Chapter 23A. Summary of the North Herat Area of Interest

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Abstract

This chapter summarizes and interprets the results from this study of the North Herat area of interest (AOI) and its subareas. Joint geologic and compilation activities were conducted during 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 23B and 23C address hyperspectral data and geohydrologic assessments, respectively, of the North Herat AOI. Additionally, supporting data and other information for this chapter are available from the Ministry of Mines in Kabul.

The AOI, located north of the city of Herat in western Afghanistan, forms a polygon in the shape of a boot with 9,684 square kilometers in the main segment (limestone) elongated to the northwest, and 2,630 square kilometers in the limestone-clay subarea extending to the east. Additional deposit types found in the AOI include bedded barite, vein barite, marble, brick clay, and iron skarn. The North Herat area is underlain by a northwest-trending geochemical halo anomaly (70 kilometers long and 20-30 kilometers wide), located along a northern strand of the Herat fault. A cluster of vein and bedded barite deposits in the Herat area are hosted in terrigenous Paleogene sedimentary rocks. There are six documented barite occurrences in the AOI within the northwest-trending geochemical anomaly following the northern strand of the Herat fault. The largest barite and gypsum deposit is the Sangilyan deposit, which covers an area of more than 3 square kilometers, is hosted in Eocene to Oligocene volcanic and sedimentary rocks, and contains three mineralized zones. Three limestone areas have been investigated as a source of limestone for a possible cement plant east of the city of Herat. Clay occurrences are present in the eastern subarea within a Cenozoic basin where the Karoku and Malumart clay deposits are found. Two iron skarn occurrences lie on the western side of the Herat AOI.

23A.1 Introduction

Bedded barite, vein barite, chemical limestone, marble, brick clay, and iron skarn contain minerals of potential economic significance in the area of interest (AOI). The U.S. Geological Survey/Afghanistan Geological Survey assessment team identified an extended narrow east-west zone as being a likely tract for lead and zinc deposits and for the occurrence of epigenetic barite deposits (Peters and others, 2007). The zone is located north of–and adjacent to–the Herat fault complex extending for about 500 km across Afghanistan (see chapter 16A, figure 16A–2). Two main deposit clusters are present along the zone: the Farenjal area near the eastern end of the zone in Parwan Province, and the Herat area at the western end. The somewhat smaller Kushk bedded barite near the Haji Gak iron deposit lies in Ghor Province in the central part of the fault zone. The Northern Heart AOI addresses the vein and bedded barite occurrences in Herat Province the west.

The Northern Heart AOI intersecst the following districts: Gulran, Kushk, Khosan, Zinda Jan, Injil, Herat, Karukh, Kushki Kuhna, Obe, and Pashtun Zarghun. Figure 23A–1 shows the perimeter of the North Herat AOI on a generalized geologic map where colors indicate the age of the exposed geologic units. Most of the surface rocks are primarily of Tertiary age. Deposit types of economic interest and locations are shown in figure 23A–2, along with the AOI and its neighboring provincial districts.

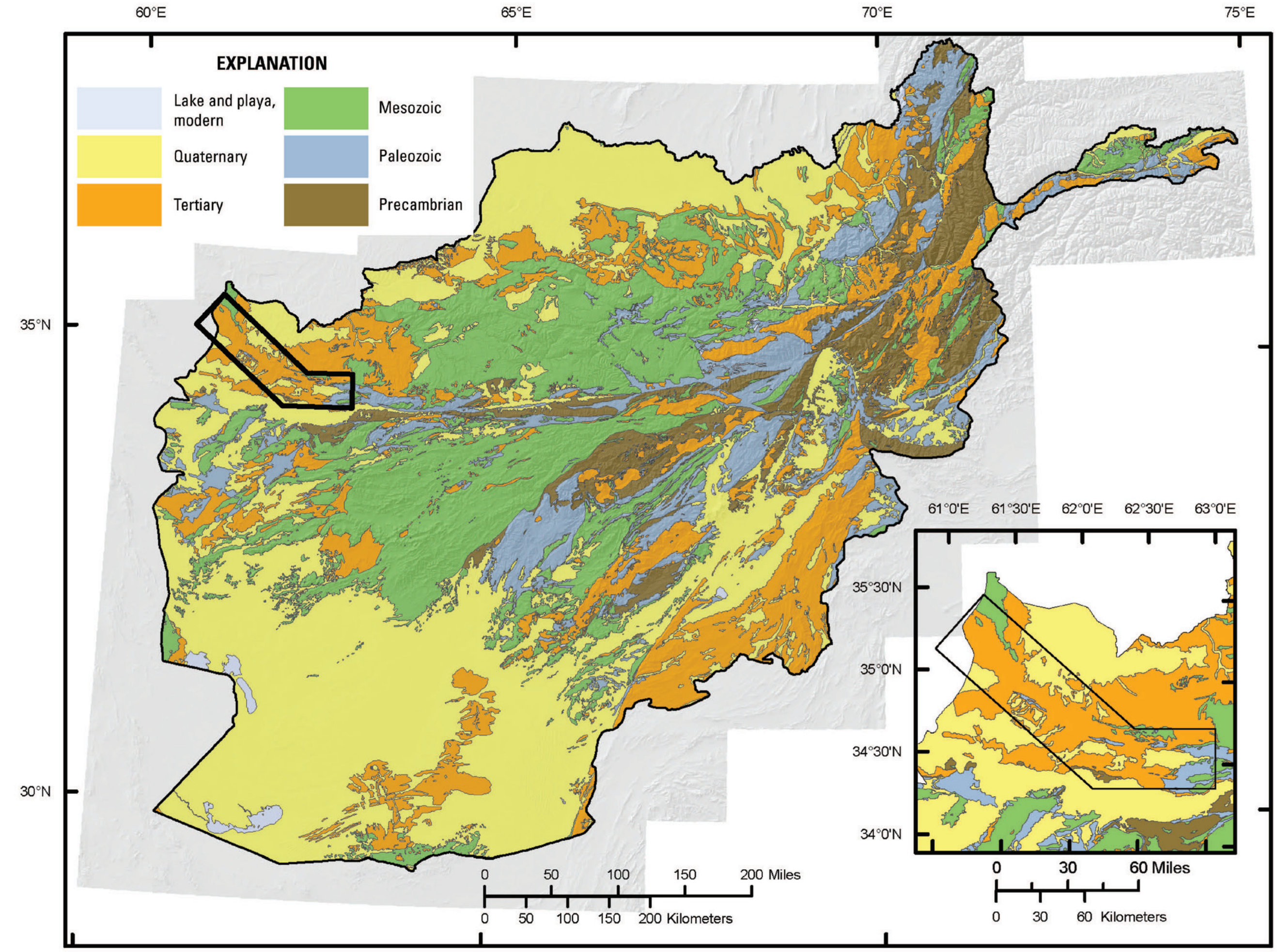

Figure 23A–1. Index map showing generalized geologic rock age and location of the Herat-Barite area of interest.(Map from U.S. Geological Survey, Western Mineral and Environmental Resources Science Center, Digital Information and Analysis Project; base maps from Doebrich and Wahl, 2006.)

23A.2 Barite

Barite occurs in a variety of depositional environments, and is deposited by processes including biogenic, hydrothermal, and evaporative (Hanor, 2000). Barite commonly occurs in lead and zinc veins in limestones, in hot spring deposits, and with hematite ore. It is often associated with the minerals anglesite and celestine. It has also been identified in meteorites (Rubin, 1997). About 77 percent of world demand for barite is for use as a weighting agent for drilling fluids in oil and gas exploration to suppress high-pressure formation and to prevent blowouts. The deeper the hole, the more barite is needed as a percentage of the total drilling-mud mix. An additional benefit of barite is that it is nonmagnetic and thus does not interfere with magnetic measurements taken in the borehole (Miller, 2009). Other uses include filler in paint and plastics, sound reduction in engine compartments, automobile finishes for smoothness and corrosion resistance, radiation-shielding cement, glass ceramics, and medical applications (for example, barium is taken before a contrast CAT scan) (Miller, 2009).

23A.2.1 Bedded Barite and Vein Deposit Models

Stratiform barite deposits consist of barite interbedded with dark-colored cherty and calcareous sedimentary rock, shale, mudstone, limestone or dolostone, quartzite, argillite, or greenstone. Deposits range in age from Proterozoic to Paleozoic. The depositional environment of the host rocks includes epicratonic marine basins or embayments (often with smaller local restricted basins)(Peters and others, 2007, p. 304). The tectonic setting of the deposits is in hinge zones controlled by syndepositional faults. The deposits are spatially proximal to many sedimentary exhalative zinc and lead deposits (Peters and others, 2007, p. 304). Mean tonnage for bedded barite deposits in the AOI is 1.24 million metric tons (Mt) and the mean grade is 52.7 weight (wt.) percent barite. Barite vein deposits contain a mean tonnage of 110,000 metric tons (t) and a mean grade of 60 percent barite (Peters and others, 2007, p. 304).

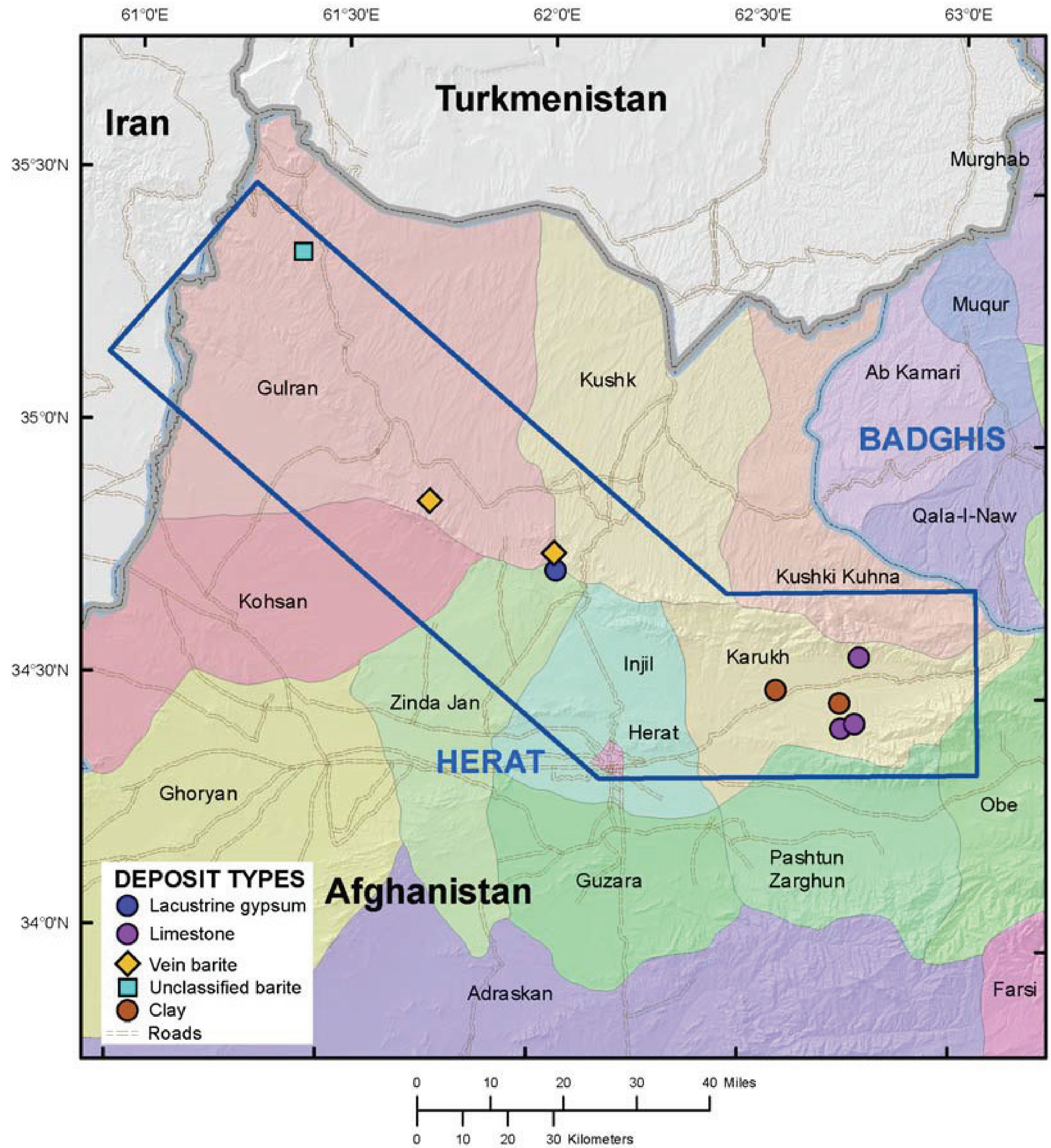

Figure 23A–2. Map showing mineral occurrences and location of the Herat-Barite area of interest within the neighborhood of provincial districts at a scale of 1: 1,500,000. Map from U.S. Geological Survey, Western Mineral and Environmental Resources Science Center, Digital Information and Analysis Project; base maps from Doebrich and Wahl (2006).

The ore mineralogy of barite vein deposits consists of barite with minor amounts of witherite, pyrite, galena, or sphalerite (Orris and Bliss, p. 62). Barite typically contains less than 10 percent organic matter plus some hydrogen sulfide in fluid inclusions (Miller and others, 1977). Ore textures are stratiform, commonly lensoid to poddy, with ore laminated to massive, and with layers of barite nodules or rosettes (Peters and others, 2007, p. 304). Barite may exhibit primary sedimentary features. Small country rock inclusions may show partial replacement by barite. Alteration is typified by secondary barite veining and weak-to-moderate sericitization may also be present. Weathering is indistinct, generally resembling limestone or dolostone. Occasionally, weathered-out rosettes or nodules are present. A geochemical signature consists of elevated barite, and, where peripheral to sediment-hosted zinc and lead, it may have lateral copper-lead-zinc-barite zoning or regional manganese haloes. Organic carbon content is usually high. Many of the barite occurrences and deposits in Afghanistan are crosscutting and are clearly vein-type deposits.

23A.2.2 Known Occurrences and Example Deposits

The Ferenjal barite area in Ghor province represents an important example of barite associated with lead and zinc mineralization. The Ferenjal barite zone contains six barite occurrences that are hosted in Ordovician sedimentary rocks. The main Ferenjal barite occurrence lies in Ordovician brecciated limestone, and consists of barite-bearing bodies with lead- and zinc-disseminated mineralization over an area that contains 16 fine-grained barite lenses that are 10 to 70 meters (m) long and 1 to 9 m wide and grade 84 wt. percent barite. The lead and zinc mineralization is proximal with the barite in the brecciated limestone and in an area 500 m long, 100 m down dip, and 10 to 40 m thick. There are ancient workings in the area and the speculative resources are about 200,000 t of barite and 25,000 to 30,000 t of combined lead and zinc (Kazak and others, 1965). Also in the Ferenjal area, the northern Farenjal occurrence is hosted in Ordovician massive and bedded limestone, and composed of a 200-m-long barite vein, 2 m thick, and with a grade of approximately 97 wt. % barite. The occurrence is hosted in Lower Quaternary brecciated limestone and contains six fragmental barite-bearing zones over an area of 305 square kilometers (km^2). Additional unnamed occurrences are located in Ordovician brecciated limestones.

23A.2.3 Tract Delineation and Boundary Criteria

The map in figure 23A–3 shows the permissive tract for undiscovered barite deposits along the Herat fault within the North Herat AOI; locations of barite occurrences in the area are also shown. The northwestern-trending tract is underlain dominantly by Tertiary sedimentary and volcanic rocks interpreted to be a tectonized zone along splays of the Herat fault. The spatial distribution of geochemical anomalies is also used for tract delineation.

23A.2.4 Deposits and Prospects

The four most significant barite occurrences in the AOI are located in the Herat area. The AOI is underlain by a northwest-trending geochemical halo anomaly [70 kilometers (km) long and 20 to 30 km wide) along a northern strand of the Herat fault.

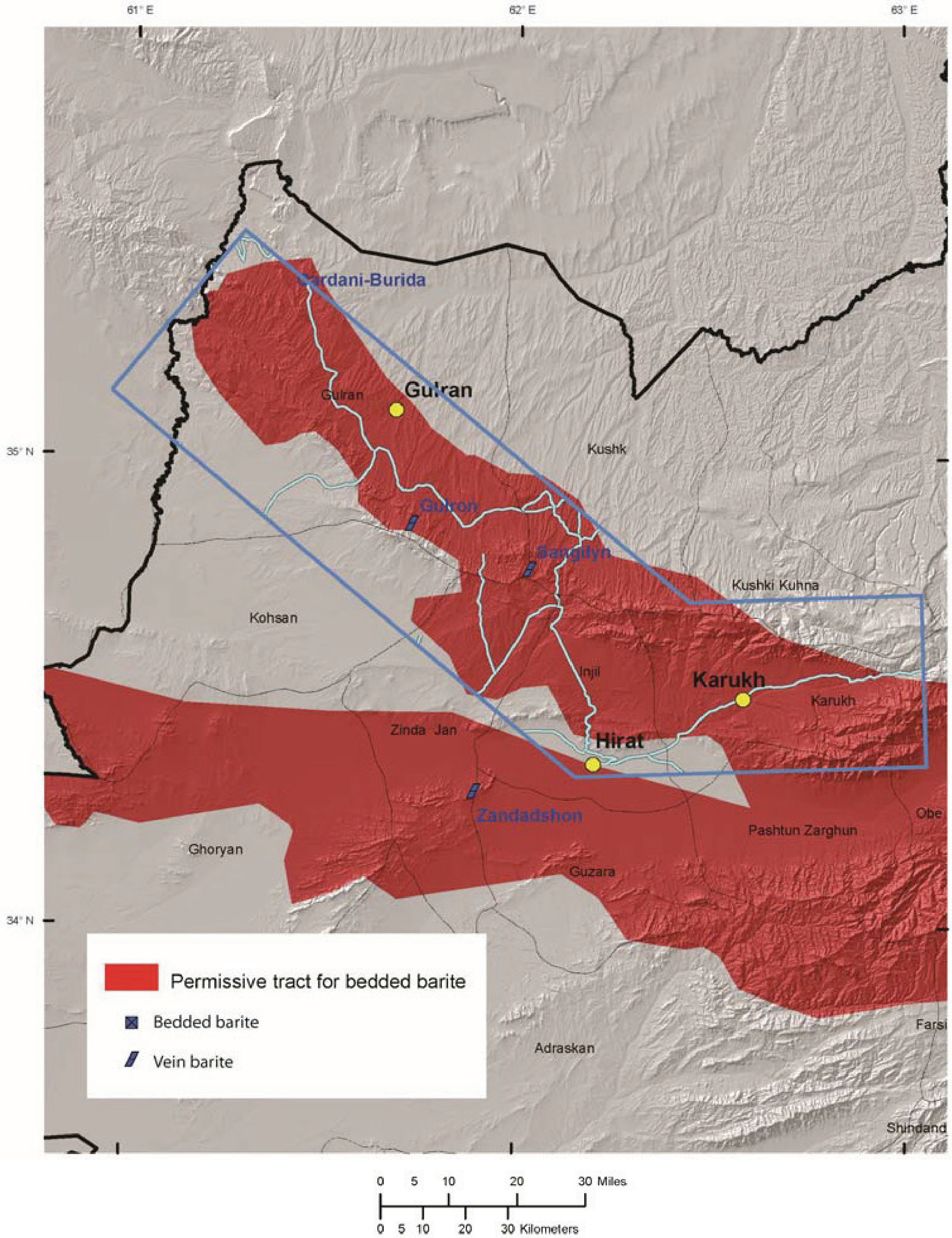

Figure 23A–3. Permissive tract for undiscovered bedded barite deposits and location of barite occurrences in the North Herat area of interest. Map from U.S. Geological Survey, Western Mineral and Environmental Resources Science Center, Digital Information and Analysis Project; base maps from Doebrich and Wahl (2006).

23A.2.4.1 Sangilyan Deposit

The largest prospect is the Sangilyan occurrence, which covers an area of more than 3 km^2, and is hosted in Eocene to Oligocene volcanic and sedimentary rocks and contains three mineralized zones. Each of the zones is up to 2,500 m long and 200 to 700 m wide and is characterized by 24 major and numerous minor fracture-filled barite veins that are 70 to 1,000 m long and 0.4 to 5.7 m thick. A number of different barite types are present, including: monomineralic, coarse-crystalline barite that is 0.5 to 5.5 m thick and grades 80 to 98.6 wt. percent barite; fine-grained barite, present along chilled contacts between the enclosing veins and host rock, that is 0.1 to 0.7 m thick and grade 75 to 94 wt. percent barite; coarse-grained mixtures of barite and calcite; barite with fault breccia; and disseminated barite. Vertical zoning is present in some of the monometallic coarse-crystalline barite veins where the surface 50 to 100 m grades downward to coarse-grained barite and calcite and then to calcareous barite grading 10 to 60 wt. percent barite. The barite veins are usually monomineralic and also may contain witherite, galena, sparse-disseminated chalcopyrite and pyrite, as well as small quartz crystals, calcite, malachite, and limonite. Resources calculated for the deposit are 1.493 Mt of barite, and the mine was active in 1977 (Abdullah and others, 1977).

23A.2.4.2 Gardani-Burida Prospect

Barite occurrences near the city of Herat are the Gardani-Burida prospect hosted in terrigenous Paleogene sedimentary rocks; the prospect contains five milky-white to pink coarse- to fine-grained, lenticular barite-bearing bodies that are 5 to 20 m long and 0.2 to 0.6 m thick (Abdullah and others, 1977).

23A.2.4.3 Gulron Occurrence

This deposit lies within a fault zone (30–700 m long and 0.15–0.7 m thick) that cuts Eocene sedimentary rocks. The occurrence contains 8 barite veins with transparent Iceland spar crystals that are 10 by 20 centimeters in size, 15 barite-calcite veins, and 2 calcite veins. The barite veins assay 80 to 95.5 weight percent (wt. %) barite and the barite-calcite veins grade 12 to 26 wt. % barite (Abdullah and others, 1977).

23A.2.4.4 Zandadshon Deposit

This prospect is located along the Herat fault zone in Proterozoic, Cambrian, and Middle to Upper Jurassic rocks, and is 20 to 90 m long with 0.05 to 1.60 wt. percent barite.

23A.3 Limestone

Limestone is generally defined as a carbonate rock containing greater than 50 percent calcite and (or) dolomite, with calcite predominating. Dolomite, which is a carbonate rock as well as a mineral, is composed of calcium magnesium carbonate. Dolomite rock, also referred to 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). The following minerals form epitaxial relationships with dolomite: siderite ($FeCO_3$), rhodochrosite ($MnCO_3$), calcite ($CaCO_3$), and antigorite $[(Mg,Fe^{2+})_3(Si_2O_5)(OH)_4]$. Subordinate amounts of dolostone or marble are not differentiated among carbonate rock units on the geologic maps utilized for this report; they are assumed to be locally present within the limestone units. Limestone deposits of all ages exist from Precambrian to Recent.

23A.3.1 Importance and Economic Outlook of Deposits

Limestone is an extremely versatile commodity that is typically available at a fairly low cost. Limestone, when its value is associated with the chemistry of the rock, is the most important component in cement. 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). Crushed limestone (industrial grade) is used for aggregate, concrete, ballast, and fill.

A significant use of limestone, and perhaps the application with the greatest aesthetic appeal, is when its value is associated with the physical properties of the rock. Typically such properties include strength, resistance to staining, and resistance to weathering. This application is most commonly witnessed where limestone has been fabricated into standardized building stone and used for buildings and monuments of all sizes and scales. The demand for limestone normally increases with increasing gross domestic product. Most currently active limestone quarries in Afghanistan are mined on a small scale and provide building stone for local markets; larger operations would use standard open-pit mining methods.

23A.3.2 Deposit Models

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). Available information is insufficient to allow a quantitative assessment of the grade and tonnage model.

23A.3.3 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 specific to limestone deposits, especially information pertaining to quality and potential application of limestone resources.

23A.3.4 Known Occurrences and Example Deposits

Limestone occurrences are widespread in Afghanistan.

23A.3.4.1 Sabz Sangilyan Deposit

This early Carboniferous deposit in Badakshan Province has speculative limestone resources of about 500 Mt (United Nations Economic and Social Commission for Asia and the Pacific, 1995).

23A.3.4.2 Pul-e Khumri Limestone Deposit

The Pul-e Khumri limestone deposit in Baghlan Province (lat 35°58'24"N, long 68°40'56"E) is light colored, thick bedded, and fine crystalline. The deposit consists of Danian-Paleocene limestone beds, 300 to 400 m thick, exposed in the area of several thousand square kilometers. The Paleocene limestone rest on a large Upper Cretaceous limestone deposit; the sequence is described in chapter 16A, section 16A.1.1 The limestone is pure, containing 52 to 53 percent lime, 0.8 to 1.3 wt. percent MgO, and 1.3 wt. percent insoluble residue and is readily available for cement production at Pul-e Khumri.

23A.3.4.3 Dudkash Limestone Deposit

A 30-m-thick limestone bed in Baghlan Province (lat 36°00'40"N, long 69°46'00"E) is interbedded with Jurassic clays and siltstones. The limestone is grey, stratified, compact, and aphanitic. To be used for cement production, additional materials and other chemical agents would be needed.

23A.3.4.4 Dudkash Dolomite Deposit

A 3.9-m-thick dolomite bed in Baghlan Province (lat 36°00'47"N, long 68°47'20"E) occurs in Lower Cretaceous siltstone, limestone, and gypsum units. The rock is almost chemically pure dolomite in composition.

23A.3.4.5 Shine Oghor (Shenivaghur) Mine

This bed of massive black dolomite in Dahana-i-Ghori District, Baghlan Province (lat 35°43'47"N, long 68°33'0"E) is about 1,000 m long and 80 m thick. The deposit appears to have been mined for some time in the past and may currently be active.

23A.3.5 Tract Delineation and Boundary Criteria

Figure 23A–4 shows permissive tracts in the North Herat AOI for clay (brown), bauxite (fuschia), fire clay (red), gypsum (green), and limestone and marble-bearing units (green or violet). The main limestone permissive tract plotted in figure 23A–4 was delineated using knowledge of existing deposits and the digital geologic map of Afghanistan (Doebrich and Wahl, 2006; Ludington and others, 2007). The tract consists of map units where limestone or marble was identified as a major or dominant component. Although limestone of different ages may have differing economic potential, limestone of all ages was combined for the delineation of the bauxite and limestone permissive tract (fig. 23A–4) because information was insufficient to develop criteria for establishing differing probabilities of occurrence in rocks of different ages.

23A.3.6 Deposits and Prospect

A number of limestone and dolomite deposits are present in the North Herat AOI, including the following (United Nations Economic and Social Commission for Asia and the Pacific, 1995):

23A.3.6.1 Darra-i-Chartagh Deposit

This early Triassic deposit in Darra-i-Chartagh, Herat Province (lat 34° 26' 20" N, long 62° 46' 00" E) is more than 5 km long, more than 200 m thick, and is suitable for cement production.

23A.3.6.2 Rod-i Sanjur Deposit

This middle Triassic limestone in Rod-i Sanjur, Heart Province (lat 34° 26' N, long 62° 44' E) is up to 400 m thick.

23A.3.6.3 Benosh-Darrah Deposit

This deposit in Benosh-Darrah, Heart Province (lat 34° 34' 30" N, long 62° 46' 20" E) is cement-grade limestone estimated to host about 12,000 Mt, and is 464 m thick.

23A.3.7 Optimistic Factors

Limestone is widespread and occurs in large masses that could host large deposits. Some limestone has been metamorphosed, and is of higher quality for some uses.

23A.3.8 Pessimistic Factors

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

23A.4 Clay

Environments for clay formation include soil horizons, continental and marine sediments, geothermal fields, volcanic deposits, and weathering rock formations. Most clay minerals form where rocks are in contact with water, air, or steam. Examples of these situations include weathering boulders on a hillside, sediments on sea or lake bottoms, deeply buried sediments containing pore water, and rocks in contact with water heated by magma. All of these environments may cause the formation of clay minerals from preexisting minerals (Klett and others, 2006). Extensive alteration of rocks to clay minerals can produce relatively pure clay deposits that are of economic interest.

23A.4.1 Importance and Economic Expectation

Kaolinite is a clay mineral with the chemical composition $Al_2Si_2O_5(OH)_4$ (Deer and others, 1992). Kaolinite occurs in abundance in soils that have formed from the chemical weathering of rocks in hot, moist climates; 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. 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 to modify gloss levels, and in rubber and in adhesives, to modify rheology.

23A.4.2 Deposit Models

Clay minerals are naturally occurring aluminum phyllosilicates. Although a wide variety of clay types occurs in nature, all clays are primarily composed of a mix of fine-grained minerals with a lesser amount of organic material. These components collectively impart plasticity to wet clay and cause clay to harden when dried or fired in a kiln. Clay minerals are typically formed over long periods of time by the gradual chemical weathering of rocks, usually silicate bearing, and by low concentrations of carbonic acid (Velde, 1995). These reactants, usually acidic, migrate through the weathering rock after leaching through upper-weathered layers. 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.

There are three or four main groups of clays, the number depending on the reference used, with approximately 30 different types of pure clays in these categories. The dominant clay species are montmorillonite, bentonite, illite, and kaolinite. Montmorillonite is the main constituent of bentonite. Bentonite usually forms from weathering of volcanic ash. 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. Much of bentonite's usefulness is for drilling muds because of its unique rheological properties. Bentonite subclasses are also used in ceramics. Heat-resistant (refractory) clays with melting points around 1,600°C are known as fire clay (Theng, 1979). Available information is insufficient to allow a grade and tonnage assessment in Affghanistan.

23A.4.3 Previous Work and Exploration History

The geology and mineral resources of Afghanistan have been summarized by Abdullah and others (1977), Orris and Bliss (2002), Doebrich and Wahl (2006), Peters and others (2007), and Abdullah and Chmyriov (2008). Three categories of clays were considered: brick and refractory clays, porcelain, and adobe brick clay. Much of the information presented here are adaptations from these earlier sources.

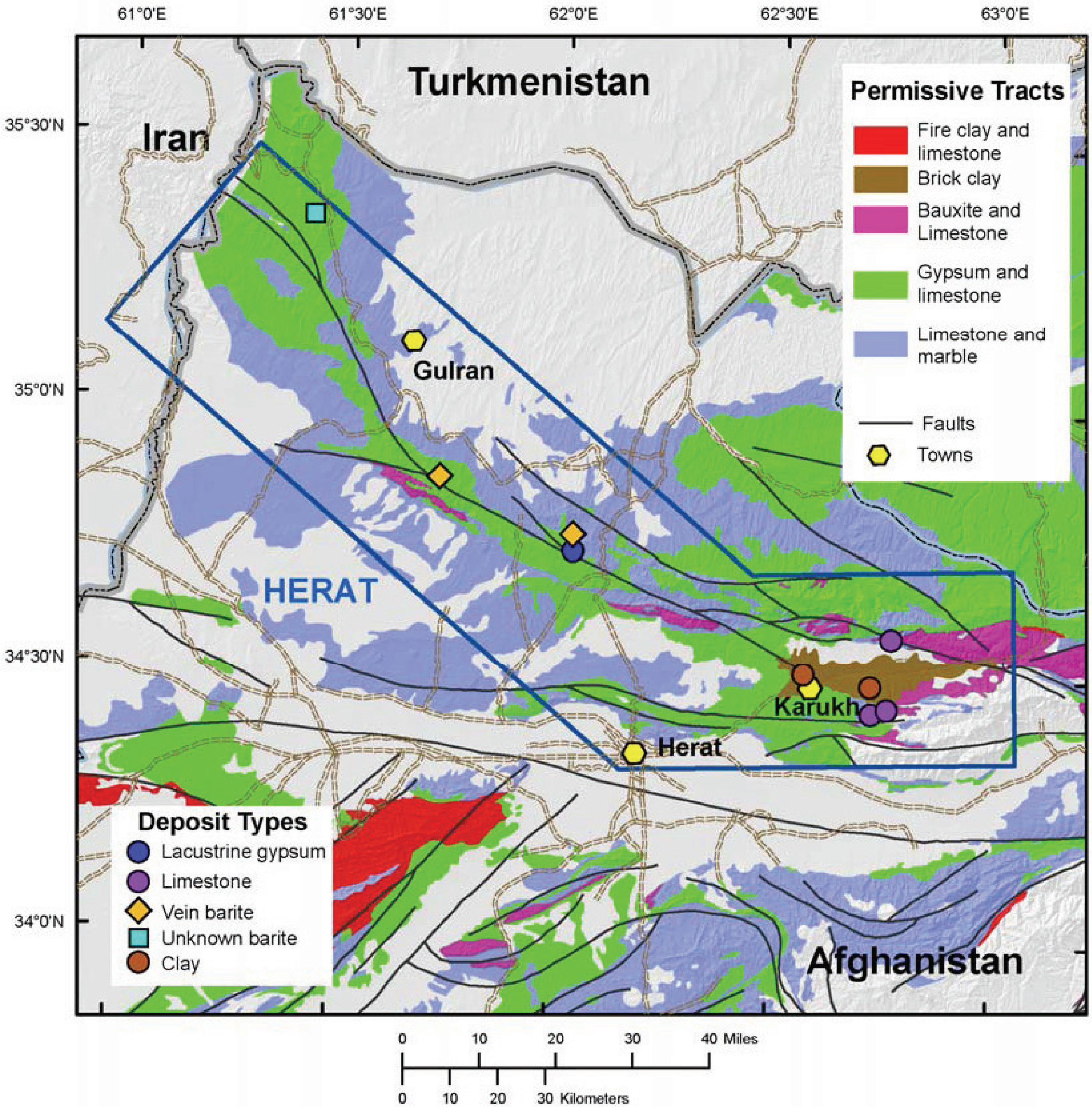

Figure 23A–4. Map showing permissive tracts in the North Herat area of interest. .(Map from U.S. Geological Survey, Western Mineral and Environmental Resources Science Center, Digital Information and Analysis Project; base maps from Doebrich and Wahl, 2006.)

23A.4.4 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 the kaolins associated with the coals, little information is available about the composition of the clays. (Peters and others, 2007, p. xxxiv). Example deposits include the following:

23A.4.4.1 Karukh

The deposit in Karukh, Herat Province (lat 34°30'N, long 62°34'40"E) consists of Quaternary clay applicable for brick manufacture. The clay is being extracted to make bricks for domestic construction (Peters and others, 2007 p. 327).

23A.4.4.2 Maluma

The area in Maluma, Herat Province (lat 34°29'N, long 62°44'E) is underlain by Quaternary clays, varying in lime content and rich in silty and sandy material.

23A.4.4.3 Surkhab Clay Deposit

A bed of Neogene clay in Surkhab, Baghlan Province (lat 35°58'25"N, long 68°40'32"E) is used as an additive in cement production.

23A.4.4.4 Kawkpar Clay Deposit

Clay in 2 to 17-m-thick beds in Kawkpar, Baghlan Province (lat 35°56'55"N, long 68°52'36"E) have been found between Neogene sandstone and conglomerate beds. The clay is lumpy and slightly gypsiferous.

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