufficient to allow a quantitative assessment.

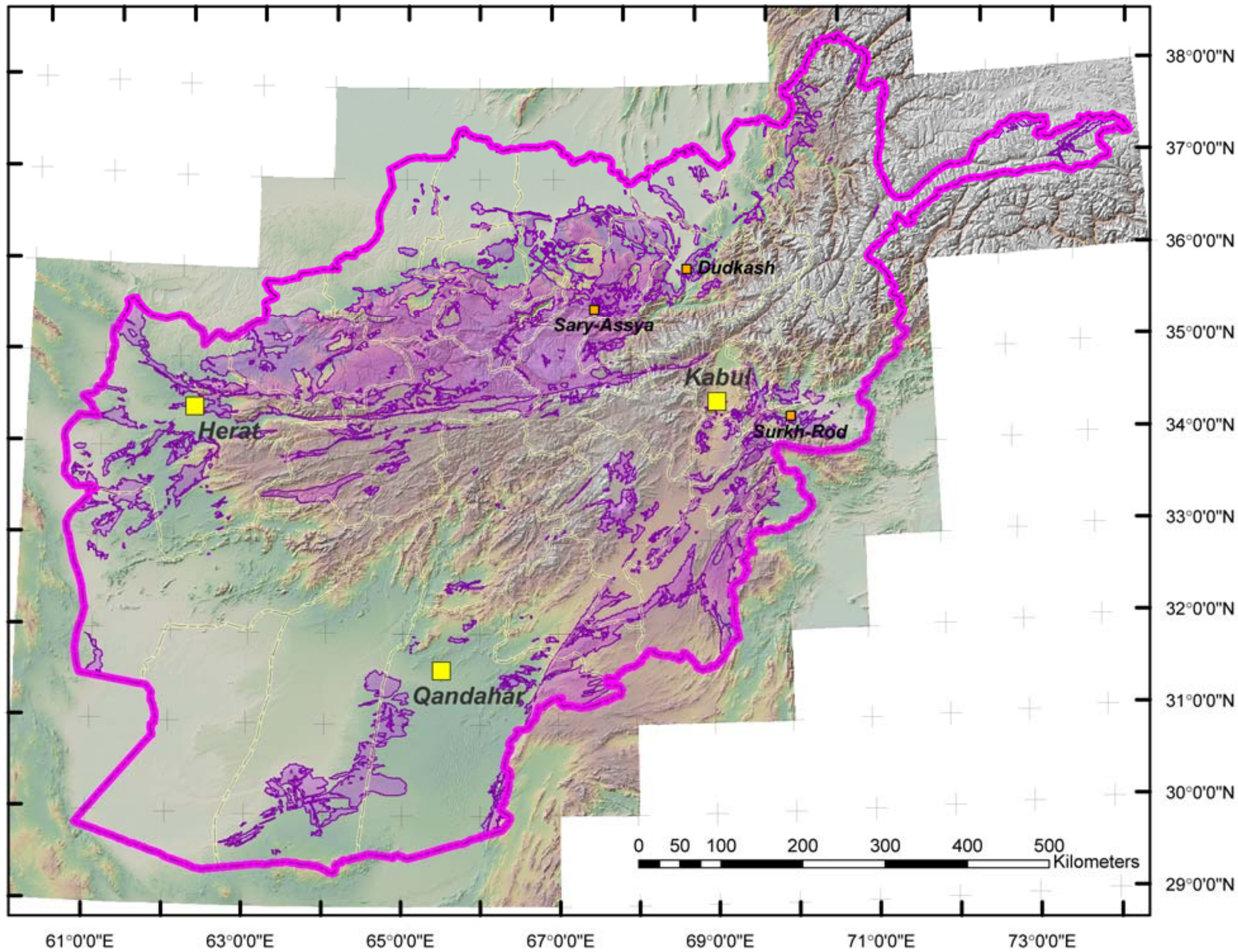

Figure 15. Map showing tract gyp01 and major gypsum deposits (orange squares).

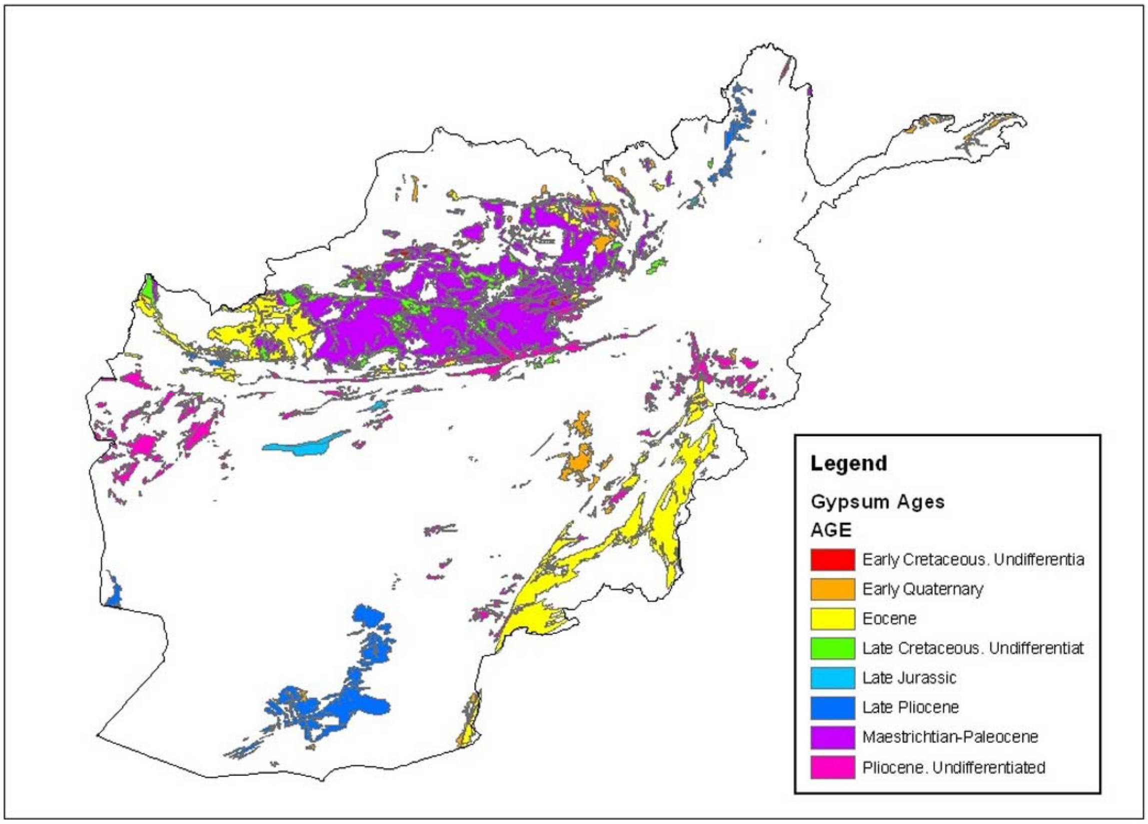

Figure 16. Map showing age of gypsum-bearing rocks in Afghanistan.

Potash-Bearing Bedded Halite Tract Description

Tract ID—kbbhal01 (fig. 17)

Deposit types—Potash-bearing bedded halite

Age of mineralization—Jurassic

Examples of deposit type—Several potash-bearing bedded halite deposits in Turkmenistan (Gaurdak, Karlyuk, Okuzbulak) and in Uzbekistan (Tyubegatanskoe, Khodzhaikan, Kyzylmazar)

Exploration history—Very little exploration has been done for halite deposits; some of the oil and gas exploration data is pertinent.

Importance of deposits—Potash is a key ingredient in most fertilizers. Potash-bearing halite deposits can be of high value.

Tract boundary criteria—The tract was delineated on the basis of exposed and hidden Jurassic sedimentary rocks in the basins of northern Afghanistan. This is the setting of all important known prospects. The tract is bounded on the south by major tectonic boundaries and extensive outcrops of pre-Jurassic rocks. This tract is identical with tract bedhal01.

Important data sources—geologic map, mineral deposit database, data from oil and gas assessment

Needs to improve assessment—Information about quality and size must be determined for known halite prospects and occurrences. This would require site visits.

Optimistic factors—There is documented salt of Jurassic age at depth in the Amu-Darya, Tirpul (Herat), and Tajik basins (Ulmishek, 2004; Klett and others, 2006).

Pessimistic factors—Part of the permissive rocks may be at extreme depth, as deep or deeper than 3 km. There is no quality or thickness information for known halite deposits. No potash mineralization has been reported.

Quantitative assessment—Available information is not sufficient to allow a quantitative assessment.

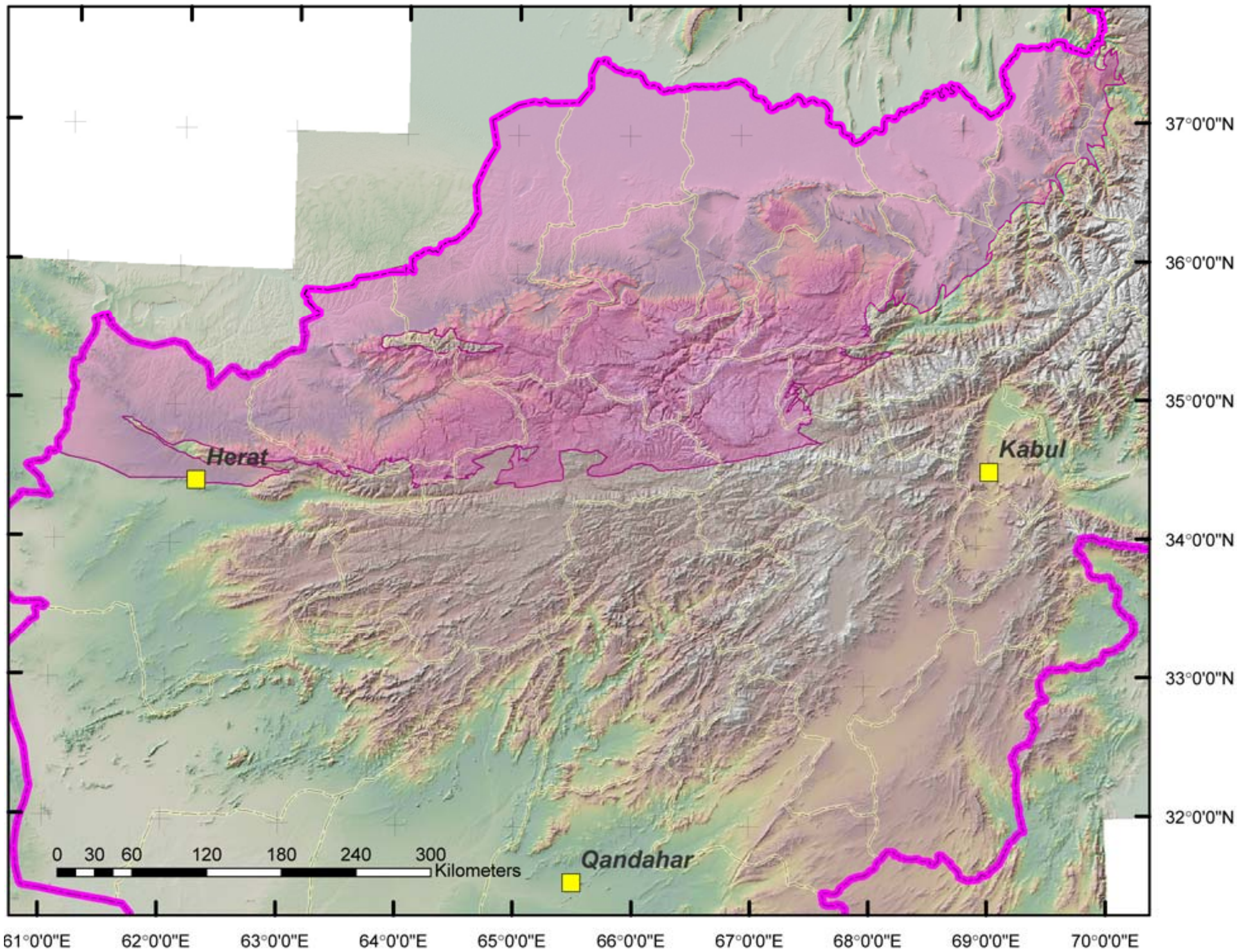

Figure 17. Map showing tract kbbhal01 and bedhal01 (they are identical).

Bedded Halite Tract Description

Tract ID—bedhal01 (fig. 17)

Deposit types—Bedded halite

Age of mineralization—Jurassic

Examples of deposit type—Several potash-bearing bedded halite deposits in Turkmenistan (Gaurdak, Karlyuk, Okuzbulak) and Uzbekistan (Tyubegatanskoe, Khodzhaikan, Kyzylmazar)

Exploration history—Very little exploration has been done for halite deposits; some of the oil and gas exploration data is pertinent.

Importance of deposits—Salt products are major components of many industrial processes. Near-surface salt deposits can be hazardous, causing negative impacts on water quality.

Tract boundary criteria—The tract is delineated on the basis of exposed and hidden Jurassic sedimentary rocks in the basins of northern Afghanistan. This is the setting of all important known prospects. The tract is bounded on the south by major tectonic boundaries and extensive outcrops of pre-Jurassic rocks. This tract is identical with tract kbbhal01.

Important data sources—geologic map, mineral deposit database, data from oil and gas assessment
Needs to improve assessment—Information about quality and size must be determined for known halite prospects and occurrences. This would require site visits.

Optimistic factors—There is documented salt of Jurassic age at depth in the Amu-Darya, Tirpul (Herat), and Tajik basins (Ulmishek, 2004; Klett and others, 2006).

Pessimistic factors—Part of the permissive rocks may be at extreme depth, as deep or deeper than 3 km. There is no quality or thickness information for known halite deposits. No potash mineralization has been reported.

Quantitative assessment—Available information is not sufficient to allow a quantitative assessment.

Limestone Tract Description

Tract ID—lms01 (fig. 18)

Deposit types—Limestone

Age of mineralization—Early Carboniferous, Late Permian to Late Triassic, Triassic, Late to Middle Jurassic, Late Cretaceous to Paleocene

Examples of deposit type—The Early Carboniferous Sabz deposit in Badakshan Province has speculative reserves of about 500,000,000 t. The Early Triassic Darra-I-Chartagh deposit in Herat Province is more than 5 km long, more than 200 m thick, and is suitable for cement production. The Late Cretaceous to Paleocene limestone mined at the Pul-I-Khumry mine in Baghlan Province covers several thousand km^2 and currently produces limestone for cement. The Middle Triassic limestone at the Rod-I-Sanjur deposit in Herat Province is up to 400 m thick (ESCAP, 1995).

Exploration history— Soviet and Afghanistan geologists identified a number of limestone deposits during geological surveys in the 1970s, but there is very little known exploration specifically for limestone deposits.

Importance of deposits—Limestone is the most important component in cement, and lime has many additional uses in infrastructure, agriculture, and industry. Most currently active limestone quarries are mined on a small scale and provide building stone for local markets; larger operations would use standard open-pit mining methods. The demand for limestone normally increases with an increasing GDP.

Tract boundary criteria— The tract was delineated using the digital geologic map of Afghanistan (Doebrich and others, 2006). The tract consists of those map units that have limestone or marble identified as a major or dominant component. Although limestones of different ages may well have differing potential, we combined all ages of limestone for this tract because we lack information to develop criteria for differing probabilities of occurrence in rocks of different ages. Areas of less promise consist of map units in which limestone is listed as only a minor component (fig. 19).

Important data sources—Geologic map, mineral deposit database, data from oil and gas assessment, ESCAP report (Economic and Social Commission for Asia and the Pacific, 1995; Abdullah and others, 1997; Doebrich and Wahl, 2006)

Needs to improve assessment—Information about consistency of chemical and physical properties of limestone within known deposits would be particularly helpful, along with information about the quality of specific stratigraphic units. This would require extensive field investigations.

Optimistic factors—Limited information about limestone quality indicates high (more than 90 percent) values of $CaCO_3$ in limestones of varying ages. Limestone is widespread and occurs in large masses that could host large deposits. Some limestones have been metamorphosed, which can improve the quality for some uses.

Pessimistic factors—There is almost no information about quality or consistency of quality of limestones of any age.

Quantitative assessment—Available information is not sufficient to allow a quantitative assessment.

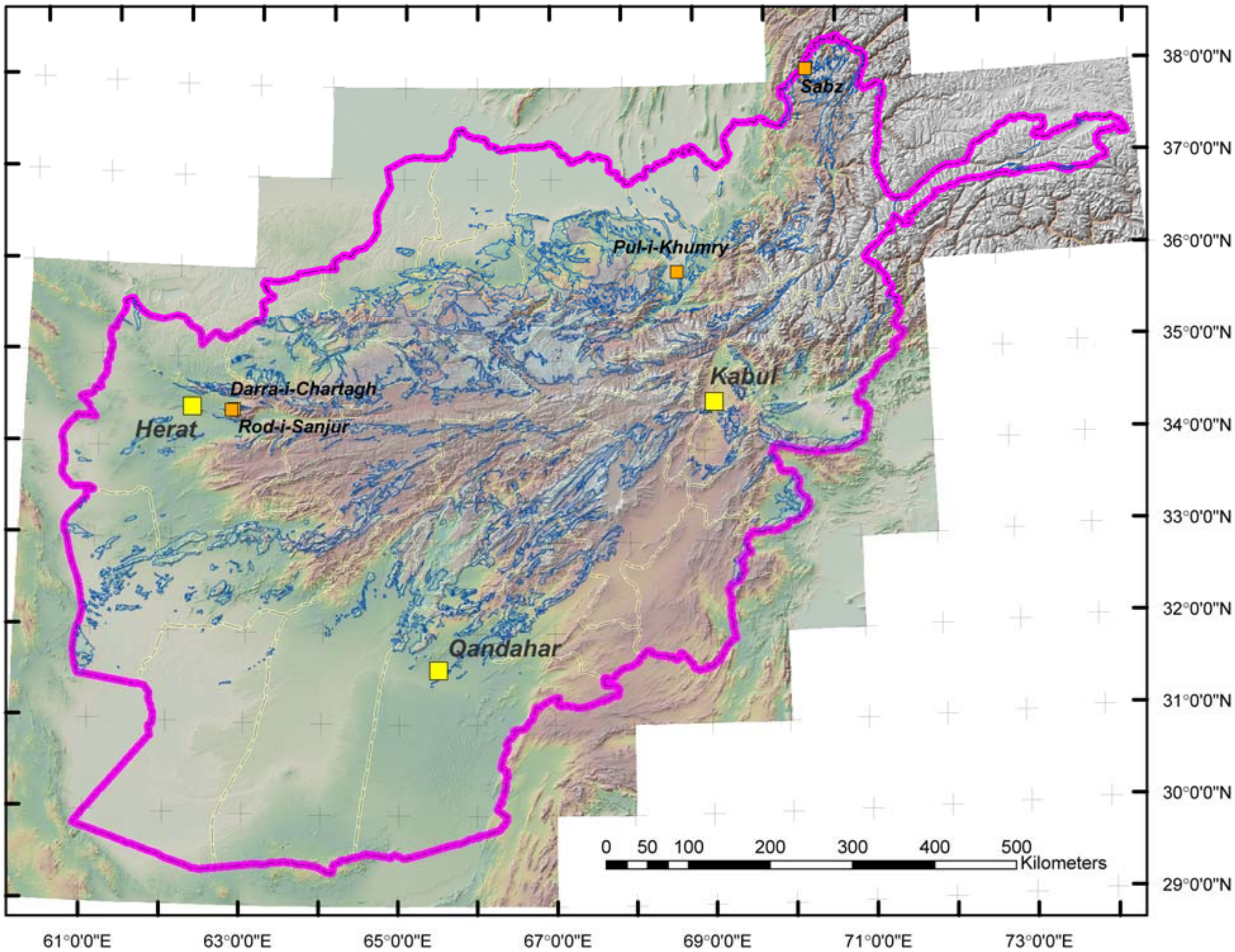

Figure 18. Map showing tract lms01 and some important known deposits and prospects (orange squares).

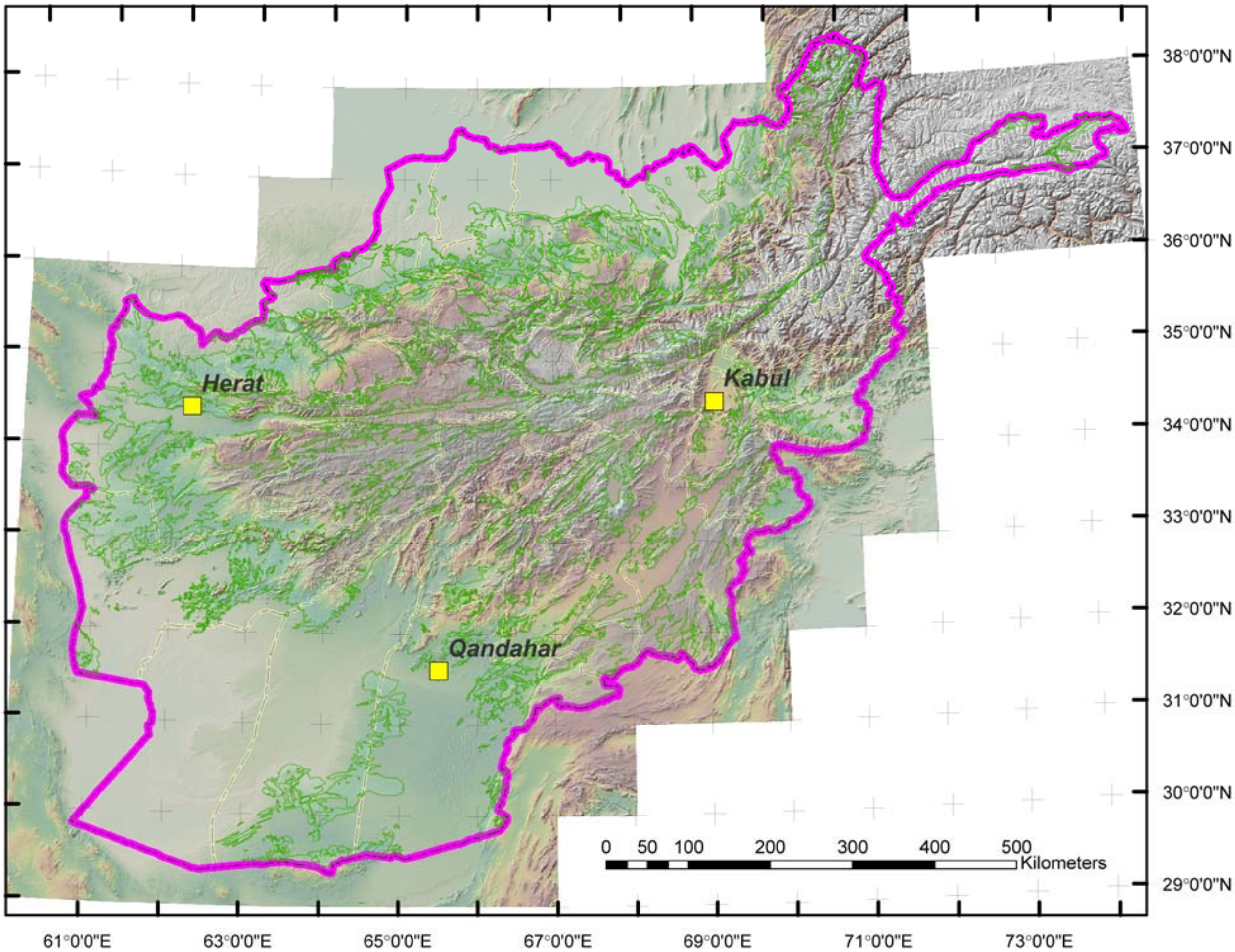

Figure 19. Map showing map units in which limestone is a minor component.

Sand and Gravel Preliminary Assessment Part I

Aggregate deposits are fundamentally different from many other deposit types addressed in this assessment because the rocks themselves are the deposit! Aggregate is a fundamental material needed for construction of roads, canals and other types of infrastructure required for nation building. Without adequate roads and airport runways, a sustainable and expanding commerce will be difficult to achieve.

Aggregate comes from two very different sources—unconsolidated sand and gravel deposits readily extracted from sediments along rivers and streams and bedrock crushed to a size suitable for use. Unconsolidated sand and gravel extraction requires less effort, money and equipment than does crushing bedrock. However, both aggregate sources have low in-place value. Most of the cost to the user is from transportation, not from the cost of extraction. Therefore, both types of aggregate need to be near the customer. This necessary proximity to populated areas can lead to conflict over land use, issues related to local environmental impact, and, in some areas, to life quality issues.

Only sand and gravel is assessed, as tools for assessing crushed bedrock deposits are not available. Sand and gravel tract development is completed and summarized below. Adequate data are available to allow computer simulation that will predict sand and gravel resources in Afghanistan (Bliss, J.D., and Bolm, K.S., in press).

Sand and gravel tract description

Tract ID—Two types of tracts are used. However, all tracts are defined as those areas with slope of 10 degrees or less. One set of tracts consists of all areas within 18 basins and 5 additional areas, as shown on the basin index for Afghanistan given below, that meet the slope criteria. Some areas within these basins are excluded because they are covered by sand dunes or because that they are lake beds. A second set of tracts is a subset of the first that includes just those areas within 25 km of towns and roads. These areas are more likely to be explored for sand and gravel deposits than are isolated areas.

Permissive tracts were combined from tracts in all basins and areas. Some of the permissive areas on this map has also includes areas with lakes beds and sand dunes that will not be considered as permissive. The second set of tracts has also been combined that includes a subset of permissive tracts that are within 25 km of roads and towns. These areas are designated as "subset of permissive tract adjacent to towns and roads" and shown in gold on a map of the country as a whole (Bliss, J.D., and Bolm, K.S., in press).

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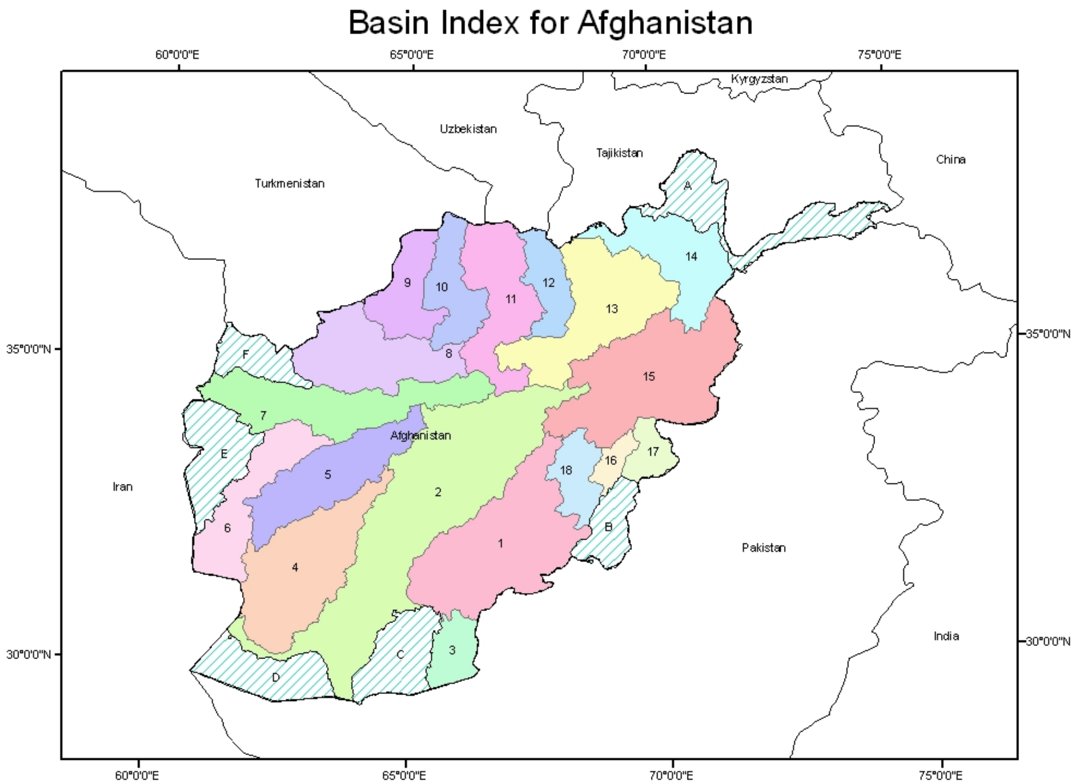

Figure 20. Basin Index of Afghanistan showing location of sand and gravel tracts.

Deposit types—Fluvial sand and gravel deposits associated with streams and rivers including glacial-fluvial systems. Also considered in this assessment are sand and gravel deposit found in alluvial fans. Not addressed in this assessment are sand and gravel deposit types produced by catastrophic flood events and those developed on lake margins.

Age of mineralization—Quaternary, sand and gravel degrade in quality with the increased weathering likely in older deposits.

Examples of deposit type— Sand and gravel deposits are in many different types of surficial settings in Afghanistan. Many deposits are likely marginal as they contain too much fine-grain material or oversized material that makes extraction or use difficult. Some deposits are too small for anything beyond local use and artisanal mining.

Exploration history—The US Corp of Engineers, Russian and Afghanistan civil engineers, geologists and others have likely identified a large number of sand and gravel deposits during various road building efforts in the country. Therefore, deposits adjacent to roads and town are locally recognized or known by specific organizations involved in construction activities of all types. However, deposit locations and qualities are not reported, a situation that is not an uncommon situation throughout the world.

Importance of deposits—Sand and gravel is one of the primary sources of aggregate, along with crushed stone. Aggregate is a key element in the development of infrastructure. Most currently active sand and gravel operations are likely small scale and provide sand and gravel for local markets; larger operations would use standard open-pit mining methods. The demand for sand and gravel normally increases with an increasing gross domestic product.

Tract boundary criteria—Tracts were defined using slope criteria (10 degrees or less) together with stream basin outlines, location of rivers, streams and alluvial fans.

Important data sources—digital elevation model, fluvial networks, town and road systems, geomorphology, and geologic map.

Needs to improve assessment—Information about the grain-size distribution, chemical and physical properties of sand and gravel deposits in Afghanistan are not available. Also missing are data describing contaminates that may make deposit unsuitable for use in cement and other high end uses. However, knowledge of weathering products from the bedrock types shown on the geologic map of Afghanistan may help to identify basins that may contain sand and gravel deposits with quality problems.

Optimistic factors—The geomorphology and recent geologic history suggest that there is considerable sand and gravel present.

Pessimistic factors—There are no data about the grain-size distribution, chemical and physical properties of sand and gravel deposits in Afghanistan. Also missing are data describing contaminates that may make deposit unsuitable for use in cement and other high end uses. Many areas in Afghanistan that are expected to contain sand and gravel resources will not be developed given that these areas are used for agriculture and other priority utilizations. Other deposits will not be available do to economic limitations, such as a maximum transportation distance that will make some deposits unworkable, security issues and other factors unique to Afghanistan.

Quantitative assessment—Quantitative models giving the distribution of sand and gravel volumes and a spatial model that gives distribution of numbers of sand and gravel deposits per unit area are available and will allow an estimate of sand and gravel resource volume to be made(Bliss, J.D., and Bolm, K.S., in press). A second part of the Assessment will include a Monte Carlo Simulation that will probabilistically predict how much sand and gravel can be expected for each basin and in those areas within 25 km of road and towns in each basin.

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Table 1. Summary of estimate for Preliminary Non-fuel Mineral Resource of Afghanistan

Tract ID	90th	50th	10th	5th	1st	mean	Area (m^2)	Density deposits/ (m^2)	^10*3
ppycu07	0	0	2			**0.6**	988,515,757	**0.000607**	**0.607**
ppycu02	0	1	2			**1**	2,621,442,257	**0.000381**	**0.381**
ppycu05	0	1	2			**1**	3,047,094,925	**0.000328**	**0.328**
ppycu04	0	0	3			**0.9**	4,239,419,676	**0.000212**	**0.212**
ppycu01	0	1	3			**1.3**	6,697,885,829	**0.000194**	**0.194**
ppycu08	0	0	2			**0.6**	6,265,804,535	**9.58E-05**	**0.096**
ppycu12	0	0	1			**0.3**	7,396,403,112	**4.06E-05**	**0.041**
ppycu03	0	0	2			**0.6**	17,047,524,155	**3.52E-05**	**0.035**
ppycu06	0	0	2			**0.6**	17,163,116,895	**3.5E-05**	**0.035**
ppycu09	0	1	3			**1.3**	64,819,664,846	**2.01E-05**	**0.020**
ppycu10	0	0	1			**0.3**	33,721,101,086	**8.9E-06**	**0.009**
ppycu11							495,605,845		
Total						9	**164,503,578,917**	**5.17E-05**	**0.052**
sedcu01	1	3	8			3.833			

Note these estimates are preliminary and represents consensus estimates of the individual Assessment Team