Chapter 19A. Summary for the Dudkash Industrial Minerals Area of Interest

Contribution by Victor G. Mossotti, Barry C. Moring, Greta J. Orris, and Kathleen D. Gans

Abstract

This chapter summarizes and interprets the results from the study of the Dudkash industrial minerals area of interest (AOI) and its subareas from joint geologic and compilation activities conducted from 2009 to 2011 by the U.S. Geological Survey, the U.S. Department of Defense Task Force for Business and Stability, and the Afghanistan Geological Survey. Accompanying complementary chapters 19B and 19C address hyperspectral data and geohydrologic assessments, respectively, of the Dudkash industrial minerals (gypsum) AOI. Additionally, supporting data and other information for this chapter are available from the Ministry of Mines, Kabul.

The Dudkash industrial minerals AOI is a rectangular expanse of mountainous and semi mountainous terrane covering 4,922 square kilometers overlapping the north and central Baghlan Province and intersecting the southeastern Kunduz and Takhar Provinces. The following districts are present in the AOI: Dahana-i-Ghori, Dushi, Pul-e Khumri, Nahrin, Baghlan, Burka, Baghlan-e Jadid, Khost Wa Firing, Ishkamish, and Aliabad districts. Industrial minerals of the AOI described in this report include cement-grade limestone, dolomite, celestite, gypsum, brick clay and coal.

The AOI is underlain by Upper Paleozoic and Lower Mesozoic sedimentary rocks that lie on the southeast and southwest parts of the area. These rocks are uncomformably overlain by Jurassic to Paleogene sedimentary rocks that contain evaporite, limestone, clay and coal deposits. These rocks are covered in large areas by Quaternary fill. Known deposits with measured reserves in the AOI include: Pul-e Khumri limestone and Tangi Murch celestite; Mined or prospected commodities within the AOI include gypsum, clay, dolomite-limestone, and coal. The potential economic value of these commodities is still undetermined.

19A.1 Introduction

Gypsum, limestone-dolomite, clay, celestite, and coal are minerals of potential economic significance in the Dudkash industrial minerals area of interest (AOI). The AOI is an elongated rectangular expanse of mountainous, semimountainous, and basin terrane covering 4,922 square kilometers (km^2) with about 80 percent of the AOI overlapping Baghlan province to the southwest and the remainder extending into Kunduz province and Takhar province to the northeast.
Figure 19A–1 shows the perimeter of the AOI on a map layer of generalized lithological ages at a scale of 1:8,000,000; the insert in figure 19A–1 represents the AOI at a nominal scale of 1:2,500,000. The Dudkash industrial minerals AOI is underlain by Upper Paleozoic and Lower Mesozoic sedimentary rocks in southeast and southwest parts of the area. These rocks are unconformably overlain by Jurassic to Paleogene sedimentary rocks that contain evaporite, limestone, and clay deposits. These rocks are covered in large areas by Quaternary fill. Coal is mined in Nahrin district in Jurassic rocks of the central North Afghan Platform.

Figure 19A–2 shows the AOI in the context of the neighborhood of provincial districts at a scale of 1:1,500,000 and locations of mineral occurrences. The following districts are present: Dahana-i-Ghori, Dushi, Pul-e Khumri, Nahrin, Baghlan, Burka, Baghlan-e Jadid, Khost Wa Firing in Baghlan Province, Aliabad in Kunduz Province, and Ishkamish in Takhar Province.

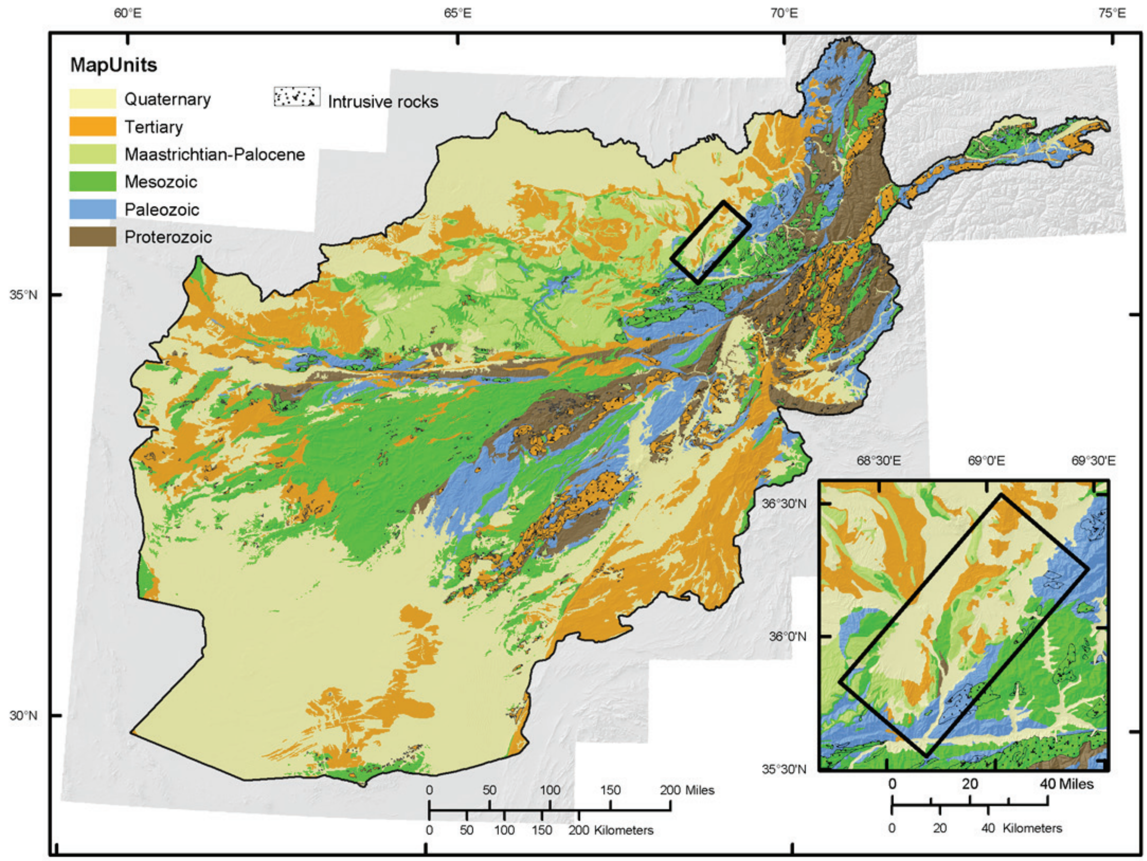

Figure 19A–1. Index map showing generalized geologic rock age and location of the Dudkash industrial minerals (gypsum) area of interest.

19A.2 Regional Geologic Setting

The Dudkash industrial minerals AOI lays along the southern boundary of the Afghan–Tajik basin which extends from southern Tajikistan onto the North Afghan Platform. In its deepest portions in Tajikistan, the basin contains more than 10 kilometers (km) of post-Jurassic sedimentary fill. Stratigraphic details are discussed in chapter 16A. The rocks filling the basin were detached above a Late Jurassic salt unit in Neogene time and deformed into a series of large-scale folds and thrusts. In the anticlinoria, Paleogene rocks are commonly exposed on or near the surface; the intervening synclinoria contain as much as several kilometers of Neogene and younger continental clastic deposits (Harben, 2002).

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).

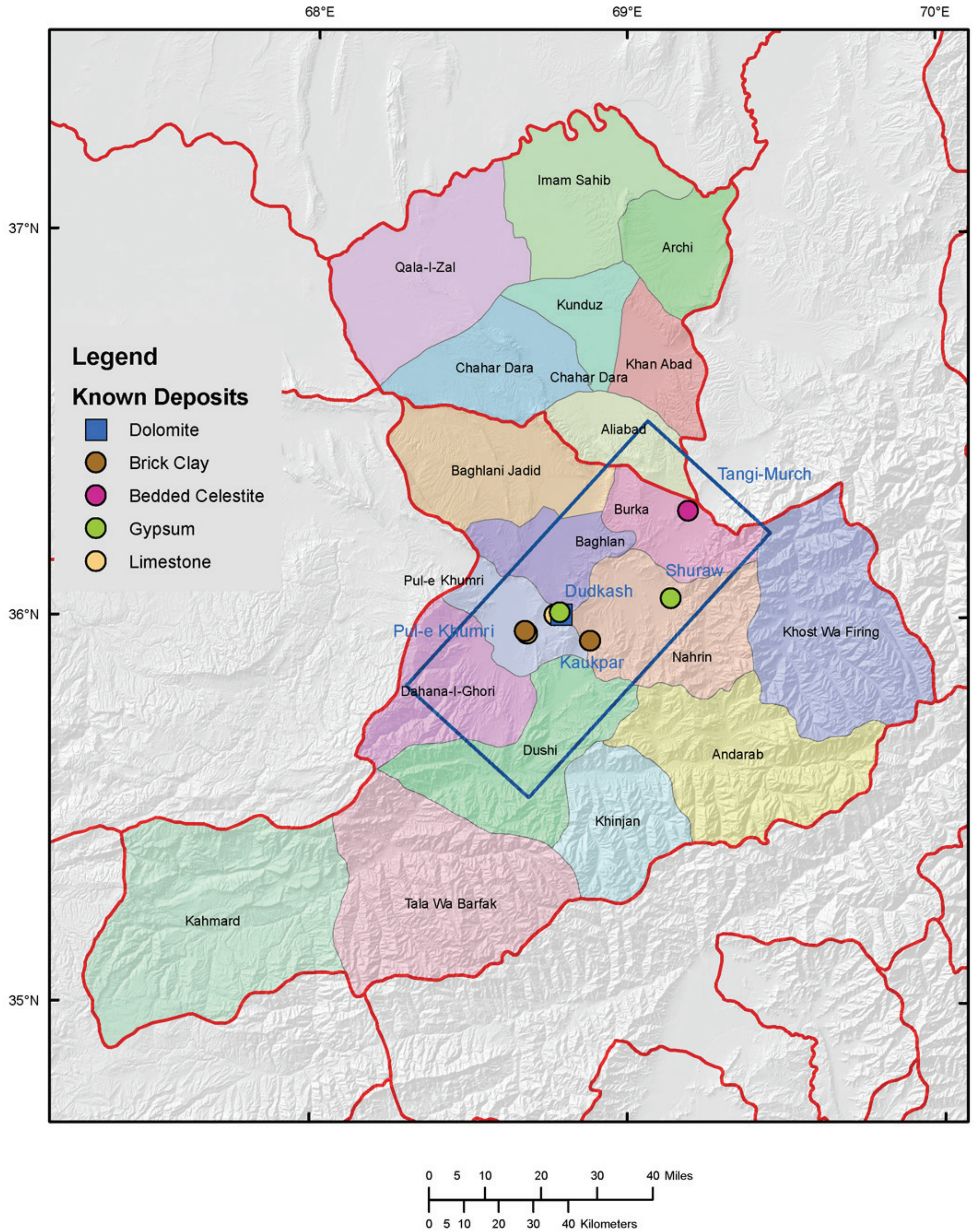

Figure 19A–2. Map showing mineral occurrences and the location of the Dudkash industrial minerals (gypsum) area of interest within the neighborhood of provincial districts at a scale of 1:1,500,000.

19A.3 Limestone-Dolomite

19A.3.1 Deposit Type

For the purposes of this assessment, limestone is defined as a carbonate rock containing greater than 50 percent calcite and (or) dolomite, with calcite predominating. Dolomite ($CaMg(CO_3)_2$ is also a carbonate rock and a mineral, both comprising calcium magnesium carbonate. Dolomite rock (also known as dolostone) is composed predominantly of the mineral dolomite. Limestone that is partially replaced by dolomite is referred to as dolomitic limestone (Tucker and Wright, 1990). Siderite ($FeCO_3$), rhodochrosite ($MnCO_3$), calcite ($CaCO_3$), and antigorite $(Mg,Fe^{2+})3(Si_2O_5)(OH)_4$ commonly form epitaxal relationships with dolomite. Dolostone or marble are not differentiated among carbonate rock on the geologic maps prepared for this report, and hence are assumed to be locally present within the limestone units.

19A.3.2 Probable Age(s) of Mineralization

Limestone deposits can be of any age, from Precambrian to Recent.

19A.3.3 Importance and Economic Expectation of Deposits

Limestone, the most important component in cement, is an extremely versatile commodity that is typically available at a low cost. The value of industrial grade limestone is associated with the chemistry of the rock. Ground calcium carbonate is used as filler in a variety of commodities from paper to pharmaceuticals, coatings, fertilizers, and other products. Among other applications, lime (CaO) is consumed for environmental uses such as wastewater treatment and flue gas desulfurization, as a soil treatment, in the production of steel and iron and other metals, in the production of chemicals, and in sugar refining (Harben, 2002; Oates, 1998, Freas and others, 2006). The value of dimension grade limestone is associated with the physical properties of the rock. Dimension stone is used for its strength, resistance to staining and weathering, and an aesthetic appeal. The demand for limestone normally increases with increasing gross domestic product (GDP). Most limestone quarries are small-scale and provide building stone for local markets; larger operations use standard open-pit mining methods.

19A.3.4 Descriptive Genetic Model

Most limestone of economic importance was deposited in a relatively shallow marine environment from a variable mix of biogenic, and to a lesser degree, chemical and mechanical processes (Oates, 1998; Freas and others, 2006). Limestones that were deposited in relatively high-energy depositional environments tend to contain less non-carbonate material and thus be higher grade (Freas and others, 2006). Deposits are commonly large and spatially extensive. Sedimentary sequences that contain limestone may also have dolomite, siltstone, and shale. Minor variations in depositional processes and conditions can lead to heterogeneity in CaCO3 grade, susceptibility to weathering, trace element content, and other factors that may negatively impact suitability of the limestone for development. Some sedimentary limestone deposits are of continental origin and can also be quite extensive. Carbonate rocks are susceptible to post-depositional alteration that may affect the $CaCO_3$ content, trace element content or physical characteristics. These processes may enhance or detract from the suitability of the deposits for development. Some of these processes may lead to the formation of sulfide minerals, which can limit the use of the limestone for environmental reasons. Scholle and others (1983) provide a comprehensive overview of carbonate depositional environments.

19A.3.5 Grade and Tonnage Model

Available information is insufficient to allow a quantitative assessment.

19A.3.6 Exploration History

Soviet and Afghan geologists identified a number of limestone deposits during geological surveys in the 1970s, but very little is known about exploration specifically for limestone deposits, especially information pertaining to quality and potential application of limestone resources.

19A.3.7 Known Occurrences and Example Deposits

Limestone occurrences are widespread in Afghanistan. The Early Carboniferous Sabz deposit in Badakhshan Province has speculative limestone resources of about 500 million metric tons (United Nations Economic and Social Commission for Asia and the Pacific, 1995). The Early Triassic

Darra-i-Chartagh (34°26'20"N; 62°46'00"E) deposit in Herat Province is more than 5 km long, more than 200 m thick, and is suitable for cement production. The Middle Triassic limestone at the Rod-i-Sanjur (34°26'N; 62°44'E) deposit in Herat Province is as much as 400 m thick (United Nations Economic and Social Commission for Asia and the Pacific, 1995). Other occurrences are located at the Bakunvij quarries in Badakhshan (United Nations Economic and Social Commission for Asia and the Pacific, 1995).

19A.3.8 Tract Delineation and Boundary Criteria

Figure 19A–3 shows permissive tracts lms01 and lms02 (Doebrich and Wahl, 2006; Ludington and others, 2007) for limestone and marble with selected deposits and prospects within Dudkash AOI and surrounding area. The main limestone permissive tract (lms01) was delineated using the digital geologic map of Afghanistan (Doebrich and Wahl, 2006; Ludington and others, 2007). The tract consists of map units that have limestone or marble identified as a major or dominant component. Although limestone of different ages may well have different economic potential, limestone of all ages was combined for the delineation of tract lms01 because of lack information to develop criteria for establishing differing probabilities of occurrence in rocks of different ages.

19A.3.9 Deposits and Prospects

The following limestone-dolomite deposits are present in the Dudkash industrial minerals AOI.

19A.3.9.1 Pul-e Khumri Limestone, Baghlan Province (35°58'24"N, 68°40'56"E)

Upper Cretaceous–Paleocene 300- to 500-m-thick limestone occurs over an area of several thousand square kilometers. The rock is light colored, thick-bedded, and fine-crystalline. A large limestone deposit located close to Pul-e Khumri has been a readily available resource of raw material for the Ghori-I cement plant. The deposit consists of Danian (Paleocene) limestone beds, 300 to 400 m thick, exposed in the area of several thousand square kilometers. The limestone is pure, containing 52 to 53 percent lime, 0.8 to 1.3 weight percent (wt. %) MgO, and 1.3 wt. % insoluble residue.

19A.3.9.2 Dudkash Limestone, Baghlan Province (36°00'40"N, 69°46'00"E)

A 30-m-thick limestone bed crops out in between Jurassic clays and siltstones. The limestone is grey, stratified, compact, and aphanitic. To be used for cement production, it would need additional other agents.

19A.3.9.3 Dudkash Dolomite, Baghlan Province (36°00'47"N, 68°47'20"E)

A 3.9-m-thick dolomite bed occurs in Lower Cretaceous siltstone, limestone, and gypsum units. In composition the rock is almost chemically pure dolomite.

19A.3.9.4 Shine Oghor Mine (Shenivaghur Mine), Dahana-i-Ghori District, Baghlan Province (35°43'47"N, 68°33'0"E)

A massive, kilometer-long and 80-m-thick black dolomite bed has been mined for some time (Mindat, 2011).

19A.3.10 Optimistic Factors

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

19A.3.11 Pessimistic Factors

There is almost no information about quality or consistency of quality of limestone of any age.

19A.3.12 Important Data Sources

The main sources for information on limestone resources in Afghanistan include United Nations Economic and Social Commission for Asia and the Pacific (1995), Abdullah and others (1997), and Doebrich and Wahl (2006).

19A.4 Gypsum

19A.4.1 Probable Age(s) of Mineralization

Late Cretaceous to Neogene.

19A.4.2 Importance and Economic Expectation

Gypsum is a key component of wallboard, a cost-effective building material, and has additional uses in cement and agriculture. Gypsum demand increases with an expanding national GDP. Most of the currently active gypsum quarries are mined on a small scale and the utilization of the mined material is not specified in the literature.

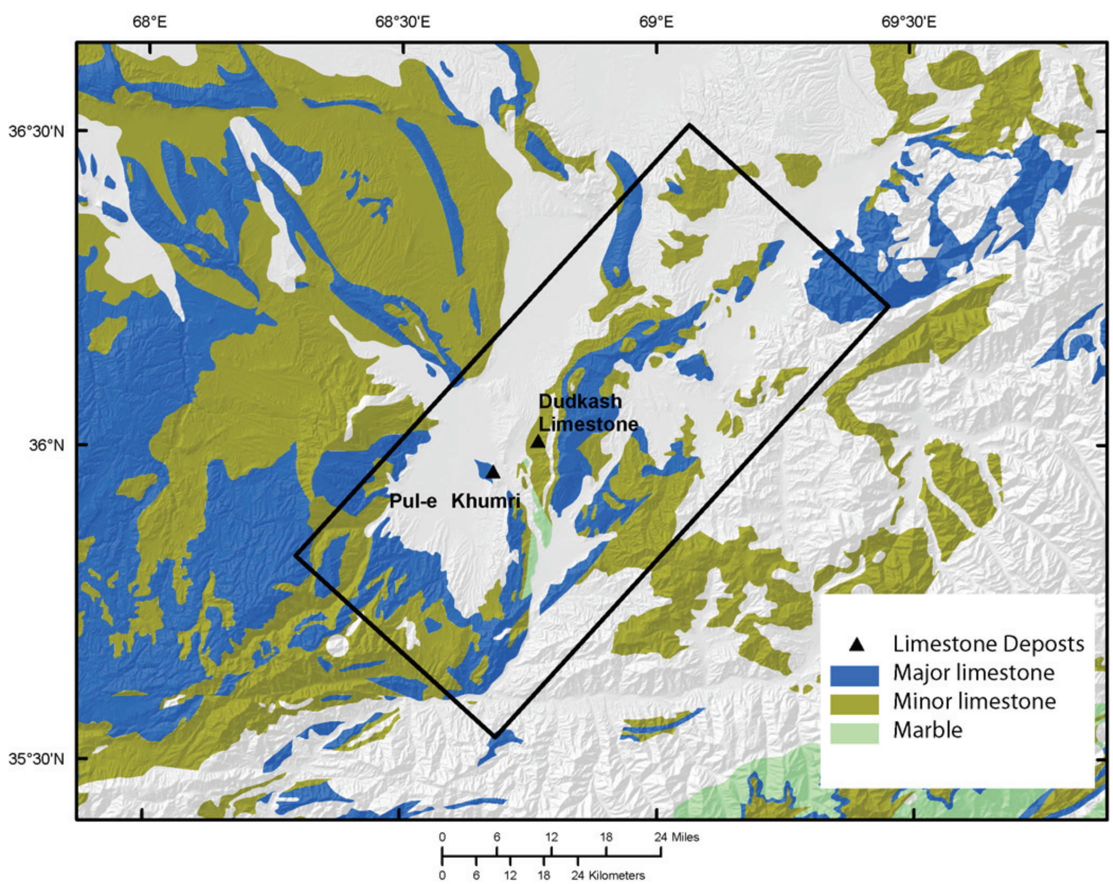

Figure 19A–3. Map showing limestone and marble permissive tracts (lms01, lms02) with selected deposits and prospects (triangles) in Dudkash AOI, where blue, tract lms01 limestone, major component; olive green, tract lms02, industrial limestone, minor component; light green: marble.

19A.4.3 Descriptive Genetic Model

Gypsum and anhydrite are usually deposited in evaporitic sedimentary environments, peripheral to halite and bittern deposition (bromides, magnesium, calcium), if present. Gypsum deposits of both marine and continental origin are present in Afghanistan. Figure 19A–4 shows the permissive tract

(AFGy-01, from Doebrich and Wahl, 2006) for the occurrence of gypsum and anhydrite in the AOI and nearby regions, with locations of known major occurrences.

19A.4.4 Grade and Tonnage Model

Available information is insufficient to allow a quantitative assessment.

19A.4.5 Exploration History

Largely unknown, although the Soviets and Afghans conducted geological surveys in the 1960s and early 1970s that made note of some of the deposits reported here. Supporting geologic studies of mineralized systems and assessment areas is available at the USGS Afghanistan website (http://afghanistan.cr.usgs.gov/ and at the Afghanistan Geological Survey website (http://www.bgs.ac.uk/afghanminerals/).

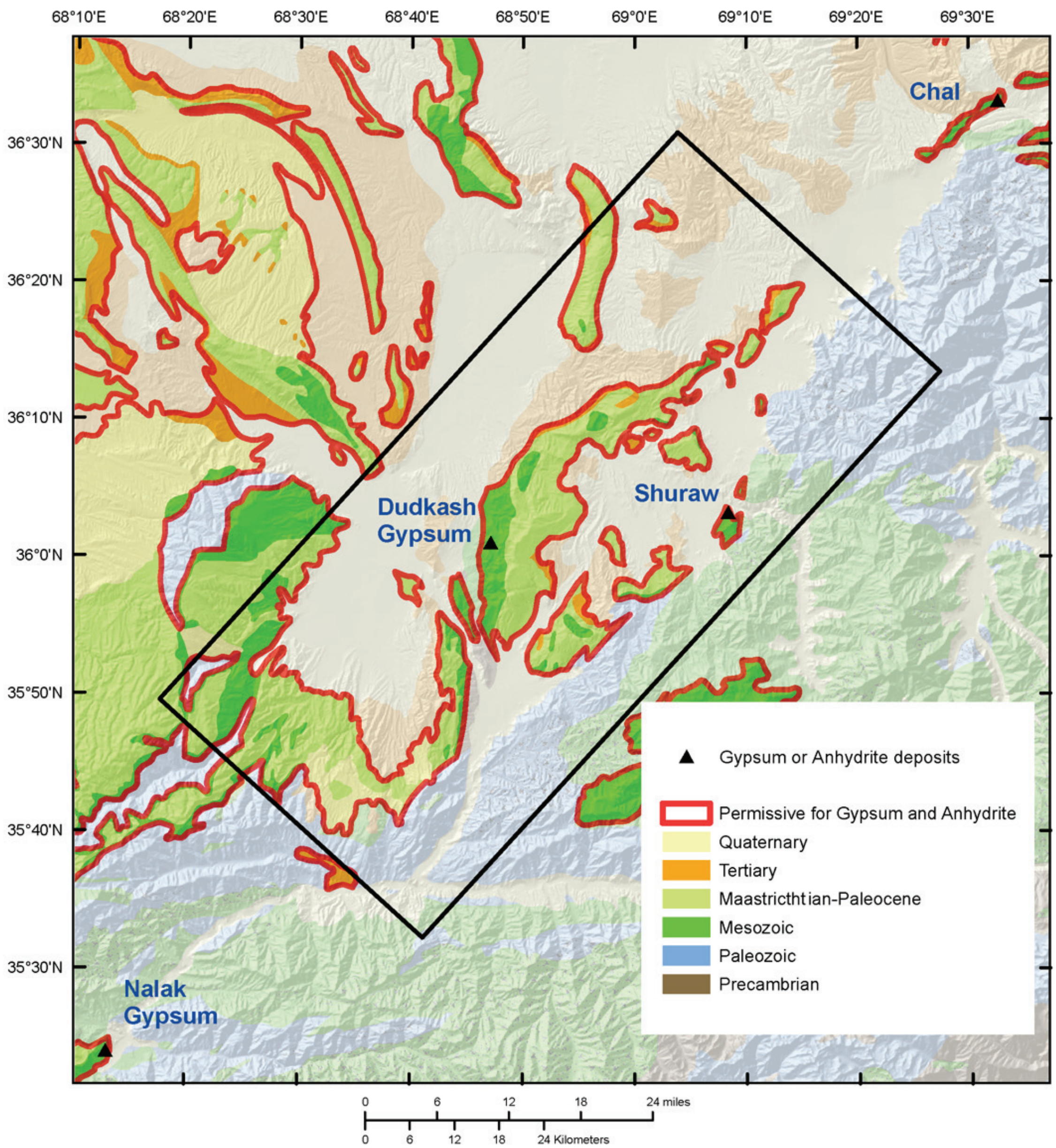

Figure 19A–4. Area considered permissive for the occurrence of gypsum and anhydrite with locations of known major occurrences (Tract AFGy-01) (From Doebrich and Wahl, 2006).

19A.4.6 Known Occurrences and Example Deposits

Gypsum deposits in the Dudkash industrial minerals AOI have been identified in Baghlan Province with exposures of Late Jurassic, Late Cretaceous to Paleocene, and less commonly, Neogene ages. Figure 19A–4 maps mixed permissive tracts for gypsum-bearing rock in the Dudkash AOI and surroundings. Examples of additional deposits far beyond the perimeter of the Dudkash AOI include the Sary-Asya deposit in Samangan Province and the Neogene Surkh-Rod deposit in Nangarhar Province.

19A.4.5 Deposits and Prospects

The gypsum deposits present in the Dudkash industrial minerals AOI including the following:

19A.4.5.1 Shoraw, Baghlan Province (36°03'45"N, 69°08'56"E)

A 1-m-thick gypsum bed occurs in Jurassic sandstone, clay and gritstone. The occurrence is being worked manually.

19A.4.5.2 Dudkash Gypsum, Baghlan Province (36°00'55"N, 68°47'30"E)

Note that the name of the Dudkash industrial minerals AOI is taken from the name of this mine. The occurrence comprises massive 1.5- to as much as 6-m-thick gypsum beds, which occasionally extend for 12 km in Upper Jurassic clay, siltstone, sandstone, and dolomite. The gypsum has been mined.

19A.4.6 Optimistic Factors

Some of the deposits are many thousands of meters long and 5 to more than 30 m thick. The few reported grades range from 89 percent to greater than 99 percent gypsum. Tracts are large in area and would readily host large deposits if present.

19A.4.7 Pessimistic Factors

Very little data have been reported on gypsum quality; there is no information available on the consistency of the gypsum in terms of chemical or physical characteristics across the outcrop areas of gypsum of any given age.

19A.4.8 Tract Delineation and Boundary Criteria

The gypsum tract shown in figure 19A–4 was delineated using outcrops of sedimentary units where gypsum was listed as a major or dominant component. Although it is likely that gypsum-bearing rocks of different ages have different potential, we lumped all ages due to an equal lack of distinguishing geologic information other than age. Areas of less promise consist of geologic units in which gypsum is listed as a minor component (area in bright blue in figure 19A–6).

19A.4.9 Important Data Sources

Oil and gas assessment data; known salt occurrences (Klett and others, 2006).

19A.5 Clay

All clays are a mix of fine-grained minerals with microscopic crystals of phyllosilicate minerals and with lesser amounts of organic material. These components collectively impart plasticity to wet clay and cause clay to harden when dried or fired in a kiln. There are three or four main groups of clays, the number depending on the reference source, with approximately 30 different types of pure clays in these categories. The three categories of clays considered by the USGS-AGS Assessment Team were adobe-brick clay, refractory clay and porcelain clay (Ludington and others, 2007). Refractory clay (also known as fire clay) melts around 1,600°C (Theng, 1979). Refractory clay is used to line pouring spouts or entire furnaces for molten iron and steel, and with proper selection it can be used in kilns for cement production, to fire bricks and to contain molten glass without contaminating the glassy flux (Theng, 1979). Porcelain clay is selected for a multiplicity of products because it turns glassy at elevated temperature, and adobe-brick clay is used for construction, but may swell and fall apart at elevated temperatures.

19A.5.1 Importance and Economic Expectation

Kaolin is used in ceramics, medicine, coated paper, as a food additive, in toothpaste, as a light diffusing material in white incandescent light bulbs, and in cosmetics. It is generally the main component in porcelain. It is also used in paint to extend titanium dioxide (TiO_2) and modify gloss levels, and in rubber and adhesives to modify rheology. Bentonite is used for drilling muds because of its rheological properties. Bentonite subclasses are also used in ceramics.

19A.5.2 Mineralization

The dominant clay species are montmorillonite, bentonite, illite, and kaolinite. Montmorillonite is the main constituent of bentonite. For industrial purposes, two main classes of bentonite exist: sodium bentonite and calcium bentonite; a minor class, potassium bentonite is commonly referred to as illite. Kaolinite is a clay mineral with the chemical composition $Al_2Si_2O_5(OH)_4$ (Deer and others, 1992). Montmorillonite is the main constituent of bentonite. Bentonite usually forms from weathering of volcanic ash.

19A.5.3 Descriptive Genetic Model

Clay minerals are typically formed over long periods of time by the gradual chemical weathering of rocks, usually silicate-bearing, by low concentrations of carbonic acid (Velde, 1995). These solvents, usually acidic, migrate through the weathering rock after leaching through upper weathered layers. Clay minerals form from preexisting minerals where rocks are in contact with water, air, or steam (Klett and others, 2006). As such, environments for clay production are ubiquitous, including soil horizons, continental and marine sediments, geothermal fields, volcanic deposits, weathering rock formations, in sediments at the bottom of lakes or seas, and rocks in contact with water heated by magma (hydrothermal fluids). Clay deposits are typically associated with very low energy depositional environments such as large lakes and marine deposits in Mesozoic and Cenozoic strata.

Clay deposits may be formed in place as residual deposits in soil, but thick deposits usually are formed as the result of a secondary sedimentary deposition process after they have been eroded and transported from their original location of formation. Primary clays, also known as kaolins, are located at the site of formation; secondary clay deposits have been moved by erosion and water from their primary location. Kaolinite occurs in abundance in soils that have formed from the chemical weathering of rocks in hot, moist climates; kaolinite typically occurs as a primary deposit. Rocks that are rich in kaolinite are known as white clay. Kaolinite-dominated clays are typically associated with coal.

19A.5.4 Grade and Tonnage Model and Economic Expectation

Available information is insufficient to allow a quantitative assessment.

19A.5.5 Exploration History

Soviet and Afghan geologists identified a number of limestone deposits during geological surveys in the 1970s, but very little is known about exploration specifically for limestone deposits, especially information pertaining to quality and potential application of limestone resources.

19A.5.6 Known Occurrences and Example Deposits

Brick and refractory clays are present in the west in Herat Province, in the central parts of the country in Samanghan and Baghlan Provinces, and in Kabul Province. The clays occur mainly in Upper Jurassic and in Cenozoic clay-rich sedimentary rocks. Herat Province contains the Karukh and Malumat brick and fire-clay occurrences within calcareous silty and sandy material in Quaternary sedimentary formations. Delineation of the permissive area was guided by the occurrences of clay occurrences in the

Loghar Valley, Loghar Province. In Samanghan and Baghlan Provinces the, coal-bearing Jurassic units contain sedimentary kaolin in unspecified map unit J12ssl. Clay occurrences include Rafak in the Ruyi Du Ab District within Lower Cretaceous siltstone that consists of a green to gray, 5-m-thick clay bed. The Nalak occurrence, in Upper Triassic weathered diorite porphyry, is a tabular deposit about 13 m thick consisting of gray, laminated clay. The Talin occurrence is hosted in Lower to Middle Jurassic rocks and contains five clay beds, 500 m long and 0.5 to 2.7 m thick. Speculative resources are 385,000 metric tons (t) of clay (Abdullah and others, 1977).

19A.5.7 Deposits and Prospects

The hyperspectral (2-millimeter) image of an area overlapping Pul-e Khumri and Nahrin districts in the Dudkash AOI shown in figure 19A–5 reveals the spatial distribution of kaolinite (Hillside blue).

The Dahan-e Tor occurrence (35°43'13"N, 67°15'41"E), Dara-i Suf, Bala District, Samangan Province, is in Lower to Middle Jurassic clay-rich sedimentary sequences and is blue-gray, 40 to 50 m thick, and suitable for manufacturing of brick and roof tile. The Shabashak occurrence (34°41'36"N, 67°27'0"E), Bamiyan district, Bamiyan province, is alkaline and suitable for drilling mud and as moulding clay. Cenozoic sedimentary rocks also contain clay-rich deposits. The Deh-Kapal occurrence in Kabul Province (34°37'00"N; 66°04'30"E consists of Quaternary clays grading 5.63 percent silica and 5.04 wt. percent hematite. Speculative resources of clay suitable for the ceramic industry are about 2,200,000 m3 to a depth of 5 m. The Surkhab and Kaukpar occurrences in Pul-e Khumri and Nahrin districts, Baghlan Province, are hosted within sedimentary bentonite units of Neogene sandstone and conglomerate beds (Abdullah and others, 1977).

19A.5.7.1 Surkhab Clay, Baghlan Province, 25°58'25"N, 68°40'32"E

Hosted within sedimentary bentonite units of Neogene sandstone and conglomerate beds (Abdullah and others, 1977). A bed of Neogene clay is used as an additive in cement production.

19A.5.7.2 Kawkpar Clay, Baghlan Province, 35°56'55"N, 68°52'36"E

Clay 2- to 17-m-thick beds have been found between Neogene sandstone and conglomerate beds. The clay is lumpy, slightly gypsiferous.

19A.5.8 Optimistic Factors

Afghanistan contains abundant clays, with quantities sufficient to meet the demands of domestic construction where the application is relatively insensitive to the type of clay used. With the exception of the kaolins associated with the coals, little information is available about the composition of the clays. Further investigation into the type and composition of the clays would be necessary to determine where efforts should be put into developing them for other specialized uses.

19A.6 Celestite

19A.6.1 Mineralization

Sedimentary celestite ($SrSO_4$) deposits are the main source of celestite production. The strontium to form these deposits is variously believed to be sourced from 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 (Warren, 1999; Hanor, 2000). In the area of Afghanistan represented by the Dudkash AOI, celestite mineralization is typically spatially associated with coal and petroleum (Abdullah and others, 1977). The two celestite deposits known in Afghanistan are reported to be Paleogene in age (Abdullah and others, 1977). Since the known deposits in Iran are also Paleogene, specifically Oligocene, in age, it is believed that any undiscovered deposits will also be found in sediments of that age.

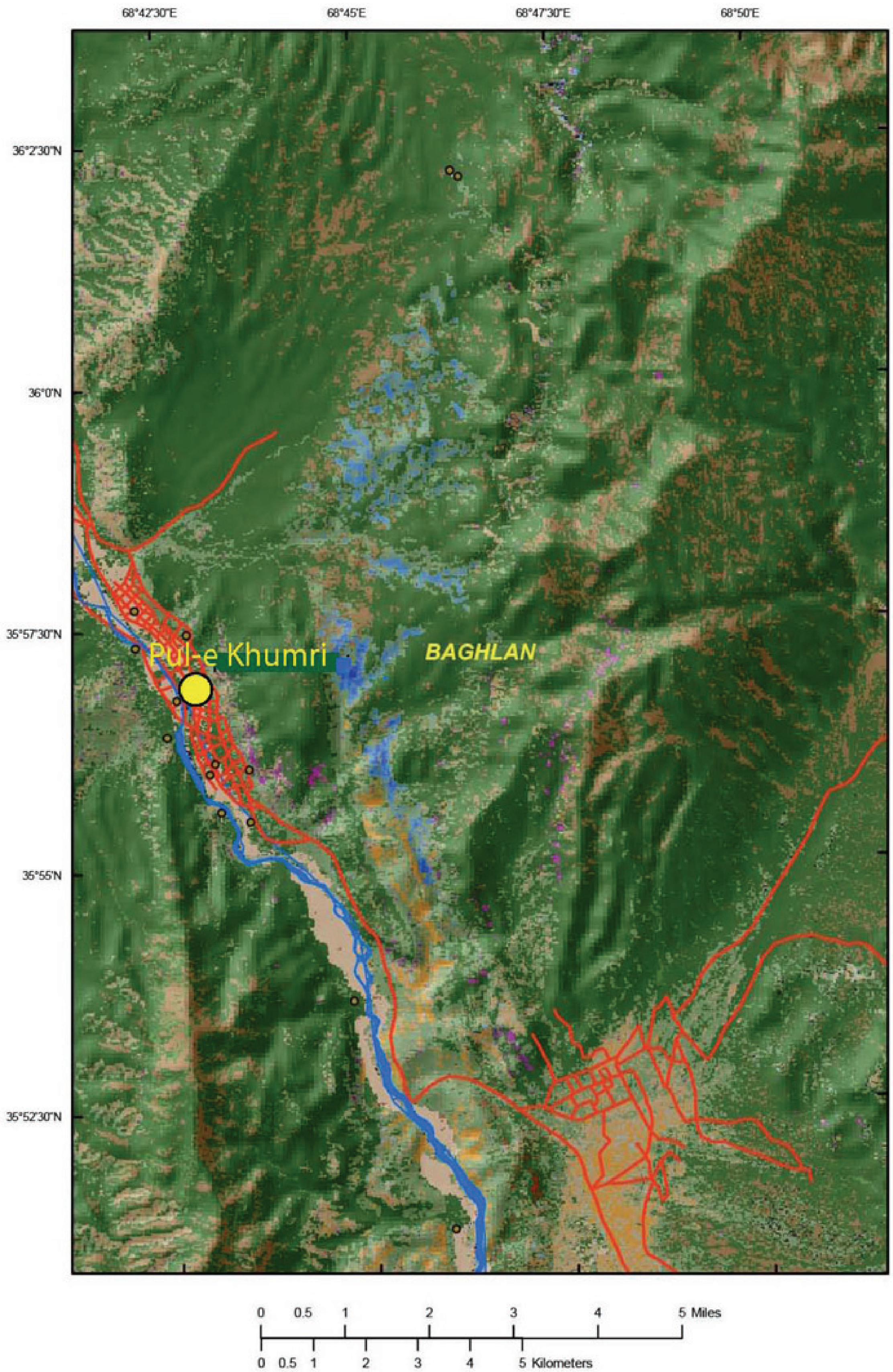

Figure 19A–5. Hyperspectral image of an area overlapping Pul-e Khumri and Nahrin districts: Hillside Blue, kaolinite. From Hubbard, chapter 19B of this report.

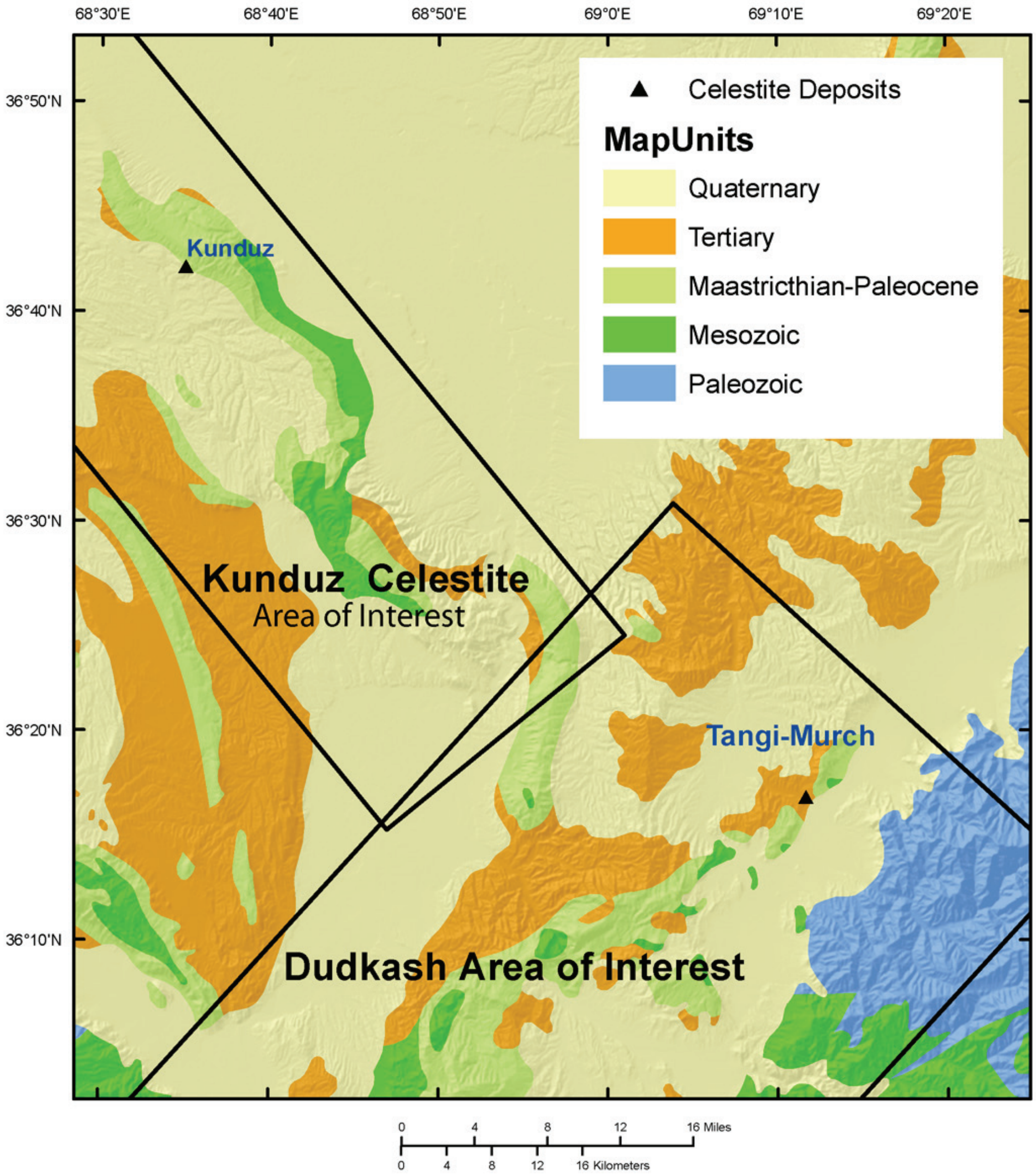

Figure 19A–6. Location of important celestite deposits in the Dudkash AOI (Doebrich and Wahl, 2006).

19A.6.2 Importance and Economic Expectation

Sedimentary celestite deposits are the main source of celestite production. Celestite ($SrSO_4$) is currently the dominant, if not the sole commercial source of strontium. More than 75 percent of the production of celestite is used in the production of radiation-absorbent glass for television, computer, sonar, and other screens (Harben, 2002). Half of the world's annual production of just over 300,000 t is sourced from Mexico; most of the remaining production is from Spain (Harben and Kuzvart, 1996). The single most significant celestite deposit in Afghanistan is in Baghlan Province at Tangi Murch.

19A.6.3 Descriptive Genetic Model

The known deposits in Afghanistan and Iran contain characteristics similar to the bedded celestite type (Model 35a.1, Orris, 1992). Sedimentary celestite deposits can form in a variety of ways including primary precipitation, and through diagenetic and alteration processes. Celestite is commonly associated with evaporate deposits, as well as limestone and dolomite. In the Dudkash AOI, celestite ($SrSO_4$) deposits of potential economic significance are hosted by layered limestone and gypsiferous clays of the Paleocene Bukhara and Suzak Formations.

19A.6.4 Exploration History

In the mid-1970s, the Russians explored the Baghlan and Kunduz Provinces, reporting celestite deposits 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. Two deposits were estimated by the Russian workers to contain together more than 1 million metric tons (Mt) of celestite ore. It is probable that large celestite deposits, similar to those in Pakistan and Iran, occur in Afghanistan. Targeted exploration would probably reveal additional deposits (Harben, 2002).

19A.6.5 Known Occurrences and Example Deposits

Preeminent celestite deposits are the Early Cretaceous deposits of Coahuila, Mexico, where they are found around the periphery of the Coahuila Platform (Rodriguez Garza and McAnulty, 1996). A major celestite deposit in the Dasht-e Kavir desert of Iran occurs in the lower part of the Oligocene Qum (Qom) Formation and is exposed in a northwest-trending ridge system. At the Nakhjir-kuh celestite deposit (Varamin, South Tehran, Iran, a 2- to 4-m-thick seam of celestite is mined by open-pit; more than 1 Mt of celestite is reported to be present at the nearby Talheh deposit (Harbena and Kuzvart, 1996). Small amounts of celestite production have also been reported in Pakistan.

19A.6.6 Known Prospects in Afghanistan

Abdullah and others, 1977, report two celestite deposits in Afghanistan: Kartaw and Tangi Murch.

19A.6.6.1 Kartaw Deposit, Chahar Dara District, Kunduz Province: 36°42'N, 68°35'E

(This deposit is outside the Dudkash AOI.) The celestite forms a bed 1,400 m along strike that extends 10 to 14 m down dip and averages 0.9 m in thickness. Speculative resources of 1 Mt of white to bluish crystalline celestite were estimated.

19A.6.6.2 Tangi Murch, Burka District, Baghlan Province: 36°16'13"N, 69°12'24"E

(This deposit is within the Dudkash AOI.) This celestite deposit is a bedded occurrence hosted by Paleogene bituminous limestone and other sedimentary rocks of the Bukhara and Suzak Formations (Kasak and others, 1965; Orris and Bliss, 2002). The ore beds consist of fine to coarse-crystalline celestite-bearing rock. Four celestite ore beds have been located, their thicknesses ranging from 0.4 to 1.67 m and over a maximal length of 170 m. The celestite content is from 29 to 77 vol. percent and the specific gravity, from 3.00 to 3.94 grams per cubic centimeter (g/cm^3). The speculative reserve of the celestite ore is 85,600 t, the average celestite content of 54 vol. percent and specific gravity of 3.43 g/cm^3. Statistics on the number of samples, reproducibility of the analytical results, or spatial sampling technique were not available. It is probable that large celestite deposits, similar to those in Pakistan and Iran, occur in Afghanistan. Targeted exploration would probably reveal additional deposits.

19A.6.7 Tract Boundary Criteria

A permissive tract was delineated using the digital geologic map of Afghanistan (Doebrich and Wahl, 2006). The tract area consists of those map units that have evaporite deposits identified as a major or dominant component. Evaporite-bearing rocks of all ages were combined in this tract because we lacked information to develop criteria for differing probabilities of occurrence in rocks of different ages. Gypsum-anhydrite-bearing sediments of Late Cretaceous to Paleogene age were selected as proxies for celestite and then buffered five km outward because of the uncertainty of map unit boundaries due to near-horizontal stratigraphy (Orris and Bliss, 2002). Units in which limestone is a minor component in this area could be considered to have lower potential. Additional areas of interest were noted proximal to the known occurrences.

19A.7 Coal

Mineralization coal is formed by geological processes requiring a setting of elevated pressure and temperature over an extended period acting on buried detrital biotic material. The process begins with layers of plant matter accumulating in an anoxic environment, usually on the muddy bottom of a body of water. Over time, the chemical and physical properties of the vegetative remains are changed into a solid material that is mainly composed of carbon along with variable quantities of other elements, chiefly hydrogen, with smaller quantities of sulfur, oxygen and nitrogen. The harder forms of coal, such as anthracite, can be regarded as metamorphic rock because of longer exposure to elevated temperature and pressure. In general, the deeper the coal is buried, the higher the grade (rank) (Jones, 1949). of the coal. Moreover, deep coal deposits are considered prospectively valuable for coal-bed methane (CBM). The general quality of Afghan coals appears to vary considerably, both stratigraphically and laterally (SanFilipo, 2005).

Most of the coal being mined in Afghanistan occurs in Jurassic rocks of the Northern Afghan platform. While this coal is of relatively high rank and grade, it is far from most major population centers, and can only be delivered by truck over primitive roads that cross difficult terrain. Paleogene coal also occurs in Afghanistan, but is generally restricted to the Katawaz Basin and associated areas of eastern Afghanistan. The Mesozoic and Paleogene coal basins are separated by continental-scale faults that mark current and ancient tectonic plate boundaries. The less mature Tertiary-age coals are typically high-ash and of low heating value. The shallower coal areas could have commercial potential for underground mining, CBM, and to a limited extent, surface mining.

19A.7.1 Importance and Economic Expectation

Coal utilization in Afghanistan has historically been restricted to households and small industry (notably in the manufacturing of cement and textiles, and in food processing). The main demand for coal is for brick making. A significant demand also exists for cooking and domestic heating during the winter season. Lack of transportation is the main factor limiting more widespread use of coal. The main factors limiting the widespread use of coal appear to be its limited availability, a consequence of inadequate mineral exploration, poor extraction infrastructure and transport problems.

Although Afghanistan produced more than 100,000 t of coal annually as late as the early 1990s, the country was producing only around 4,000 t as of 1998. Currently about 20 percent of coal production is from government owned mines operated by the Northern Coal Department (NCD) of the Afghan Ministry of Mines and Industry (MMI), or by associated agencies in Herat Province (Clough, 2007). The remainder of the production comes from small private artisanal mines. NCD mines have fallen into nearly total disrepair during the past 30 years, and all existing coal mines use obsolete extraction methods and inferior infrastructure for worker safety. The MMI estimates an increased in annual demand for coal to several million metric tons from the present level of 0.5 Mt in order to support the needs of new cement, brick and iron factories.

19A.7.2 Exploration History

Coal occurrences in Afghanistan were reported in Afghanistan starting with Griesbach (1881, 1885, 1887a, 1887b) 130 years ago. Exploration continued into the twentieth century with Hayden (1911), West (1942) and others. Over the period 1963–1965, Soviet geologists and others carried out a geological survey on a scale of 1:200,000 in Northern Afghanistan (K.Ya. Mikhailov, V.P. Kolchanov, V.V. Kulakov, B.P. Pashkov). As a result of the survey the area of coal-bearing formations was studied and the North Afghanistan Coal Basin was recognized. There are nine coal fields and about 42 coal deposits in Afghanistan (Votrubec, 1982; Harben, 2002), most of which are found in the north of the country and all of which have been surveyed by the former Soviet Union. Coal resources in Balkhab, Samangan Province have recently been assessed by remote sensing sponsored by USAID (Sabins and Ellis, 2010). Two deposits were described in the report and designated as Balkhab East and Balkhab West (Sar-e Pol Province).

19A.7.3 Known Occurrences and Example Deposits

Of the 40 coal deposits in Afghanistan, there are 11 coal mines with a history of production, and only 1 to 5 believed to be marginally viable for local production (Addison, 2007). Reserves associated with these deposits are listed as 98 Mt of coal (all quantitative estimations should be regarded as subject to refinement). Chapter 16A provides an overview of coal occurrences in Afghanistan on a regional scale. Apart from the Karkar and Dudkash coal mines near Pul-e Khumri in Baghlan (Afghan Chamber of Commerce, 2011), detailed information on actual production activities has been elusive. Coal occurrences of note in Afghanistan include:

19A.7.3.1 Ishpushta Deposit, Baghlan Province

Reserves are estimated to be 2.5 Mt of coal with a calorific value less than 20.90 megajoules per kilogram (MJ/kg).

19A.7.3.2 Dara-i Suf Deposit, South of Mazar-i-Sharif, Samangan Provine

Reserves of the Dara-i Suf basin in 8 to 40-m-thick coal seams with 10 to 35 percent ash content and 23.10 MJ/kg calorific value are estimated to be 50 Mt.

19A.7.3.3 Gora Zabzak Deposit, Daykundi Province

The deposit contains 12 seams of coal with 16.74 MJ/kg calorific value and 73.77 Mt of reserves (20.7 Mt of proved and mineable coal, 23.7 Mt of probably coal and 29.3 Mt of estimated coal). A further deposit north of Zabzak contains 6.55 Mt of probably coal and 3.0 Mt of possible coal.

19A.7.3.4 Madzid-i Cobi Deposit, Kabul Province

Of 4 coal seams contains 9.5 Mt of coal reserves (4.9 Mt of proved and mineable reserves and 4.3 Mt of probably reserves).

19A.7.3.5 The Sari-i Assia Deposit, Kunduz Province

This occurrence contains 5.84 Mt of coal (1.07 Mt of proved and mineable reserves and 4.77 Mt of probably reserves) (Votrubec, 1982, p. 418).

This report focuses on the Karkar and Dudkash coal mines in the Dudkash industrial minerals AOI.

19A.7.4 Karkar and Dudkash Deposits and Prospects

Figure 19A–7 shows the area considered permissive for coal and the deposits described below in the Dudkash industrial minerals AOI (Doebrich and Wahl, 2006).

A shepherd discovered coal at Karkar in 1938, and production began the following year. Coal was initially loaded into bags and taken out by donkey (Andrade, 2006). The coal mines branch of the Ministry of Mines was set up to develop the coal resources at Karkar and Dudkash, and at one time had 30 regular employees at the mines, 111 officials in Kabul, 1667 contractors and 5 foreign experts from Czechoslovakia. It was restructured as a government enterprise in 1971 (Grantham, 2011).

In 2006–07 the four mines at Karkar, Dudkash, Ahandara and Khurdara mines and a cement works at Pul-e Khumri were privatized, with all movable and fixed assets transferred to the private Afghan Investment Company (AIC) in April 2007 (Abdullah and others, 1977; Orris, 1992). The mines are now operated by AIC subsidiary Afghan Coal LLC, with the intention to provide fuel for a proposed 25 MW thermal power plant (Harben, 2002) and in limited quantities for AIC's Ghori-I cement plant in Pul-e Khumri. From 1957 until 1988 the mine operated with assistance from Czechoslovakia, and used equipment supplied from the Warsaw Pact states. In addition, experts from India and Russia also provided assistance. Production peaked in the 1970s, with the Karkar mine employing 1,600 people and producing 600 to 700 t of coal daily. Virtually no capital investment was made in the mines after the Soviets left in 1989. The equipment fell into a very dilapidated state, with the mines resorting to manual pick-and-shovel operations. In 2004, Karkar had 318 staff, and the four mines produced around 100 t daily. Figure 19A–8 shows the Karkar and Dudkash mines situated side-by-side about 12 km northeast of Pul-e Khumri in central Baghlan province (2004) (Ministry of Mines-Islamic Republic of Afghanistan, 2011). Currently, the Karkar and Dudkash mines are under the management of the Afghan Investment Company, which has vertically integrated cement production at the Ghori Cement Works in Pul-e Khumri with coal production to fire the kilns and for steam turbine electrification of the cement plants (Erreck, 2011).

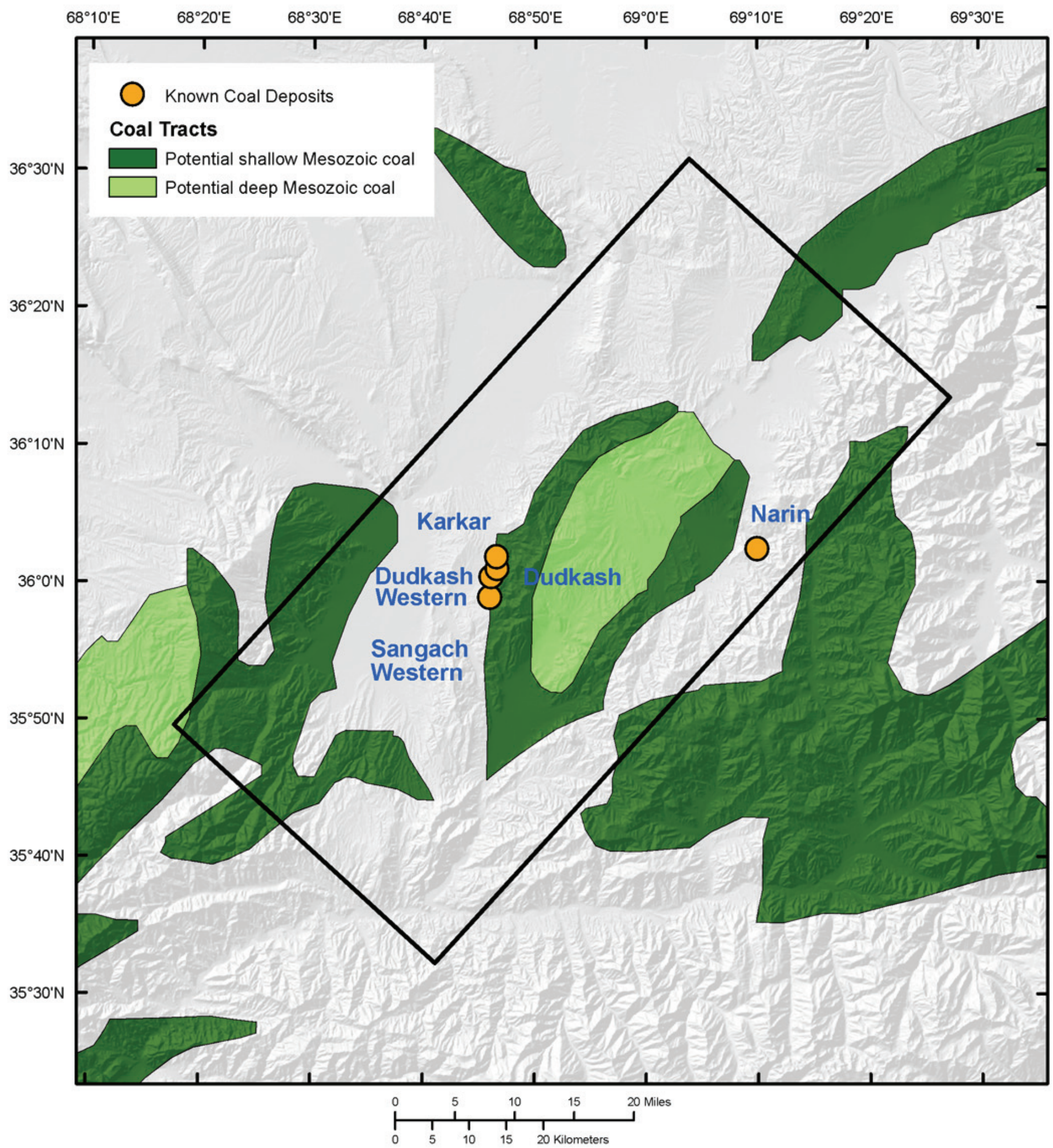

Figure 19A–7. Permissive tract for coal occurrences. From Doebrich and Wahl (2006).

19A.7.5 Pessimistic Factors

Although 75 percent of Afghan coal production came from the Karkar and Dudkash mines at some time, these mines are currently barely in production. The coal is of low quality with 10 percent ash content and 20.90 MJ/kg calorific value.

Coal mining in Afghanistan is a largely unregulated affair. Total annual production in Afghanistan is about 200,000 t, but only about 20 percent is from government mines, mainly operated by the North Coal Department or associated agencies in Herat Province (SanFilipo and others, 2006).

19A.8 References Cited

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

Addison, M.W., 2007, Energy sector strategy: Islamic Republic of Afghanistan for the Afghanistan National Development Strategy, available at *http://pdf.usaid.gov/pdf_docs/PNADT239.pdf*.

Afghan Chamber of Commerce, 2011, Mining: Afghan Chamber of Commerce, available at *http://www.afghanchamber.com/about/Mining.htm.*

Afzali, H., 1981, Les ressources d'hydrocarbures, de métaux et de substances utiles de l'Afghanistan—Aperçu général: Chronique de la Recherche Minière, no. 460, p. 29–51.

Andrade, Patrick, 2006, Amid reconstruction efforts, Afghanistan's largest coal mine rusts away: EurasiaNet, available at *http://www.eurasianet.org/departments/civilsociety/articles/eav012706.shtml*.

Clough, L.D., 2007, Energy profile of Afghanistan, *in* Cleveland C.J., ed., Encyclopedia of earth: Washington, D.C., Environmental Information Coalition, National Council for Science and the Environment, available at *http://www.eoearth.org/article/Energy_profile_of_Afghanistan*.

Deer, W.A., Howie, R.A., and Zussman, J., 1992, An introduction to the rock-forming minerals (2d ed.): Harlow, United Kingdom, Longman Scientific Technical, 696 p.

Doebrich, J.L., and Wahl, R.R., comps., *with contributions by* Doebrich, J.L., Wahl, R.R., Ludington, S.D., Chirico, P.G., Wandrey, C.J., Bohannon, R.G., Orris, G.J., Bliss, J.D., and ____, 2006, Geologic and mineral resource map of Afghanistan: U.S. Geological Survey Open File Report 2006–1038, scale 1:850,000, available at *http://pubs.usgs.gov/of/2006/1038/.*

Erreck, B.V., 2011, Afghan Investment Company, *in* Afghan biographies: Brunz V. Erreck database, available at *http://www.afghan-bios.info/index.php?option=com_afghanbios&id=39&task=view&total=2250&start=37&Itemid=2*.

Freas, R.C., Hayden, J.S., and Pryor, C.A., Jr., 2006, Limestone and dolomite, *in* Kogel, J.E., Trivedi, N.C., Barker, J.M., and Krukowski, S.T., eds., Industrial minerals and rocks (7th ed.): Littleton, Colo., Colorado Society for Mining, Metallurgy, and Exploration, Inc., p. 581–597.

Grantham, Andrew, 2011, Industrial railways—Coal: Railways of Afghanistan, available at *http://www.andrewgrantham.co.uk/afghanistan/industrial-railways-coal/*.

Griesbach, C.L., 1881, Reports on the geology of the section between the Bolan pass in Baluchistan and Girishk in southern Afghanistan: Calcutta, Geological Survey of India Memoirs, XVIII, pt. 1.

Griesbach, C.L., 1885, Afghan field notes: Calcutta, Geological Survey of India Records, XVIII, pt. 1.

Griesbach, C.L., 1887a, Field notes from Afghanistan (no. 4)—From Turkistan to India: Calcutta, Geological Survey of India Records, XX, pt. 1.

Griesbach, C.L., 1887b, Field notes (no. 5)—To accompany a geological sketch map of Afghanistan and north-eastern Khorasan: Calcutta, Geological Survey of India Records, XS, pt. 2.

Hanor, J.S., 2000, Barite-celestine geochemistry and environments of formation: Reviews in Mineralogy and Geochemistry, v. 40, p. 193–275.

Harben, P.W., 2002a, Celestite and strontium compounds, *in* The industrial minerals handbook—A guide to markets, specifications and prices (4th ed.): Worcester Park, United Kingdom, Industrial Minerals Information Ltd., p. 94–98.

Harben, P.W., 2002b, Potassium minerals and compounds, *in* The industrial minerals handbook—A guide to markets, specifications and prices (4th ed.): Worcester Park, United Kingdom, Industrial Minerals Information Ltd., p. 264–272.

Harben, P.W., and Kuzvart, Milos, 1996, Celestite, *in* Industrial minerals—A global geology: London, United Kingdom, Industrial Minerals Information Ltd., p. 91–97.

Hayden, H.H., 1911, The geology of northern Afghanistan: Calcutta, Geological Survey of India Memoirs, XXIX.

Jones, O.T., 1949, Hilt's law and the volatile contents of coal seams: Geological Magazine, v. 86, p. 303–312.

Kasak, Y.M., Lapko, F.F., Tolstukhin, E.A., and Koretsky, M.S., 1965, Report on geological exploration of the Farenjal barite deposit, carried out in 1963–1964 and prospecting and exploration of the Tangi Murch celestine deposit carried out in 1964: Kabul, Afghanistan, Department of Geological and Mineral Survey, [unpaginated].

Klett, T.R., Ulmishek, G.F., Wandrey, C.J., Agena, W.F., and U.S. Geological Survey-Afghanistan Ministry of Mines and Industry Joint Oil and Gas Resource Assessment Team, 2006, Assessment of undiscovered technically recoverable conventional petroleum resources of northern Afghanistan: U.S. Geological Survey Open-File Report 2006–1253, 237 p., available at *http://pubs.usgs.gov/of/2006/1253/*.

Ludington, S.D., Orris, G.J., Bolm, K.S., Peters, S.G., and U.S. Geological Survey-Afghanistan Ministry of Mines and Industry Joint Mineral Resource Assessment Team, 2007, Preliminary mineral resource assessment of selected mineral deposit types in Afghanistan: U.S. Geological Survey Open-File Report 2007–1005, 44 p., available at *http://pubs.usgs.gov/of/2007/1005/*.

Mindat, 2011, Dahana-i-Ghori district, Baglan province, Afghanistan: mindat.org, available at *http://www.mindat.org/loc-227469.html*.

Ministry of Mines [Afghanistan], 2011, Photo of the Dudkash mine: Ministry of Mines [Afghanistan], available at *http://mom.gov.af/en*.

Oates, J.A., 1998, Lime and limestone—Chemistry and technology, production and uses: New York, Wiley-VCH, 455 p.

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

Orris, G.J., 1992, Preliminary grade and tonnage model of bedded celestite, *in* Orris, G.J., and Bliss, J.D., eds., Industrial mineral deposit models—Grade and tonnage models: U.S. Geological Survey Open–File Report 92–437, 84 p.

Rodriguez Garza, A., and McAnulty, W.N., Jr., 1996, Overview of celestite deposits in south-central Coahuila, Mexico—Geology and exploitation, *in* Austin, G.S., Hoffman, G.K., Barker, J.M., Zidek, J., and Gilson, N., eds., Proceedings, 31st Forum on the Geology of Industrial Minerals—The Borderland Forum: New Mexico Bureau of Mines and Mineral Resources Bulletin 154, p. 27–32.

Sabins, F.F., and Ellis, J.E., 2010, Landsat analysis of mineral anomalies, Balkhab region, Afghanistan: Cathay Oil and Gas, [unpaginated].

SanFilipo, J.R., 2005, Assessing the coal resources of Afghanistan: U.S. Geological Survey Fact Sheet 2005–3073, available at *http://pubs.usgs.gov/fs/2005/3073/*.

SanFilipo, J.R., Davis, P.A., _____, Hackley, P.C., and ____, 2006, Coal mining in Afghanistan—A third-world paradigm of problems and opportunities: Geological Society of America, Philadelphia Annual Meeting, Abstracts with Programs, v. 38, no. 7, p. 96, available at *http://gsa.confex.com/gsa/2006AM/finalprogram/abstract_115740.htm*.

Scholle, P.A., Bebout, D.G., and Moore, C.H., eds., 1983, Carbonate depositional environments: Tulsa, Okla., The American Association of Petroleum Geologists Memoir 33, 708 p.

Theng, B.K., 1979, Formation and properties of clay polymer complexes, 9, *in* Developments in soil science: Amsterdam, Elsevier, 362 p.

Tucker, M.E., and Wright V.P., 1990, Carbonate sedimentology (1st ed.): Malden, Mass., Blackwell Science Ltd., 482 p.

Ulmishek, G.F., 2004, Petroleum geology and resources of the Amu–Darya basin, Turkmenistan, Uzbekistan, Afghanistan, and Iran: U.S. Geological Survey Bulletin 2201–H, 38 p.

United Nations Economic and Social Commission for Asia and the Pacific, 1995, Atlas of mineral resources of the ESCAP region—Geology and mineral resources of Afghanistan: United Nations Economic and Social Commission for Asia and the Pacific, v. 11, 85 p., 4 map sheets.

Velde, B., 1995, Composition and mineralogy of clay minerals, *in* Velde, B., ed., Origin and mineralogy of clays: New York, Springer-Verlag, p. 8–42.

Votrubec, C., 1982, Coal in Afghanistan: Uhli [Czechoslovakia], v. 30, no. 10, [in Czech, English abstract], available at *http://worldwidescience.org/topicpages/k/kabul+province+afghanistan.html*.

Warren, John, 1999, Evaporites—Their evolution and economics: Malden, Mass., Blackwell Science Ltd., p. 138–140.

West, D., 1942, Final report on the work of the government of India's coal survey party in Afghanistan: Kabul, Afghanistan, Department of Geological and Mineral Survey, [unpaginated].