Chapter 22A. Summary of the Kunduz Area of Interest

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Abstract

The main commodity of interest within the Kunduz area of interest (AOI) is celestite (strontium sulfate). The geology and existing infrastructure indicate probable resources of minerals such as sand and gravel, limestone, and gypsum. Within the Kunduz AOI, there is also the possibility for the occurrence of sulfur deposits and deposits suitable for use as dimension stone.

The known celestite resource within the Kunduz AOI appears to be of relatively small size and may be suitable for development in support of a local industry, but probably not of sufficient size on its own for export. Similar celestite deposits are likely to be dispersed in the Paleocene rocks between the Kunduz deposit and the Tangi-Murch celestite deposit over 50 kilometers to the southeast and outside of the Kunduz AOI. Infrastructure minerals such as sand and gravel and limestone are probably present in amounts sufficient to fill local needs, but no delineated resources or working mines were identified by this project.

22A.1 Introduction

This chapter summarizes and interprets results for the Kunduz area of interest (AOI) from geologic and compilation activities conducted during 2009 to 2011 by the U.S. Geological Survey (USGS), the U.S. Department of Defense Task Force for Business and Stability Operations (TFBSO), and the Afghanistan Geological Survey (AGS). Chapters 22B and 22C of this publication address hyperspectral data and geohydrologic assessments of the Kunduz AOI. Additionally, supporting data for this chapter are available from the Ministry of Mines, Kabul.

The Kunduz AOI is largely located in the Kunduz Province of northern Afghanistan (fig. 22A–1). The southwestern part of the AOI, comprising about one-third of the total area, lies in Baghlan Province. Overall, the Kunduz AOI encompasses an area of 2,266 square kilometers (km^2). The only known mineral occurrence within the area is the Kunduz (Kartau, Kartaw) celestite deposit. Although not explicitly documented, geology and infrastructure in the area indirectly indicate that sand and gravel, gypsum, and limestone resources are present; other possible resources include sulfur and rocks suitable for use as dimension stone.

22A.2 Previous Work

In the mid-1970s, the Soviets explored the Kunduz celestite deposit using multiple shallow drill holes, pits, and trenches. More than 80 samples were taken from the bituminous limestone-gypsum-celestite horizon of the Paleocene Bukhara Formation (table 22A–1). It is not known if the speculative celestite resources reported for the Kunduz deposit were derived from this effort or determined at a different time. No work is known to have occurred for other commodities.

22A.3 Regional Geologic Setting

The Kunduz AOI lies along the southern boundary of the Afghan-Tajik Basin (fig. 22A–2) that extends from southern Tajikistan into northern Afghanistan. In its deepest portions in Tajikistan, it contains more than 10 kilometers (km) of sediment. Marginal structural steps surround the depression, including the North Afghan High, and are uplifted as much as 3 to 8 km relative to the deepest parts of the basin (Klett and others, 2006).

During the Neogene, the post-Jurassic sedimentary fill of the basin was detached above the Late Jurassic salt and deformed into a series of thrust anticlinoria and synclinoria. In the anticlinoria, Paleogene rocks are commonly exposed on or near the surface in the anticlines. The intervening synclinoria contain as much as several kilometers of Neogene and younger continental clastic deposits (Klett and others, 2006).

Marine conditions existed through most of the Paleogene in the combined Amu Darya and Afghan-Tajik Basin (Klett and others, 2006). During the late Paleogene, the collision of the Arabian, Iranian, and Hindustan continental plates into the Eurasian plate closed the Neotethys Ocean resulting in uplift, marine regression, and, finally, deposition of continental sediments by the end of the Paleogene. The Paleogene rocks conformably overlie Cretaceous rocks in northern Afghanistan.

Structural movements of the Afghan-Tajik Basin during the basinal stage of development (Jurassic through Paleogene) are characteristic of block-type platform tectonics (Klett and others, 2006). Structural highs, such as the North Afghan High and smaller uplifts, experienced slower subsidence and occasional positive movements that resulted in local disconformities and the absence of parts of the sedimentary sequence (Ulmishek, 2004).

Figure 22A–1. Index map showing the location of the Kunduz area of interest in northern Afghanistan.

Table 22A–1. Celestite content of samples collected from the Kunduz deposit (Lim and Hyupperen, 1976).

[The source material did not state whether the SrO content was reported as weight percent or volume percent; the nature of the data suggest weight percent. "---" indicates no value was reported]

Sample site	Sample no.	Thickness (meters)	SrO percent)	Development thickness (meters)	Average SrO (percent)	SrO_4 (percent)
Well C-220	1011	0.25	48.16	1.01	47.85	85.45
	1012	0.76	47.75			
Trench K-519	1082	1.25	7.34	7.8	21.04	37.57
	1081	1.05	5.60			
	1080	1.00	5.99			
	1079	1.35	1.14			
	1052	0.50	47.61			
	1053	0.35	29.98			
	1054	0.35	48.84			
	1055	1.15	16.72			
	1056	0.80	51.14			
	1083	1.25	2.98			
	1084	0.95	---			
	1085	1.35	2.71			
Trench K-521	1063	1.40	14.98	5	21.54	38.46
	1064	0.45	50.73			
	1065	0.35	3.42			
	1066	0.40	46.56			
	1067	0.35	11.98			
	1068	0.45	28.84			
	1069	0.80	20.59			
	1070	0.80	13.59			
Well C-231	1091	0.57	---	5.04	32.98	58.89
	1092	0.76	14.37			
	1093	1.07	35.06			
	1094	1.12	36.64			
	1095	1.12	31.34			
	1095-1	0.97	42.95			
Outcrop	1100	0.80	46.95	2.67	21.87	39.05
	1101	0.53	0.39			
	1102	0.92	1.47			
	1103	0.42	45.89			
Trench K-502	1002	0.85	44.94	8.05	33.12	59.14
	1057	1.35	3.68			
	1058		44.87			
	1009	2.50	50.08			
	1008		47.37			
	1007		47.20			
	1006	1.15	10.00			
	1005		45.85			
	1059	1.55	0.30			
	1004	0.30	0.41			
	1003	0.35	42.42			
Well C-226	1015	0.58	21.39	8.05	35.82	63.96
	1016	0.74	29.26			
	1017	0.83	30.61			
	1018	0.48	48.50			
	1019	0.54	29.48			
	---	1.44	---			
	1020	1.38	41.13			
	---	0.35	---			
	1021	1.76	41.06			
Trench K-517, Well C-228	1051	0.40	45.74	7.85	30.69	54.80
	1050	1.35	5.19			

Sample site	Sample no.	Thickness (meters)	SrO percent)	Development thickness (meters)	Average SrO (percent)	SrO4 (percent)
	1049	0.55	51.76			
	1048	1.40	28.01			
	1047	0.70	48.76			
	1052	1.75	19.88			
	1061	0.80	6.99			
	1046	0.80	51.86			
Well C-227	1028	1.03	17.42	5.22		
	1029	0.95	20.73			
	1030	0.28	18.22			
	1031	0.59	42.77			
	1032	1.62	35.54			
	1033	0.43	43.98			
	1034	0.32	49.75			
Trench K-516	1089	1.15	0.00	3.95	30.29	54.09
	1046	1.20	47.47			
	1044	1.85	0.60			
	1045	0.90	50.18			
	1090	1.65	0.00			
Outcrop	1096	1.00	45.10	3.3	19.24	34.36
	1097	1.90	0.39			
	1098	0.40	44.14			
Trench K-512	1035	0.97	45.91	5.6	32.66	
	58.32	0.45	33.77			
	1099	2.43	4.06			
	1037	1.75	49.57			

Paleogene sediments are most complete in northern Afghanistan; these are classified as part of the Bukhara Formation and the slightly younger Suzak Formation (Klett and others, 2006; Afzali, 1981). These sediments were deposited in marine to lagoon environments and are as much as 650 m thick in the southeastern-most part of the Afghan-Tajik Basin. Although the Bukhara series is commonly divided into three members (Klett and others, 2006), it is not clear from the available literature which member(s) hosts the celestite deposits of northern Afghanistan. However, the gypsum-bearing Akdzhar and Aruktau members are the most likely candidates.

22A.4 Metallogeny

The main commodity of interest within the Kunduz AOI is celestite ($SrSO_4$), which has diverse uses that include, but are not limited to, glass for televisions, ferrite ceramic magnets, pyrotechnics, and small nuclear power sources; celestite deposits are much more restricted in a geologic sense than barite, with which it commonly occurs. Most large occurrences are related to the interaction of hypersaline strontium-bearing fluids with gypsum and anhydrite, and deposition of the strontium mineralization requires preferential concentration of strontium over barium (Hanor, 2000). This requires a tectonic regime which drives water enriched in strontium at depth into shallow, oxidizing conditions where sulfate is stable. Strontium can be concentrated and precipitated in a variety of ways that include biologically mediated precipitation, reaction of strontium-rich fluids with non-seawater sulfate, precipitation from changes in fluid pressure or temperature, or release of strontium during diagenesis of marine carbonates (Hanor, 2000).

Celestite mineralization is widely developed in the Mesozoic-Cenozoic sediments, albeit unevenly, of the southern Tien Shan Mountains of Central Asia and Afghan-Tajik depression (Khasanov, 1983; Abdullah and others, 1977; Abdullah and Chmyriov, 2008). In the Afghan-Tajik depression, the sandstone, clay, and marl average 0.2-0.8 weight percent strontium, but the strontium content commonly exceeds 1 percent in dolomite, gypsum, and anhydrite. Most often, the associated mineralization is present as disseminated grains, fine streaks, or micro-lenses of celestite with associated calcite, dolomite, fluorite, and barite (Khasanov, 1983). The celestite mineralization of this area is commonly spatially associated with coal and petroleum (Afzali, 1981).

Khasanov (1983) reports that most celestite in this region, not just that in the Paleocene Bukhara Formation, formed as result of alteration of diverse sedimentary units in coastal sea and lagoon conditions where there was significant salinity. Celestite has formed in association with gypsum, fluorite, strontianite, barite, calcite, dolomite, anhydrite, and gypsum and may be found in karsts, and as streaks, veins, and disseminated crystals. Khasanov (1983) proposes that the celestite is a product of end stage hydrothermal-metasomatic processes in the Afghan-Tajik Basin area and the deposits form from leaching and recrystallization at temperatures of less than 200 degrees C.

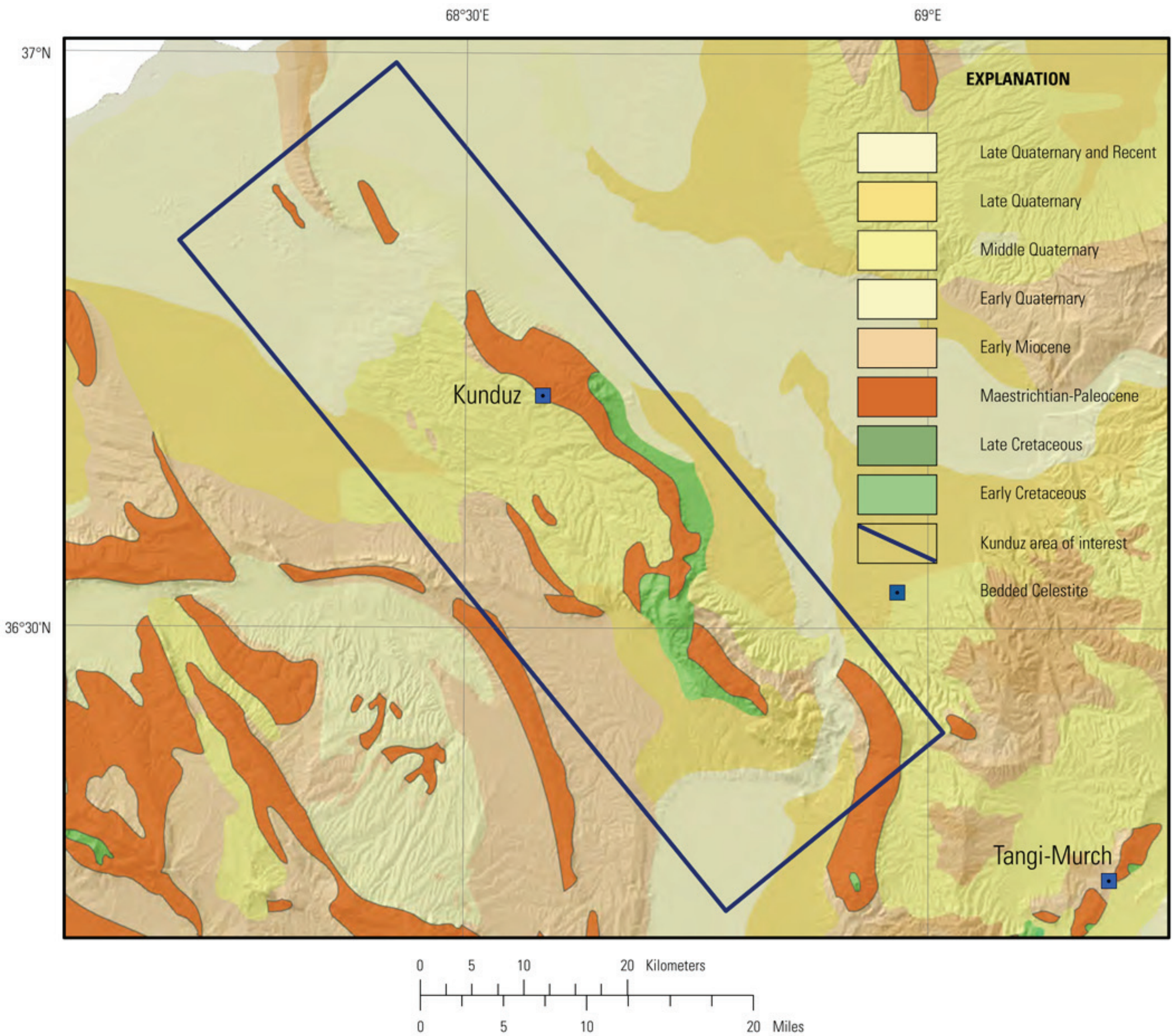

Figure 22A–2. Geology of the Kunduz area of interest as shown by Doebrich and others (2006).

Ehrlich (2002) reported that native sulfur and celestite occur in the Bukhara and Suzak Formations in the foothills of the Altai Mountain range. He recognized that bacteria reduced sulfate from the fluids in the area to produce the sulfur mineralization. He suggested that the main source of the sulfur and strontium was igneous; this is in keeping with other authors such as Abdullah and others (1977) and Abdullah and Chmyriov (2008), who describe celestite deposits in northern Afghanistan area as telethermal. The proximity in some locations of celestite and barite to faults was cited to support this hypothesis.

The celestite deposits may be epigenetic with concentration of the strontium due in part to leaching and redeposition as at the Sharabad area deposits of Tajikistan (Kotkin and others, 1979). Features of the Afghan celestite deposits that support a sedimentary-diagenetic origin for the mineralization include the occurrence of the mineralization within the same horizon(s) and the persistence of celestite mineralization over long distances. Lein and others (1978) found that similar deposits in Neogene rocks in Uzbekistan showed isotopic evidence of freshwater input. The association of these celestite deposits with coal suggests a lagoonal or near-shore depositional environment.

22A.5 Geology of the Kunduz Area of Interest

The exposed geology of the Kunduz AOI consists largely of Cretaceous to Recent sediments. The lithologies of the pre-Quaternary units consist largely of marine to lagoonal to continental sediments with contained evaporites such as gypsum and anhydrite. Most of the Quaternary units consist of continental alluvial fan and fluvial deposits.

The Pliocene Bukhara Formation hosts the documented celestite deposits of northern Afghanistan. The unit is commonly divided into three members or layers. According to the Lim and Hyupperen (1976) map of the Kunduz celestite area, the lower member consists of marl and calcareous clay. The middle Bukhara member consists of gypsum and laminated bituminous limestone and is host to the celestite mineralization. The upper Bukhara unit is composed of light-colored, laminated limestone and marl.

22A.6 Geologic Character of the Kunduz Celestite Deposit

The two celestite deposits known in Afghanistan are reported to be Paleocene in age (Abdullah and others, 1977; Abdullah and Chmyriov, 2008). Similar deposits in Iran, Tajikistan, and Uzbekistan are similar in age, all Paleogene. The expectation is that any undiscovered deposits will also be found in sediments of Paleocene, or at least Paleogene, age.

Afzali (1981) reports that the celestite deposits at Kunduz and Tangi-Murch are hosted by layered limestone of the Paleocene Bukhara and Suzak Formations. He reports that these deposits are spatially associated with coal and petroleum-bearing sediments.

22A.7 Origins of the Kunduz Celestite Deposit

Sedimentary celestite deposits are the main source of celestite production. The known deposits in Afghanistan are believed to be a variant of this deposit type. Sedimentary celestite deposits form from a mix of primary precipitation, diagenetic and alteration processes. The strontium in these deposits is variously attributed to marine-derived brines, from fluids resulting from the conversion of aragonite to calcite or gypsum to anhydrite, from waters formed by dolomitization of limestone, from dissolution of subsurface gypsum, and from basinal waters that have leached strontium from associated rocks (Evans, 1999; Hanor, 2000). The strontium has also been attributed to hydrothermal fluids as previously discussed, but the limitation of the celestite mineralization to specific horizons suggests that the primary process of deposit formation is sedimentary. Celestite is commonly associated with evaporate deposits, as well as limestone and dolomite. Mineralization is in the form of concretions, seams, or impregnations (Harben and Kuzvart, 1996).

22A.8 Known Deposits

There are two known celestite deposits in Afghanistan, Kunduz and Tangi-Murch (Orris and Bliss, 2002). At the Kunduz (Kartaw, Kortau) deposit, celestite is found in folded sediments of the Paleogene Bukhara series sediments, specifically in a horizon of gypsum and light-gray bituminous limestone (Lim and Hyupperen, 1976; figs. 22A–3 and 22A–4). None of the mineralization is shown in the younger Paleocene Suzak Formation, which has been reported in some literature (Afzali, 1981;

United Nations Economic and Social Commission for Asia and the Pacific, 1995). The celestite forms massive and disseminated ore that extends approximately 1,400 meters (m) along strike and 10 to 14 m downdip and is 0.9 to 8.0 m thick and contains speculative resources of 1 million metric tons (Mt) of white to bluish crystalline celestite (Abdullah and others, 1977; Abdullah and Chmyriov, 2008). More than 80 samples collected from wells, trenches, and pits were analyzed by Lim and Hyupperen (1976) and showed concentrations from less than 1 weight percent SrO to 51.76 percent SrO.

At Tangi-Murch, in Baghlan Province, Kazak and others (1965) report a celestite lens associated with bituminous limestone. Four celestite bodies at this location are reported to contain speculative resources of 0.085 Mt of ore containing 53.96 volume percent celestite (Abdullah and others, 1977; Abdullah and Chmyriov, 2008). Similar to the Kunduz deposit, the Tangi-Murch mineralization is present in the Paleocene bituminous limestone of the Bukhara series, but is also reported to be present in Suzak units. Figure 22A–2 shows the distribution of map units containing Paleogene sediments within the Kunduz AOI that may contain additional celestite resources.

Similar deposits are known to exist in Tajikistan and Uzbekistan in rocks of a similar age and environment of deposition.

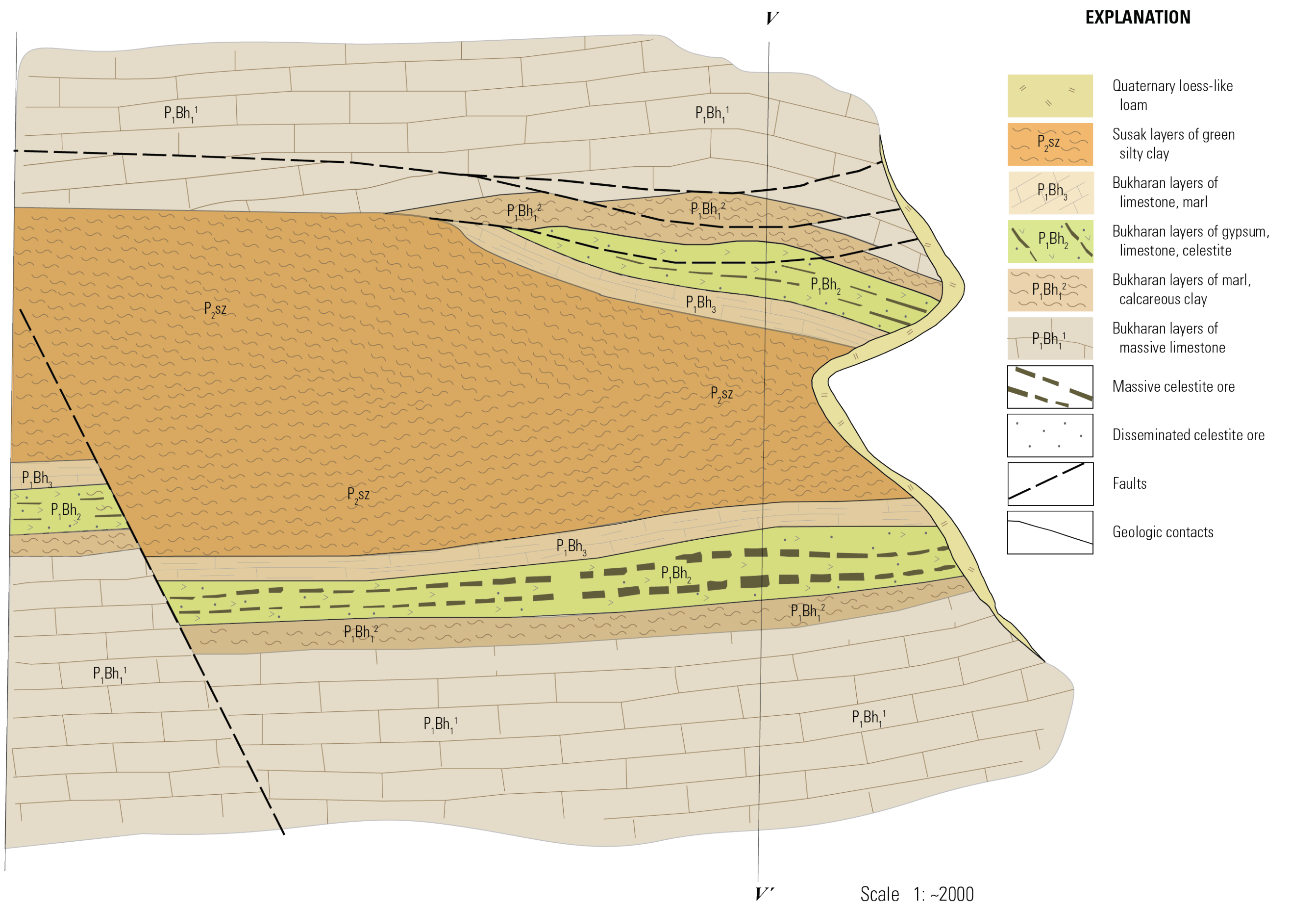

Figure 22A–3. Draft geologic map of the 990-meter horizon in exploration gallery at the southeast end of the Kunduz celestite (Chanyshev, 1976).

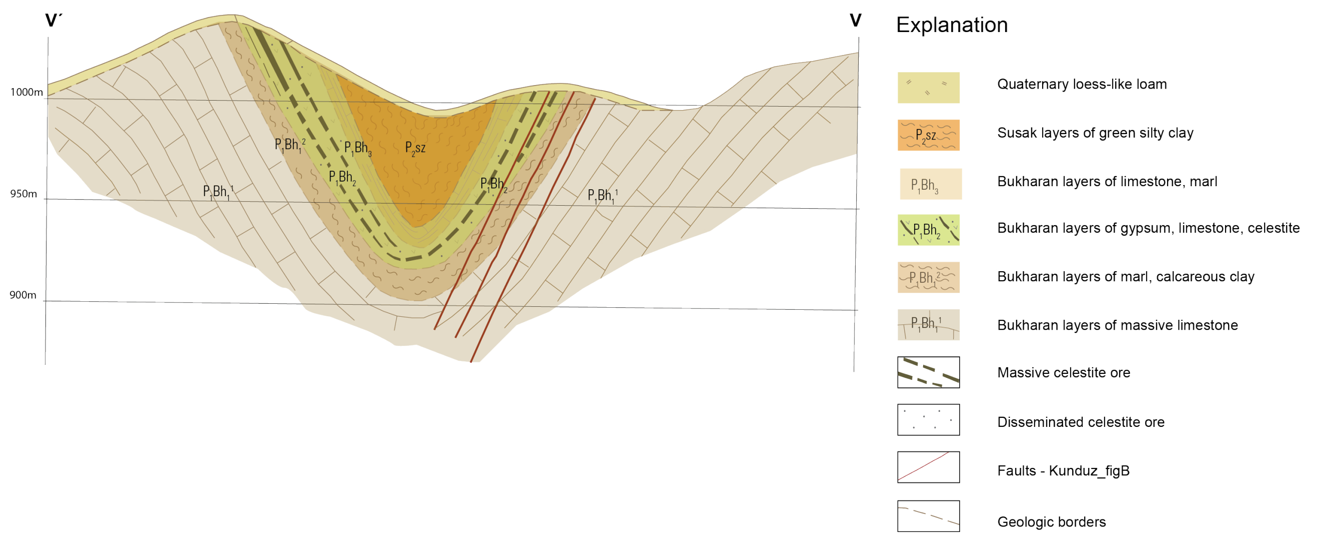

Figure 22A–4. Cross section V-V' as shown on figure 22A–3. (Chanyshev, 1976)

22A.9 Celestite Prospects

There are no other known celestite prospects or anomalies within the Kunduz AOI. However, the Tangi-Murch deposit to the southeast in the same units may indicate a persistence of suitable geology in the intervening area. Additionally, a celestite showing associated with sulfur mineralization in marl and gypsum host rocks is reported by Abdullah and others (1977) and Abdullah and Chmyriov (2008) at Dashte Safed in Baghlan Province; this showing is southwest of the two known celestite deposits. The celestite and sulfur are found as crystal accumulations in cavities and joints, as massive mineralization, as interbeds, and as concretions (Mikhalov and others, 1967). Hyperspectral data (<2 micrometers) for the Kunduz AOI did not identify additional areas of sulfate mineralization that might indicate additional celestite deposits (fig. 22A–5).

22A.10 Sand and Gravel

There are no reported sources of sand and gravel in the Kunduz AOI, which occupies part of Basin 13 as identified in Bliss and Bolm (2007, p. 484-676). However, parts of two major roads are recognized in this AOI and their presence suggests some sand and gravel may have been extracted in the vicinity of the AOI for their construction and ongoing maintenance. However, neither the intensity nor the extent of sand and gravel exploration is known. Exploitation of deposits near major and other roads is likely, given that both the U.S. Corps of Engineers and the Former Soviet Union have historically been involved in developing roads in Afghanistan. Sand and gravel are most commonly produced near the points of consumption; this implies that locations in regions that are distant from existing roads and towns are not likely to have been exploited at any scale.

Sand and gravel deposits within 25 km of towns and major roads are identified as possible sources of sand and gravel (figs. 22A–6, 22A–7). These permissive areas consist of fluvial sand and gravel deposits as determined by Bliss and Bolm (2007, p. 484-676). Areas considered permissive for fluvial sand and gravel deposits are defined by their study to have slopes of less than 10 degrees. Other factors such as the topography of individual basins, degree of association with active rivers and (or) mountain ranges, and source rock geology may affect the availability of sand and gravel with acceptable properties within the delineated areas. While the exact impact of these factors cannot be quantified given current data, some significant proportion of the permissive area for sand and gravel will not contain deposits. The reader is referred to Bliss and Bolm (2007, p. 484-676) for more detailed information on sand and gravel resources in this area.

22A.11 Sulfur and Gypsum

Native sulfur and gypsum may occur within the Kunduz AOI, although no occurrences are known. Celestite deposits in similar rocks in other areas of the Afghan-Tajik Basin are associated with native sulfur deposits and gypsum (Mikhalov and others, 1967; Petrov and others, 1971; Lein and others, 1978). The sulfur deposits are hosted by evaporitic sedimentary rocks with a biogenic component; sulfates were reduced to sulfur by bacteria feeding on hydrocarbons trapped in the host rock as part of the deposit formational process. These sulfur deposits may be notably younger than their host rocks, and within the Kunduz AOI, the late Cretaceous to Neogene evaporite-bearing rocks are permissive for the occurrence of this deposit type. Known occurrences of this deposit type in northern Afghanistan are small, but deposits of this type can be extremely large (Peters and others, 2007, p. 398–407).

Gypsum is known to occur in sedimentary formations of Late Cretaceous to Neogene age within the Kunduz AOI. These formations are suitable for the occurrence of the bedded gypsum deposit type (Raup, 1991), but there is no information available on the thickness, extent, or quality of the gypsum within the AOI. Gypsum is known to occur at Dudkash and Kahmard in northern Afghanistan. Sborshehikov and others (1974) report that the Kahmard occurrence is in gypsiferous Paleogene clay and dolomite where the gypsiferous sequence is about 20 m thick with gypsum beds between 0.2 and 2.5 m thick. They report that the Dudkash occurrence is in an Upper Jurassic evaporite sequence with gypsum beds 1.5 to 5 m thick; the beds are persistent along strike for as much as 12 km. It is not known how likely it is that deposits of these sizes or larger are within the Kunduz AOI.

22A.12 Limestone and Carbonates

Known sedimentary sequences containing limestone and other carbonates occur within the Kunduz AOI. Several of the Cretaceous to Neogene geologic units on the Doebrich and others geologic map (2006) within the AOI list limestone as a major (unit KP_1ld) or minor component (units K_2ssl, P_2csh, $N_{11}csl$), but there are no documented deposits or occurrences suitable for production within this area. The chapters on limestone (Orris and Bolm, 2007, p. 337–343) and dimension stone (Sutphin and Orris, 2007, p. 677–702) in the USGS 2007 assessment of mineral resources in Afghanistan contain more extensive discussions of the possibility for the occurrence of resources of these types.

22A.13 Summary

It is highly probable that additional celestite deposits could be found in the Paleocene Bukhara Formation in the Kunduz AOI extending southeast toward the Tangi-Murch deposit in the Dudkash AOI to the southeast; the Paleocene rocks to the west of this belt may also host undiscovered celestite resources. No other types of deposits have been documented in the Kunduz AOI, but several other commodities may be present in amounts worthy of investigation, including native sulfur, bedded gypsum, limestone, and sand and gravel deposits of sufficient size to support a local industry. Development may be hindered, especially in the northern part of the Kunduz AOI, by the limited number of major roads (fig. 22A–7).

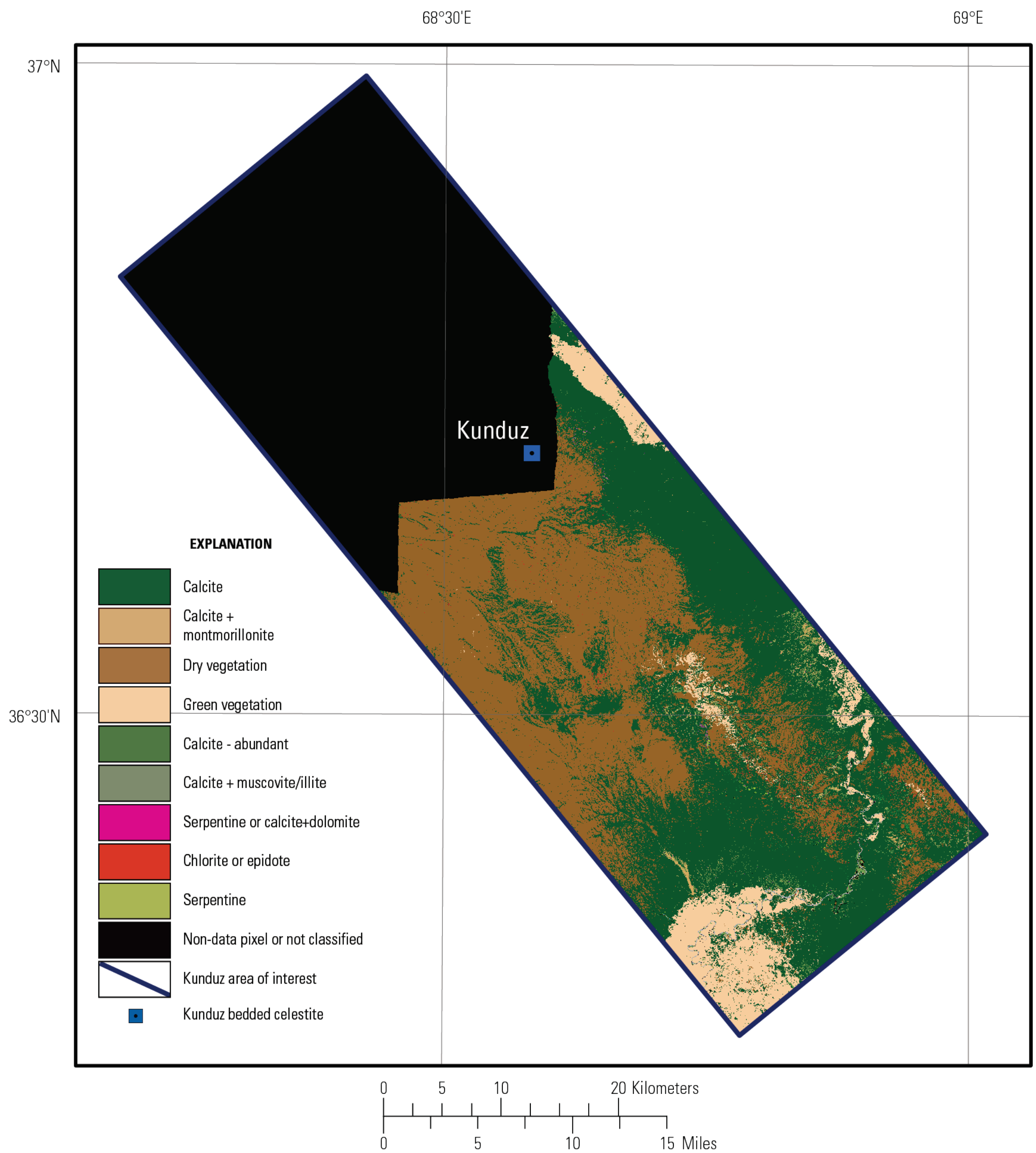

Figure 22A–5. Hyperspectral (<2 micrometers) response for the Kunduz area of interest. Note that other than a dry vegetation, calcite is the predominant response and that any gypsum (sulfate) response is not noticeable (Trude V.V. King, 2010, U.S. Geological Survey, written commun.).

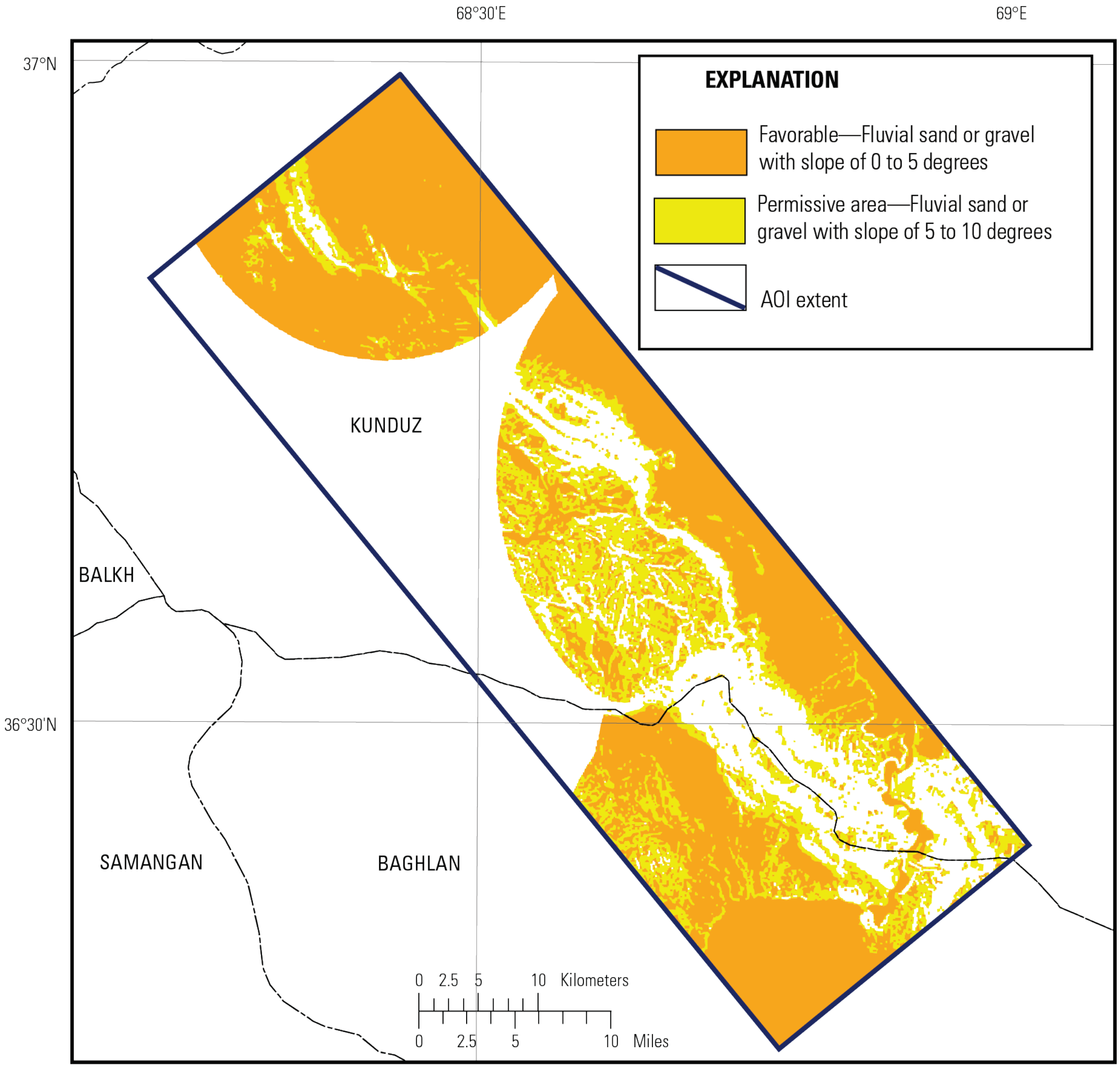

Figure 22A–6. Areas permissible for fluvial sand and gravel deposits (Bliss and Bolm, 2007, p. 484-676).

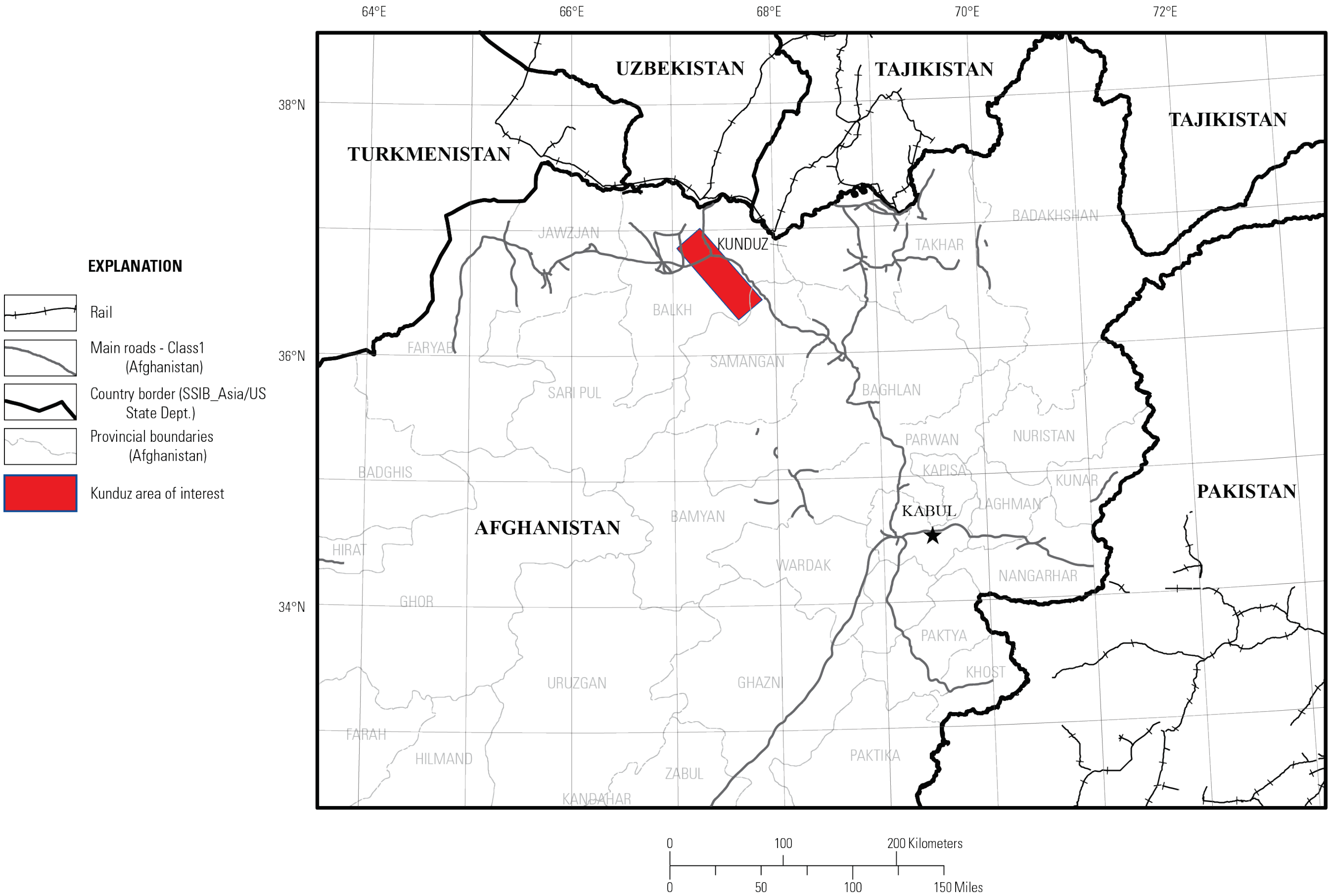

Figure 22A–7. Major roads in the vicinity of the Kunduz area of interest.

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