Chapter 17A. Summary for the Baghlan Clay and Gypsum Area of Interest

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Abstract

This chapter summarizes and interprets the results from the study of the Baghlan clay and gypsum 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 Operations, and the Afghanistan Geological Survey. Accompanying complementary chapters 17B and 17C address hyperspectral data and geohydrologic assessments, respectively, of the Baghlan clay and gypsum AOI. Supporting data and other information for this chapter also are available from the Ministry of Mines, Kabul.

The Baghlan Province is an important region for mining of clay, bauxite, gypsum, limestone, and coal, all of which are important for the production of cement. This report focuses on the clay, bauxite, and gypsum resources in the southwestern part of Baghlan Province, the southeastern part of Samangan Province, and the northeastern part of Bamian Province. Physiographically, Baghlan AOI is a rectangular-shaped 1,800- square-kilometer expanse of mountains and narrow valleys that occupies a position on the southern edge of the Afghanistan Platform. The AOI contains exposures of Paleozoic sedimentary rocks that are overlain in central Baghlan AOI by Triassic, Jurassic, and Cretaceous sedimentary rocks. These rocks, in turn, are overlain by Eocene and Neogene sedimentary rocks. Gypsum, clay, and bauxite deposits are most abundant in the Jurassic sedimentary rocks. Laterite-type bauxite occur deposits are present at Eshpushta (35°18'44"N, 68°06'22"E) and Nalag (35°25'16"N, 68°'09'20"E); gypsum deposits are present at Shoraw (36°03'45"N, 69°08'56"E) and Dudkash (36°00'55"N, 68°47'30"E); and clay deposits are present at Surkhab (35°58'25"N, 68°40'32"E) and Kawkpar (35°56'55"N, 68°52'36"E).

17A.1 Introduction

Clay, gypsum, and bauxite are minerals in the Baghlan clay and gypsum area of interest (AOI) that are considered to have potential economic significance. Figure 17A–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 map represents the AOI at a nominal scale of 1:1,200,000. The AOI is a rectangular expanse of mountains and valleys following the southwest-northeast trending flanks of the Hindu Kush and covering an area of about 1,800 square kilometers (km^2).

The map in figure 17A–2 places the AOI in the context of the neighborhood of provincial districts, and depicts faults, deposits, villages, and roads. Note in figure 17A–2 that the main road follows the river, which in turn flows along the main fault through the AOI, with settlements and known deposits distributed along the main road. In the AOI, a dependable supply of water and the presence of flat land along the river valleys are natural drivers that developed the settlements, as well as caused the inhabitants to focus their artisanal mineral exploration in the valleys rather than in the harsher terrane confining the valleys.

The exploration success along the valley bodes well for the permissiveness of unexplored sedimentary rock in the relatively inaccessible parts of the AOI. The AOI overlaps parts of three districts, one in each of three provinces: Tala wa Barfak, Baghlan Province; Kahmard, Bamiyan

Province; and Ruyi Du Ab, Samangan Province. The valley hosting the village of Tala Wa Barfak, depicted in figure 17A–3, is typical of the physiographic terrane across the AOI.

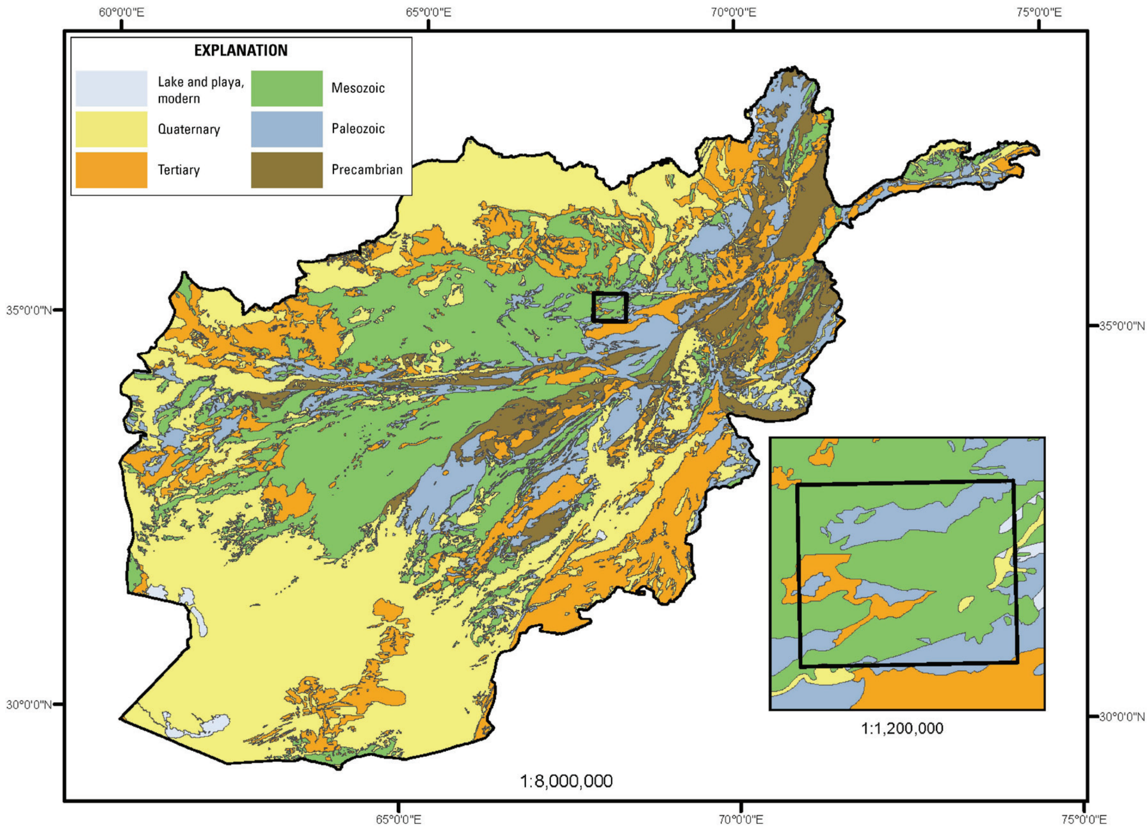

Figure 17A–1. Index map showing generalized geologic rock age and location of the Baghlan clay and gypsum area of interest. (Map from U.S. Geological Survey, Western Mineral and Environmental Resources Science Center, Digital Information and Analysis Project; base maps from Doebrich and Wahl, 2006.)

17A.2 Regional Geologic Setting

The southeastern and northwestern parts of the AOI contain exposed Paleozoic sedimentary rocks that are overlain in the central parts of the AOI by Triassic, Jurassic, and Cretaceous sedimentary rocks (green in fig. 17A–1). These rocks, in turn, are randomly overlain by Eocene and Neogene sedimentary rocks. Triassic granitic plutons and stocks intrude the older rocks in the eastern part of the AOI. Gypsum, clay, and bauxite deposits are most abundant in the Jurassic sedimentary rocks and are associated with coal. Some Eocene sedimentary rocks also contain gypsum (Abdullah and others, 1977). Figure 17A–4 is a highly generalized geologic map showing stratified formations, intrusive rock, faults, deposits, villages, and roads.

17A.3 Bauxite

17A.3.1 Deposit Type

Bauxite is chiefly a ferruginous laterite with an elevated modal proportion of aluminum minerals; as such, bauxite is not a mineral, but a sedimentary rock with minerals in it. It consists mostly of gibbisite ($Al(OH)_3$), boehmite (*gamma*-AlO(OH)), and (diaspore alpha-AlO(OH)). Other minerals include oxides of iron (goethite and hematite), kaolinite, and lesser amounts of anatase (TiO_2). Known bauxite deposits in Afghanistan are of two types, those found in karst and those in laterite; only the laterite type of bauxite deposits are found in the Baghlan clay and gypsum AOI.

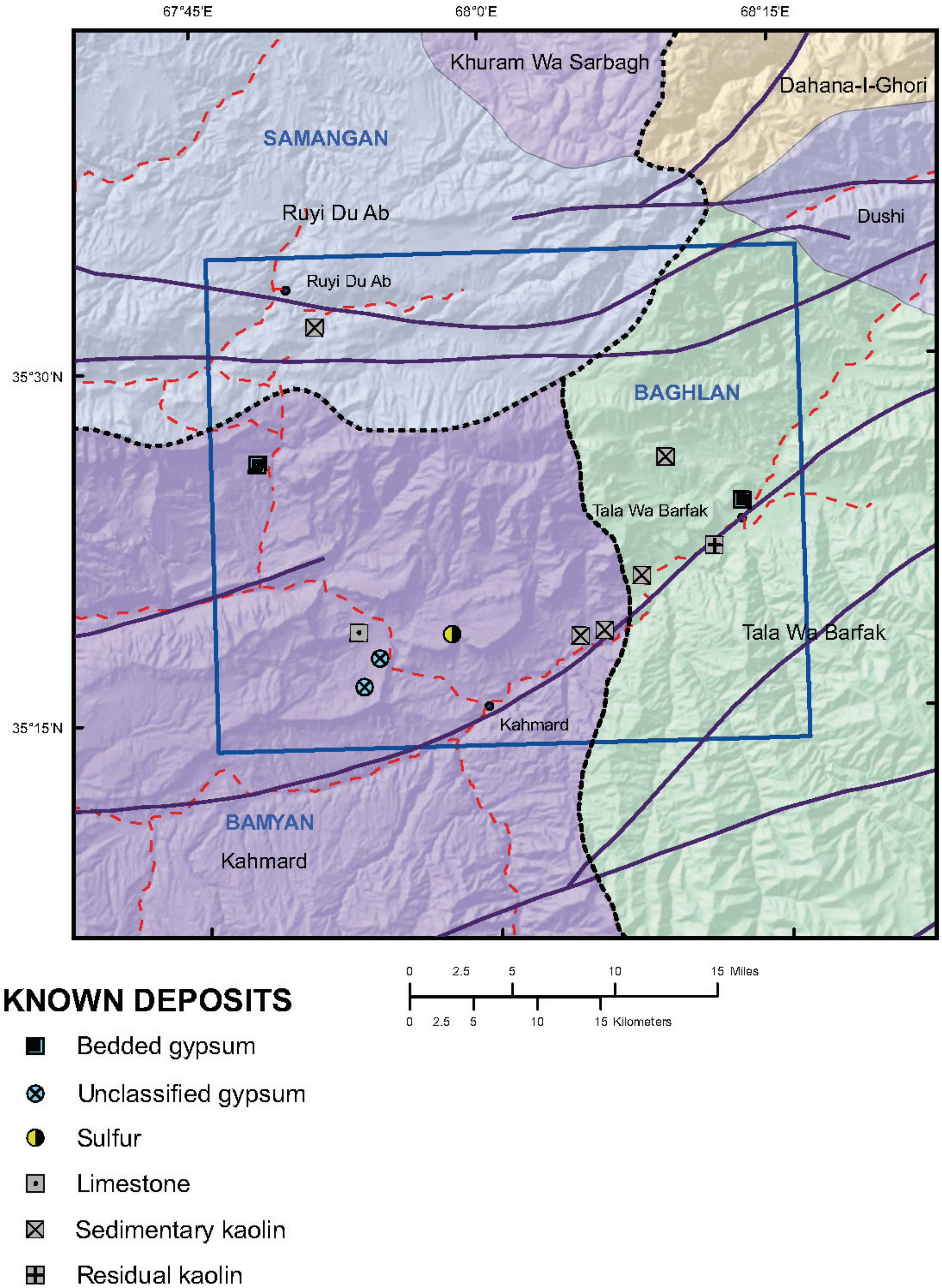

Figure 17A–2. Map of location of the Baghlan clay and gypsum area of interest within the neighborhood of provincial districts, and showing faults, deposits, and villages; roads are shown as dashed red lines (scale, 1:1,500,000). Map from U.S. Geological Survey, Western Mineral and Environmental Resources Science Center, Digital Information and Analysis Project; base maps from Doebrich and Wahl (2006).

17A.3.3 Importance and Economic Expectation of Deposits

The main application of bauxite ore is for the production of aluminum, which is one of the world's most useful and used metals. Aluminum possesses qualities of strength, flexibility, light weight, corrosion resistance, formability, and high conductivity to both heat and electricity. Rapid growth of Asian economies has dramatically increased global demand for aluminum. Although global demand for aluminum is rapidly increasing, known reserves of bauxite ore are currently sufficient to meet the worldwide needs for the near future. Increased aluminum recycling also may extend the world's bauxite supply.

Figure 17A–3. Valley hosting Tala Wa Barfak village, Baghlan Province, from Google Earth ID 45198554.

17A.3.2 Probable Age(s) of Mineralization

Mineralization ages are mainly Cenozoic, but could be older.

17A.3.4 Descriptive Models

Laterite-type bauxite deposits make up the known aluminum ore occurrences in the Baghlan clay and gypsum AOI (Patterson, 1986, model 38b; Freyssinet and others, 2005). Bauxite is an accumulated product of intensive weathering of aluminum silicate rocks with only relatively small amounts of free quartz. The deposits consist of weathered rock formed on aluminous silicate rocks and contain typical lateritic textures, including pisolitic, massive, nodular, and earthy. Bauxite deposits form in tropical and subtropical regions as a constituent of lateritic soils. In bauxite genesis, water is added, silicates are broken down, silica is lost by weathering, and iron is partly removed by organic complexing, resulting in the concentration of alumina, titanium, ferric oxide and, perhaps, manganese oxide in the residue (Jensen and Bateman, 1981). Bauxite deposits typically are found on plateaus in tectonically stable areas. The depositional environment consists of surficial weathering on well-drained plateaus in regions with warm to hot and wet climates. Locally, deposits may be present in poorly drained low energetic areas. The deposits may be overlain by a soil veneer and are usually underlain by saprolite. Mineralogy consists mainly of mixtures of gibbsite and boehmite. Gangue minerals are hematite, goethite, anatase and quartz. The geochemical signature is characterized by elevated concentrations of aluminum and gallium in parts of the lateritic profile. Residual kaolin deposits are generally associated bauxite deposits. Bauxite continues to form in present weathering environments in most deposits. The geochemical signature is characterized by elevated concentrations of aluminum and gallium in parts of the lateritic profile. Residual kaolin deposits are associated bauxite deposits.

17A.3.5 Grade and Tonnage Model

Compilation of grade and tonnage data for laterite-type bauxite deposits has shown that 90 percent of these deposits contain at least 870,000 metric tons (t) of material. The median tonnage is 25 million metric tons (Mt), and 10 percent of deposits contain 730 Mt or more of material (Mosier, 1986). Grades of laterite-type bauxite deposits have a median of 45 percent alumina. About 90 percent of deposits contain 35 percent or more alumina, and 10 percent contain 55 percent or more alumina. Currently available information on the bauxite deposits in the Baghlan clay and gypsum AOI is insufficient to allow a quantitative assessment.

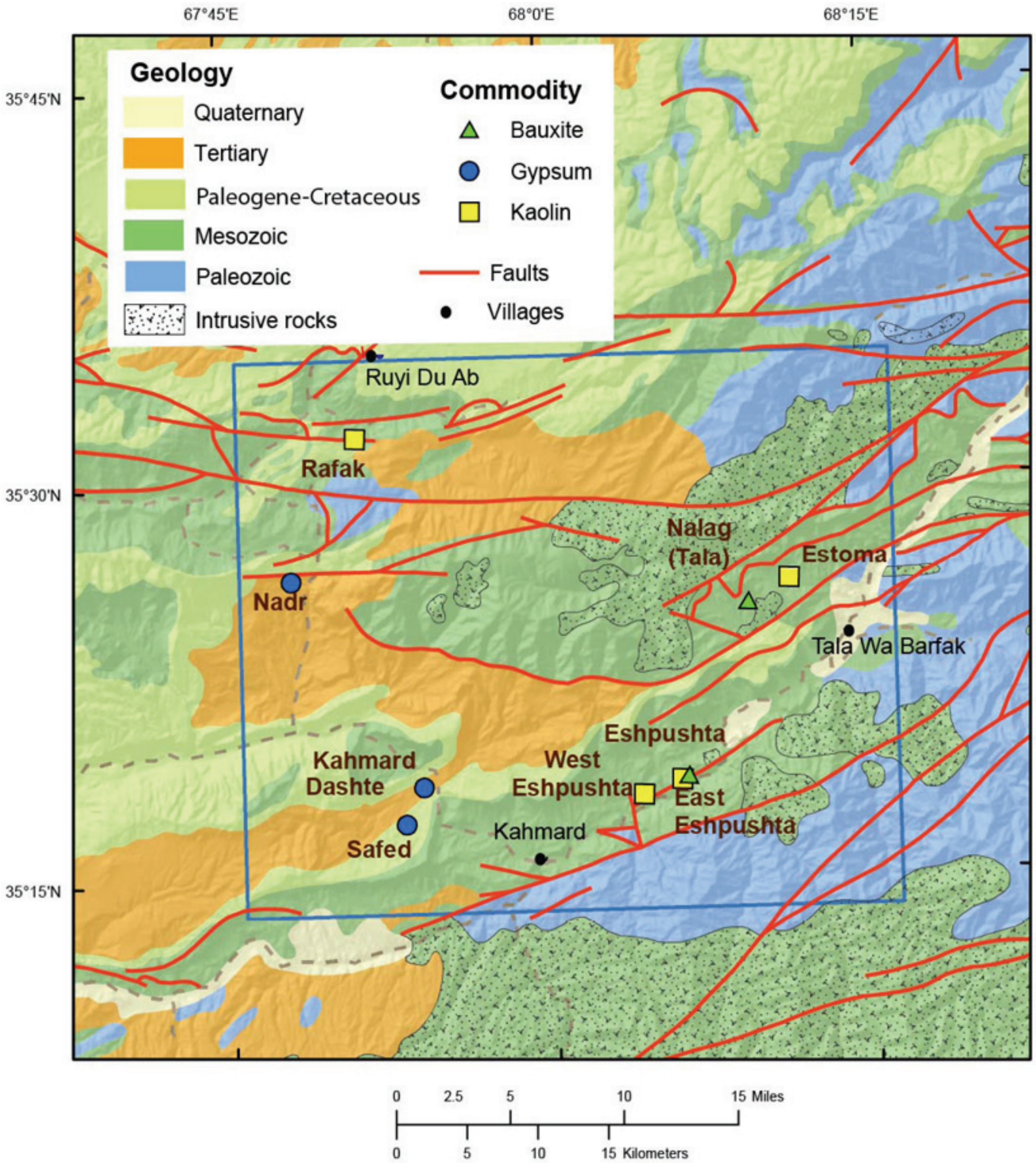

Figure 17A–4. Baghlan clay and gypsum area of interest with highly generalized geologic map units (stratified formation and intrusive rock), faults, deposits, and villages; roads are shown as dashed lines (scale, 1:1,400,000). Map from U.S. Geological Survey, Western Mineral and Environmental Resources Science Center, Digital Information and Analysis Project; base maps from Doebrich and Wahl (2006).

17A.3.6 Exploration History

Preliminary assessments of mineral occurrences and deposits related to surficial processes and unconformities in Afghanistan were conducted by Russian workers (Abdullah and Chmyriov, 1977).

17A.3.7 Known Occurrences and Example Deposits

The Koba Bauxite Project in Guinea, West Africa, is one of the largest bauxite producers in the world, hosting about 30 percent of the global bauxite resources. Three bauxite mines are in operation in the Boke Bauxite Belt, delivering high quality middle Miocene bauxite with grades of 40 to 60 percent alumina. The belt is underlain by gabbro, aluminous dolerite, and sedimentary rocks. A typical profile at Koba consists of up to 1 meter (m) of overburden, 4 to 10 m of hard bauxite (high Al_2O_3 and Fe_2O_3), 4 m of low grade transitional bauxite intercalated with clay, and 5 m of soft bauxite (high Al_2O_3 and kaolin) (Navasota Resources, Ltd., 2008).

17A.3.8 Tract Boundary Criteria

Three laterite-type bauxite deposits have been identified in Afghanistan. These deposits are in Upper Triassic weathered volcanic rocks along the contact between Jurassic carbonaceous sedimentary rocks and weathered Upper Triassic volcanic rocks. Thus, Triassic and Jurassic stratified rocks were identified as those most likely to contain laterite-type bauxite deposits. The tract could be further defined based on the presence of carbonaceous Jurassic rocks associated with Triassic volcanic rocks.

17A.3.9 Deposits and Prospects in AOI

Three laterite-type post Carboniferous bauxite deposits have been identified in Baghlan Province, Afghanistan—Eshpushta, Estoma, and Nalag (Abdullah and others, 1977).

17A.3.9.1 Eshpushta, Baghlan: 35°18'44"N, 68°06'22"E

Light grey, pinkish, and slightly ferruginous bauxite at Eshpushta occurs in Upper Triassic weathered volcanic rocks as a tabular body 300- to 400-m long and 1- to 3-m thick.

17A.3.9.2 Estoma and Nalag (Tala), Baghlan: 35°25'16"N, 68°'09'20"E

At Estoma and Nalag, bauxite is located at the contact between Jurassic carbonaceous sedimentary rocks and weathered Upper Triassic volcanic rocks (Mikhailov and others, 1967; Abdullah and others, 1977). Estoma has four tabular white bodies as much as 70-m long and 2- to 4-m thick. Bauxite is grey, light pink, and oolitic.

17A.3.9.3 Nalag, Baghlan

A total of 10 tabular bauxite bodies as much as 200-m long and up to 4-m thick are present at Nalag. The bauxite is grey, pinkish, and oolitic and grades more than 52 percent alumina, 19 percent silica, and 17 percent iron oxide. Speculative reserves at Nalag are estimated to be 4.5 Mt of bauxite (Mikhailov and others, 1967; Abdullah and others, 1977).

17A.3.10 Optimistic Factors

Although very large deposits are unlikely, geologic conditions are permissive for additional deposits, particularly in similar environments to that which the current deposits formed.

17A.3.11 Pessimistic Factors

Very little information is available about the quality of bauxite, primarily because of the lack of analytical chemical services in Afghanistan. Also, Afghanistan lies in an active tectonic zone and has not experienced low latitude stable weathering.

17A.3.12 Important Data Sources

The main source for information on industrial mineral resources in Afghanistan is the Mineral Information Database soon to be available from the Afghan Geological Survey in Kabul as well as geologic maps and mineral deposit data available in the open literature (Abdullah and others, 1977; Orris and Bliss, 2002; Doebrich and Wahl, 2006).

17A.3.13 Future Work

Further exploration in Jurassic and Upper Triassic rocks for laterite-type bauxite deposits noting newly discovered occurrences would be helpful.

17A.4 Gypsum

17A.4.1 Probable Age(s) of Mineralization

Rocks containing gypsum exposed on the surface are commonly of Late Jurassic to Paleocene, and, less commonly, Neogene age; deeply covered deposits have been dated to Silurian times (Fritz and others, 1988).

17A.4.2 Importance and Economic Expectation

Gypsum ($CaSO_4$ $2H_2O$) is a key component of wallboard, a cost-effective building material; it also is used in cement and agriculture (Harben, 2002). Anhydrite ($CaSO_4$) is the anhydrous form of gypsum. Both minerals may form as primary minerals, but they are easily converted from one to the other (Sharpe and Cork, 2006). Gypsum deposits are distributed throughout much of the world, but as a low unit-value commodity, development of deposits can be sensitive to proximity to market area, transportation and fuel/utility costs, and the availability of water for processing (Sharpe and Cork, 2006). Gypsum demand increases with an expanding national gross domestic product. Most of the currently active gypsum quarries in Afghanistan are mined on a small scale. Larger-scale exploitation uses standard open-pit methods. Gypsum deposits are often spatially associated with other evaporite deposits (Doebrich and Wahl, 2006).

17A.4.3 Descriptive 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. Available information is insufficient to allow a quantitative assessment. An important deposit model associated with bedded gypsum is potash (Raup, 1991; Harben and Kuzvart, 1996). Bedded gypsum deposits occur in large-scale basins and in sabkhas or salt flats.

17A.4.4 Quantitative Assessment

Available information is not sufficient to allow quantitative assessment (Ludington and others, 2007).

17A.4.5 Previous Work and Exploration History

The geology of the district was studied by Soviet geologists on a scale of 1:200,000 during 1963–1965 and again by the Soviets in the 1970s to estimate reserves in the deposits (Mikhailov and others, 1967).

17A.4.6 Exploration Guides

Evaporite basins with thick sequences of halite, saline wells, or springs may indicate salt and gypsum at depth. Gypsum and anhydrite are often vertically or laterally peripheral to halite. Large salt bodies produce negative gravity geophysical anomalies.

17A.4.7 Known Occurrences and Example Deposits

Gypsum is found throughout the world. The Silurian Salina Formation contains gypsum deposits that occur in the Michigan and Appalachian Basins of New York, and in Pennsylvania, West Virginia, Ohio, and Michigan. Gypsum is a major evaporite in the Paris Basin, France, and gypsum of probable Jurassic age is present at Gaurdak in Turkmenistan. Additional occurrences in Afghanistan include the

Neogene Surkh-Rod deposit in Nangarhar Province and the Late Jurassic Shoraw and Dudkash deposits in Baghlan.

17A.4.7.1 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.

17A.4.7.2 Dodkash Gypsum, Baghlan Province, 36°00'55"N, 68°47'30"E

This occurrence consists of massive gypsum beds 1.5- to 2.0-m wide and up to 6-m thick, which occasionally extend for 12 km in Upper Jurassic clay, siltstone, sandstone, and dolomite. The gypsum has the following chemical composition 99.37 weight percent (wt. %) $CaSO_4.2H_2O$, 0.2 wt. % SiO_2, 0.58 wt. % $A1_2O_3$, 0.12 wt. % Fe_2O_3, 33.34 wt. % CaO, 0.14 wt. % MgO, 52.96 wt. % SO_4, 44.08 wt. % SO_3, and 20.50 wt. % loss on ignition.

17A.4.8 Tract Boundary Criteria

Afghanistan is endowed with abundant and widely dispersed potential sources of gypsum that would be sufficient for the needs of local industry. The permissive tract for gypsum delineated using the digital geologic map of Afghanistan (Doebrich and Wahl, 2006). The tract, shown in figure 17A–5, consists of map units that have gypsum identified as a major or dominant component. Gypsum-bearing rocks of all ages are combined in this tract, because information is lacking 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.

Cursory inspection of figure 17A–5 reveals three map-unit associations relating lithological age to tectonic terranes, including the following:

- Maestrichtian-Paleocene age lithologies located north of the Herat fault system, defined by the central region of the North Afghanistan Platform;
- Eocene lithologies identified along a southwest-to-northeast trending zone defined by the complex that includes the Helmand, the Kabul, and the Nuristan blocks and the Tirin-Arghandab accretionary zone, and
- Late Pliocene lithologies associated with the Panjao Suture separating the Farad and Helmand blocks.

These associations are consistent with the generalized tectonic model for Afghanistan as reviewed in chapter 16A §16A.1.1 of this report.

17A.4.9 Deposits and Prospects in the Area of Interest

There are abundant, widely dispersed potential sources of gypsum in Afghanistan that would be sufficient for the needs of local industry.

17A.4.9.1 Nadr, Bamiyan Province, 35°26'25"N, 67°48'02"E

A 12-m-thick bed containing 89 percent gypsum occurs in Upper Cretaceous-Paleocene dolomite, clay, and limestone which crop out from beneath Eocene deposits.

17A.4.9.2 Kahmard, Bamiyan Province, 35°18'32"N, 67°54'E

Beds consisting of massive gypsum, up to 2.5-m thick, and stratified gypsum, 20- to 40-cm thick, have been found in Upper Cretaceous-Paleocene clay and dolomite. The total thickness of the gypsum unit is 20 m and the average gypsum content is 98 wt. %.

17A.4.9.3 Dashte Safed, Bamiyan Province, 35°17'09"N, 67°53'08"E

Stratified gypsum 30-m thick, occurs in Upper Cretaceous-Paleocene clay and limestone.

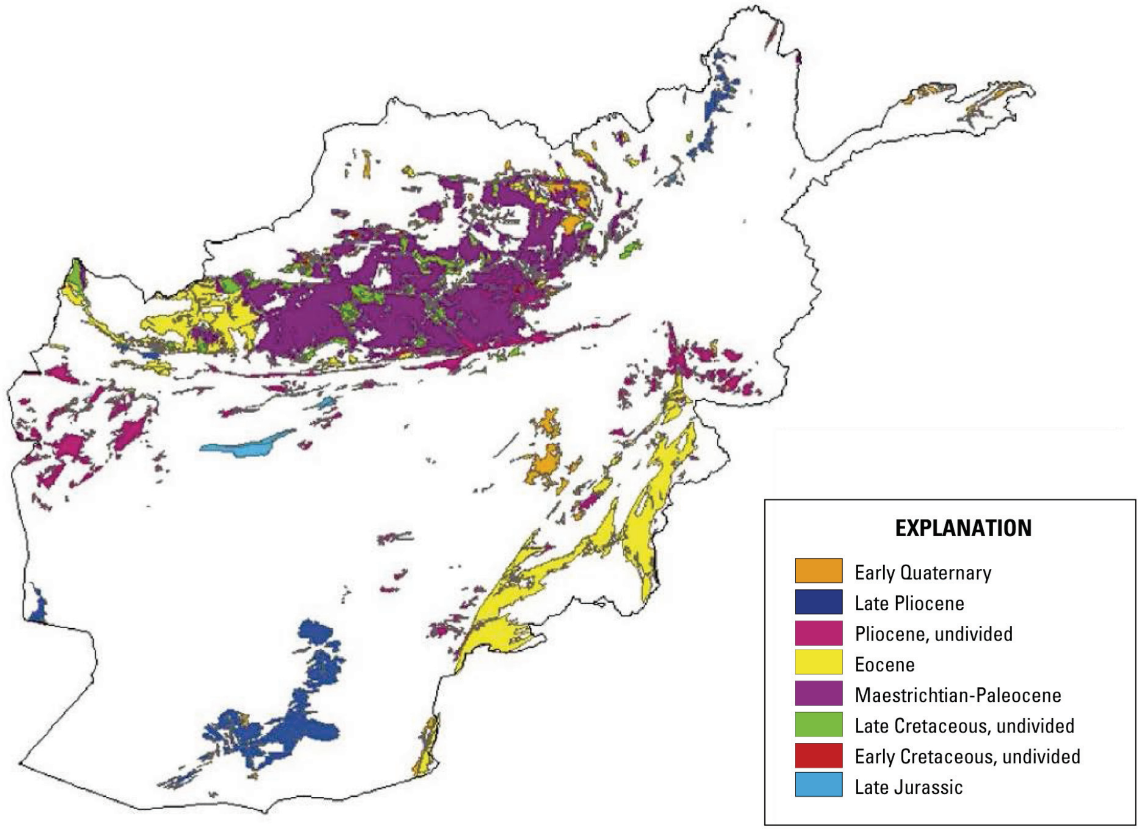

Figure 17A–5. Map of area considered permissive for the occurrence of gypsum (tract AFGy-01). Map from Peters and others (2007, p. 411), revised by U.S. Geological Survey, Western Mineral and Environmental Resources Science Center, Digital Information and Analysis Project; base maps from Doebrich and Wahl (2006).

17A.4.10 Future Directions

Information about chemical and physical properties of gypsum within known deposits, as well as confirmation of the age and mode of occurrence of different gypsum deposits, would be helpful when quantifying gypsum resources. Collecting this data would require site visits.

17A.4.11 Optimistic Factors

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

17A.4.12 Pessimistic Factors

There is no information available on the consistency of the gypsum in terms of chemical or physical characteristics across gypsum outcrops of any given age.

17A.5 Clay

17A.5.1 Mineralization

Three or four main groups of clays are present, the number depending on the scholarly source, with about 30 different types of pure clays in these categories. The three categories of clays considered by the U.S. Geological Survey-Afghanistan Geological Survey Assessment Team were brick and refractory clays, porcelain, and adobe-brick clay. Heat resistant (refractory) clays with melting points about 1,600 degrees Celsuis (°C) are known as fire clay (Theng, 1979). The dominant clay species are montmorillonite, bentonite, illite, and kaolinite. Montmorillonite is the main constituent of bentonite, which usually forms from weathering of volcanic ash. For industrial purposes, two main classes of bentonite are sodium bentonite and calcium bentonite. Potassium bentonite, a minor class, is commonly referred to as illite. The clays are mainly associated with sedimentary clay-rich zones in Mesozoic and Cenozoic strata.

17A.5.2 Importance and Economic Expectation

The primary clay mineral of interest is kaolinite ($Al_2Si_2O_5(OH)_4$) (Deer and others, 1992). Kaolinite occurs in abundance in soils that have formed from the chemical weathering of rocks in hot, moist climates. Rocks that are rich in kaolinite are known as white clay. Kaolinite-dominated clays are typically associated with coal. Kaolin is used in ceramics, medicine, toothpaste, cosmetics, coated paper, as a food additive, and as a light-diffusing material in white incandescent light bulbs. It is generally the main component in porcelain. It is also used in paint to extend titanium dioxide (TiO_2) and modify gloss levels; it is also used in rubber and in adhesives to modify rheology. Much of bentonite's usefulness is for drilling muds because of its rheological properties. Bentonite sub-classes are also used in ceramics.

17A.5.3 Descriptive Model

Clay minerals are naturally occurring aluminum phyllosilicates. A wide variety of clay types occurs in nature, all mostly consisting of a mix of fine-grained minerals with a lesser amount of organic material. Clay minerals are typically formed over long periods by the gradual chemical weathering of silicate rocks, usually by low concentrations of carbonic acid (Velde, 1995). In addition to the weathering process, some clay minerals are formed by hydrothermal activity. 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. Clay deposits are typically associated with very low energy depositional environments, such as large lakes and marine deposits in Mesozoic and Cenozoic strata. 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.

17A.5.4 Grade and Tonnage Model

Available information is insufficient to allow a quantitative assessment.

17A.5.5 Known Occurrences and Example Deposits

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 kaolins associated with coal, little information is available about the composition of the clays.

17A.5.5.1 Karukh, Herat Province, 34°30'N, 62°34'40"E

The deposit consists of Quaternary clay applicable for brick manufacture. The clay is being worked.

17A.5.5.2 Maluma, Herat Province, 34°29'N, 62"44'E

The area is underlain by Quaternary clays varying in lime content and rich in silty and sandy material.

17A.5.5.3 Surkhab Clay, Baghlan Province, 35°58'25"N, 68°40'32"E

A bed of Neogene clay is used as an additive in cement production.

17A.5.6 Deposits and Prospects in Area of Interest

Figure 17A–6 is a map showing the permissive area for brick clay in the AOI (Permissive Tract J12ssl). The following deposits have been worked in the AOI.

17A.5.6.1 Kawkpar Clay, Baghlan Province, 35°56'55"N, 68°52'36"E

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

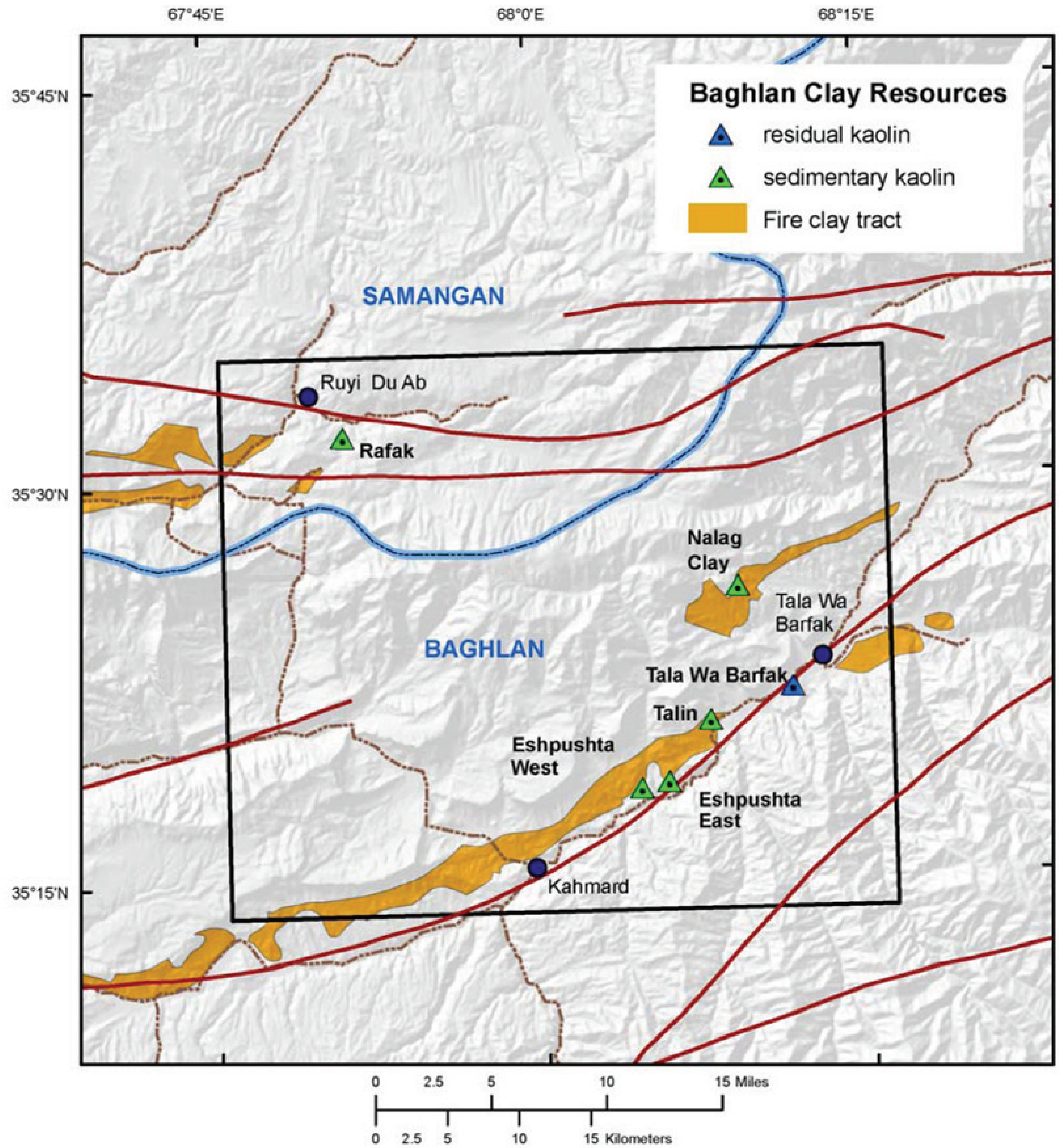

Figure 17A–6. Map of area considered permissive for the occurrence of brick-clay in the area of interest (tract J12ssl); roads are shown as brown dotted lines. Map from U.S. Geological Survey, Western Mineral and Environmental Resources Science Center, Digital Information and Analysis Project; base maps from Doebrich and Wahl (2006).

17A.5.7 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 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. Most of the clays used in preparation of adobe bricks are the product of pedological and not geologic processes.

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