



**Prepared in cooperation with the Afghan Geological Survey under the auspices of the  
U.S. Department of Defense Task Force for Business and Stability Operations**

# **Assessment of Bauxite, Clay, and Laterite Deposits in Afghanistan**

Open-File Report 2014–1210  
USGS Afghanistan Project Product No. 197

**U.S. Department of the Interior  
U.S. Geological Survey**



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By Karine M. Renaud, Bruce R. Wardlaw, and Bernard E. Hubbard

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SALLY JEWELL, Secretary

**U.S. Geological Survey**  
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U.S. Geological Survey, Reston, Virginia: 2015

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## Conversion Factors

Multiply	By	To obtain
Length		
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
meter (m)	1.094	yard (yd)
kilometer (km)	0.6214	mile (mi)
Area		
square kilometer (km <sup>2</sup> )	247.1	acre
square kilometer (km <sup>2</sup> )	0.3861	square mile (mi <sup>2</sup> )
Mass		
metric ton (tonne)	1.102	ton, short (ton)

Results of chemical analyses are given in weight percent (wt %) and volume percent (vol %).

## Datum

Horizontal coordinate information is referenced to the World Geodetic System of 1984 (WGS 84).



# Assessment of Bauxite, Clay, and Laterite Deposits in Afghanistan

By Karine M. Renaud, Bruce R. Wardlaw, and Bernard E. Hubbard

## Abstract

Bauxite-bearing rocks are present in several regions of Afghanistan; specifically, the southeast segment of the North Afghanistan Platform, the eastern parts of South Afghanistan, and within the Afghanistan-North and -South Pamir Fold Regions. Bauxite-bearing rocks occur at various stratigraphic levels, in lithologically different sequences of sedimentary rocks. The bauxites are paleosols and represent previous, rather than recent, weathering events. Bauxites and bauxite-type horizons are most common at the base of carbonate rock units, where they form the basal horizons of sedimentary rock sequences separated by erosion and stratigraphic unconformity surfaces. Less common are zones in redeposited weathering developed on igneous rocks. At present there are five known stratigraphic intervals with significant bauxite and bauxite-type deposits and occurrences: the lower Permian, the upper Permian, the Upper Triassic, the Lower Jurassic, and the base of the Upper Jurassic.

This report summarizes a compilation and review of geological data for regions in Afghanistan that contain bauxite deposits and occurrences based on work 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.

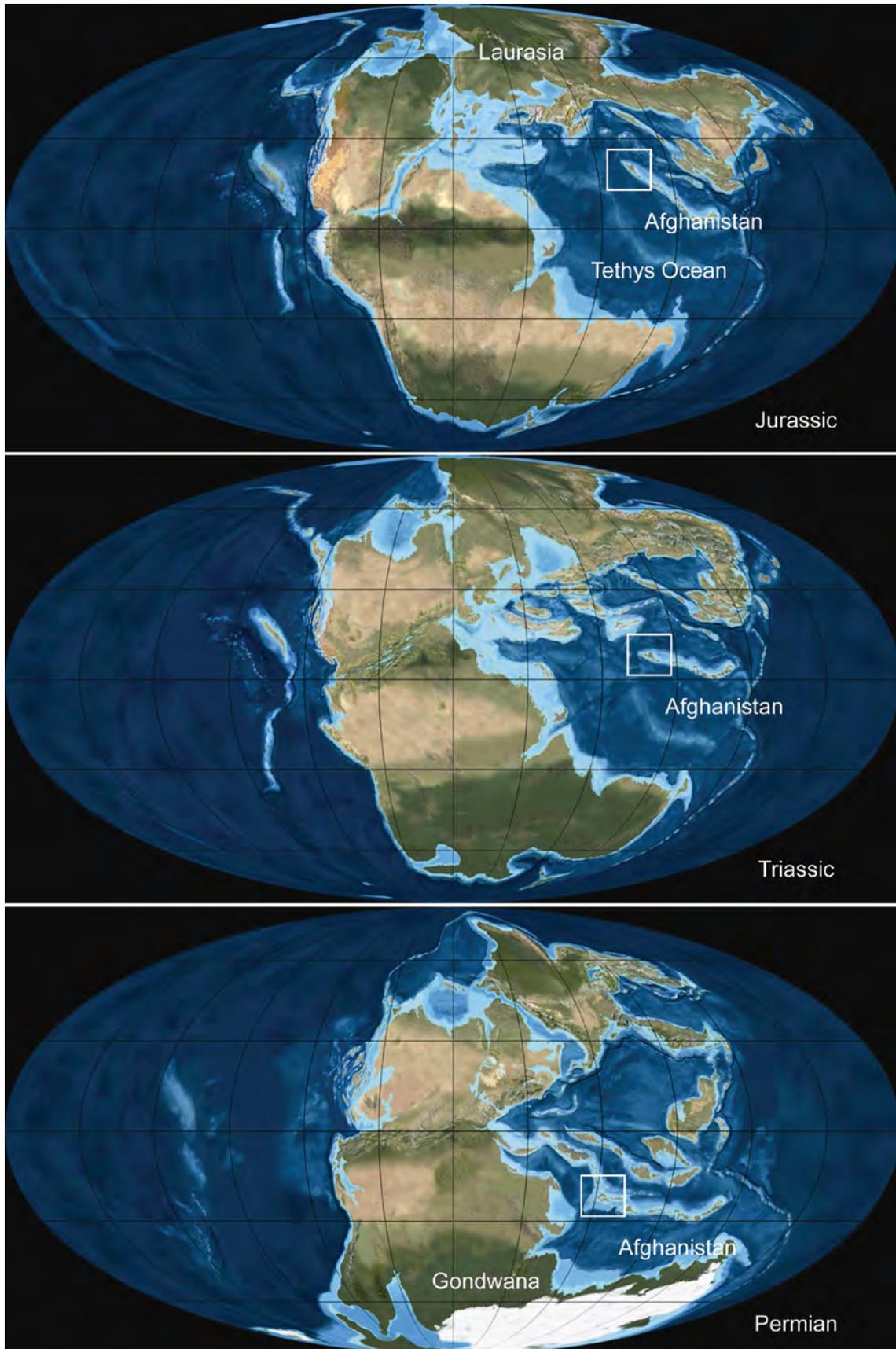
Permian strata contain bauxites and bauxite-like rocks that are recognizable at various stratigraphic intervals within several areas of southern Afghanistan and in the Central Afghan Massif in central Afghanistan. The main zones of known bauxite occurrences are the Haftqala bauxite zone (late Permian and Late Triassic), Shewa bauxite zone (early Permian), Qarghanaw bauxite zone (late Permian and Late Triassic), Arghandab block in Zabul Province (middle through late Permian), Arghandab block in Ghazni Province (early Permian), Surkhob bauxite zone (Early Jurassic), and Tirin block in Uruzgan, Zabul, and Kandahar Provinces (Late Jurassic).

Although some bauxite occurrences were sampled in the course of reconnaissance exploration by Soviet workers in the 1960s and 1970s, the bauxite areas in Afghanistan generally are underexplored. The Obatu Sheila area is a known field of bauxite deposits of Late Jurassic age that had been studied in more detail than other known bauxite deposits and occurrences in Afghanistan. Obatu Sheila has an estimated reserve of 7.2 million tons.

## Introduction

The material summarized in this report is the archival data for bauxite-bearing rock, located in several areas of Afghanistan (fig. 1) and identified by Soviet geologists in the 1960s and 1970s. Aluminum is the third most abundant element in the Earth's crust after oxygen and silicon. It is an important constituent in all clays and soil and of the silicates of common rocks (Jensen and Bateman, 1981). It occurs in nature combined with other elements mostly in silicate minerals, from which it is difficult and expensive to extract.

Bauxite, an ore of aluminum, is a complex and impure mixture of aluminum minerals, chiefly aluminum hydroxides (Patterson and Dyni, 1973). Bauxite is not a product of normal weathering in temperate regions (Jensen and Bateman, 1981). It forms in tropical and subtropical regions as a constituent of lateritic soils. Bauxite is an accumulated product of weathering of aluminum silicate rocks lacking much free quartz. The silicates are broken down, the silica is removed, iron is partly removed, water is added, and aluminum, titanium, and ferric oxide and perhaps manganese oxide become concentrated in the residue (Jensen and Bateman, 1981). The more silica removed, or the more leachable the rock in the deposit, the greater the chance that



**Figure 1.** Maps showing migration of the Cimmerian arc that assembled to form much of Afghanistan (modified from Blakey, 2011).

the deposit will be enriched in aluminum rather than iron. Gibbsite, boehmite, and diasporite are the principal minerals in bauxite. Bauxites are important for production of high-quality abrasives, ceramics, and chemical and refractory products (table 1) (Patterson, 1984).

**Table 1.** Chemical compositions associated with various industrial grades of bauxite.

[—, no data]

Grade	Content, in weight percent			
	Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	Fe <sub>2</sub> O <sub>3</sub>	TiO <sub>2</sub>
Metallurgical	50–55	0–15	5–30	—
Abrasive	Minimum 55	Maximum 5	Maximum 6	Minimum 2.5
Chemical	Minimum 55–58	Maximum 5–12	Maximum 2	—
Refractory	Minimum 59–61	Maximum 1.5–5.5	Maximum 2	Maximum 2.5

## Mineral-Rich Residual Soils of Afghanistan

A residual soil is a concentration of insoluble material that remains after the soluble material is dissolved and removed. There are at least three residual soils that can be of economic value: clays (kaolinite), iron-rich laterite, and bauxite (aluminum ore). In addition, weathering of mineral deposits containing copper, gold, and zinc may also enrich the mineralized areas, making them more metallurgically viable and therefore economically viable. Most important residual soils are formed under tropical, tectonically stable conditions because high rainfall is needed for the intense weathering required to develop clays laterite and bauxite or to develop the solutions that dissolve and remove mineral matter. Afghanistan is far from tropical or tectonically stable today, but much of what is now Afghanistan was in the tropical or subtropical belt from the Permian through the Jurassic (299.0–145.0 Ma). What makes up much of Afghanistan today were parts of the Cimmerian plate (or arc) that broke off from Gondwana by rifting in the Permian and migrated across the Tethys ocean (an ancient tropical ocean) to collide with Laurasia (Eurasia) in the Jurassic (fig. 1). So, the conditions were favorable for development of economic residual soils during this timespan.

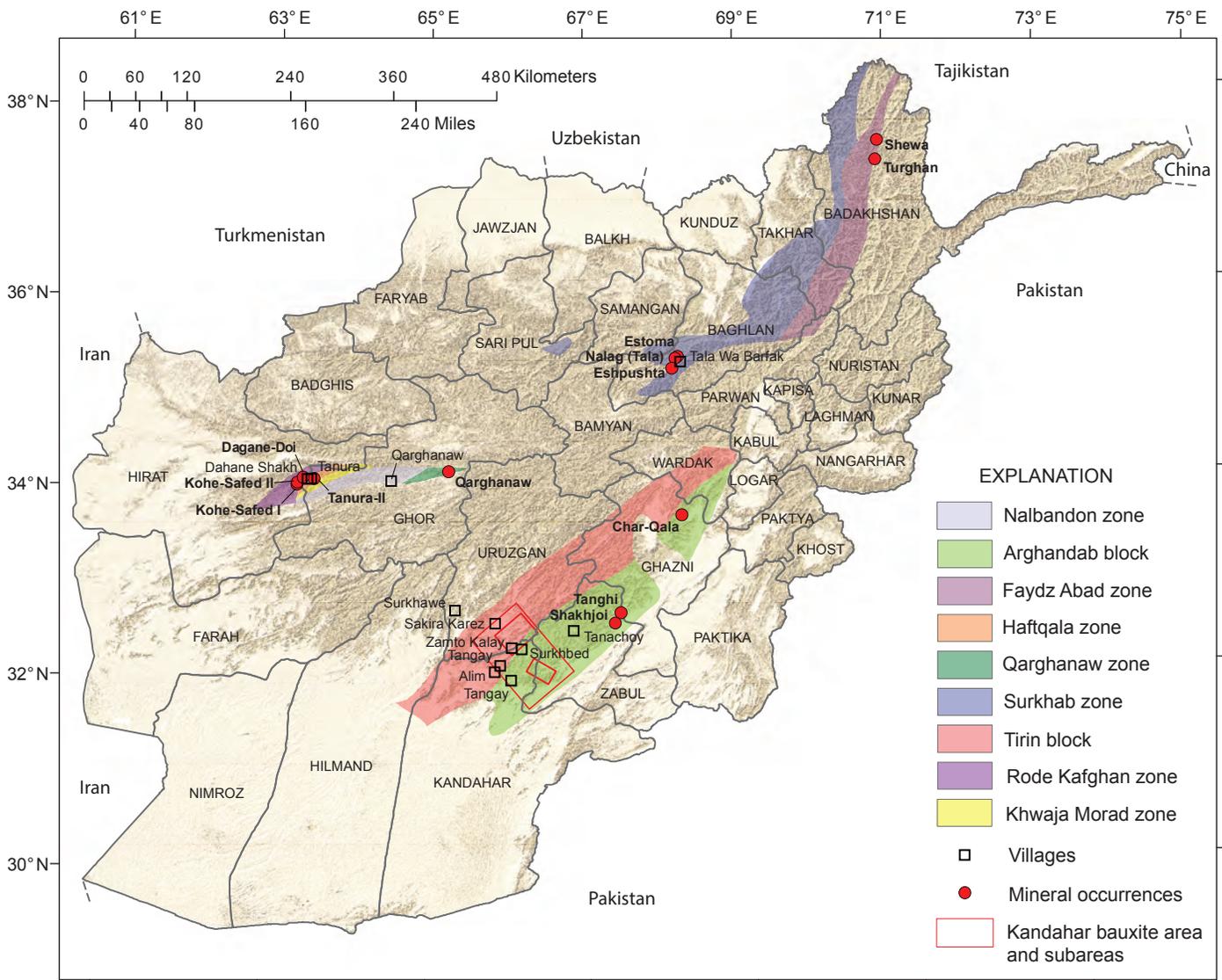
## Bauxite Occurrences and Deposits in Afghanistan

As mentioned previously, bauxite is an aluminum ore consisting of the aluminum oxide or hydroxide minerals gibbsite, boehmite, and diasporite that are commonly mixed with the iron oxides goethite and hematite, and with the clay mineral kaolinite. The economic ores of aluminum generally contain more than 45 to 50 weight percent (wt %) alumina (Al<sub>2</sub>O<sub>3</sub>), not more than 20 wt % ferric oxide (Fe<sub>2</sub>O<sub>3</sub>), and 3 to 5 wt % silica (SiO<sub>2</sub>) (Patterson, 1984).

Two basic types of bauxite deposits that are known in Afghanistan are the laterite and karst types. Favorable weathering conditions that produce deposits enriched in iron (laterites) and alumina (karst) include (1) humid tropical or subtropical climate, (2) rocks high in aluminum in a form susceptible to yielding bauxite, (3) available reagents, including precipitation, to promote the chemical weathering of the silicates and solution of silica at specific pH and Eh conditions, (4) stable surfaces that permit a slow downward infiltration of meteoric water, (5) subsurface conditions that allow the removal of dissolved products, (6) long periods of tectonic stability, and (7) preservation of the deposits (Jensen and Bateman, 1981).

**4 Assessment of Bauxite, Clay, and Laterite Deposits in Afghanistan—Part A. Description of Bauxite Areas**

Bauxite has been identified in four major structural regions of Afghanistan: (1) the Afghanistan-South Pamir folded region, (2) the Afghanistan-North Pamir folded region, (3) the North Afghanistan platform, and (4) the South Afghanistan region (Dovgal and others, 1971). The structural regions are divided by structural features and represent large fault blocks (Chmyriov and others, 1977). Zones identified with bauxite in the Afghanistan-South Pamir folded region are Haftqala, Rode Kafghan, Khwaja Morad, Safed Hers and Qarghanaw. Zones identified with bauxite in the Afghanistan-North Pamir folded region are Faydz Abad and Safed Hers (fig. 2 and table 2). A zone with bauxite in the North Afghanistan platform is Surkhab (fig. 2 and table 2). Structural regions identified with bauxite in the South Afghanistan region are the Tirin and Arghandab blocks (fig. 2 and table 2). Hereafter in this report, distinction is made between an “occurrence” (a concentration of a mineral that is considered valuable by someone somewhere, or that is of scientific and technical interest) and a “deposit” (an occurrence of sufficient size and grade that it might, under the most favorable of circumstances, be considered to have economic potential), consistent with definitions used in U.S. Geological Survey mineral deposit models (Cox and Singer, 1986).



**Figure 2.** Map of bauxite deposits and occurrences based on tectonic zones (Dovgal and others, 1971).

**Table 2.** Bauxite deposits and occurrences of Afghanistan.

Main occurrence	Bauxite zone	Host rock age	Province	Structural region	References
Kohe-Safed, Kohe Pud, Tanura-II, Dagane-Doi	Haftqala (Haftkala)	Late Permian and Late Triassic	Ghor Herat (Hirat)	Afghanistan-South folded Pamir	Dronov and others (1970, 1973, 1976), Dronov (1980), Leven (1997)
Qarghanaw (Mene Bum)	Qarghanaw	Late Permian and Late Triassic	Ghor (Nalbandon)	Afghanistan-South folded Pamir	Dronov and others (1973)
Shewa, Turghan	Shewa	Early Permian	Badakshan	Afghanistan-North folded Pamir	Dronov and others (1972, 1975), Karapetov and others (1970)
Tala Barfak (Nalag), Estoma, Eshpushta	Surkhob	Early Jurassic	Baghlan	North Afghanistan Platform	Chmyroi and others (1977)
Sokhjo, Tangi	Arghandab	Middle-Late Permian	Zabul	South Afghanistan	Dovgal and others (1971), Karapetov and others (1970), Mikhailov and others (1969)
Char-Qala	Arghandab	Early Permian	Ghazni (Gazni)	South Afghanistan	Karapetov and others (1970)
Surkhbet I, II, Tor Ghar, Doubalagh, Sekhab	Tirin	Late Jurassic	Kandahar, Uruzghan	South Afghanistan	Dovgal and others (1971)
Zamto Kalay, Obatu Sheila, Archa Ghar	Arghandab	Late Jurassic	Kandahar, Zabul	South Afghanistan	Dovgal and others (1971)

## 6 Assessment of Bauxite, Clay, and Laterite Deposits in Afghanistan—Part A. Description of Bauxite Areas

Bauxite and bauxitic rocks occur as soils that are developed on an exposure and erosional surface. They are most commonly developed on and are overlain by marine carbonate rock units. The erosional surface appears to represent a maximum regression, and the soil represents initiation of a transgressive system tract. Five stratigraphic levels are notable for the presence of bauxite and bauxitic beds: the lower Permian, the upper Permian, the Upper Triassic, the base of the Jurassic, and the lower part of the Upper Jurassic.

1. Bauxite beds of early Permian age (such as the Char-Qala occurrence in Ghazni (Gazni) Province) overlie Carboniferous rocks and occur at the base of a thick sequence of limestone and dolomite that starts in the Artinskian (middle early Permian) and extends to the late Permian in age (fig. 3).
2. The upper Permian bauxites (such as the Kohe-Safed occurrence in Ghor Province) occur as lenses on top of a thick-bedded white limestone and are overlain by an upper Permian (Pamirian) limestone unit, Late Devonian-Mississippian and Permian-undifferentiated.
3. Several exposed surfaces in the Late Triassic have locally developed bauxitic soils, such as the Estoma and Eshpushta, and in Permian Undifferentiated and late Permian, Tanura village and Qarghanaw occurrences (fig. 3).
4. The bauxite-bearing rocks at the base of the Jurassic in northern Afghanistan are notable because they occur on volcanic rocks followed by Jurassic carbonate deposition (Tala Barfak occurrence in Baghlan Province). The bauxite forms tabular bodies in a weathering crust developed over Upper Triassic basalts (Leven, 1976) (fig. 3).

Bauxite occurrences of Upper Jurassic age are known from five localities near Kandahar. Most thoroughly studied of these five occurrences is the Obatu Sheila occurrence, where the bauxite-bearing rocks are present at the base of the Vargach Formation (Jurassic to Cretaceous) of terrigenous-carbonate rocks that transgressively overlie Middle through Upper Jurassic limestone of the Paynawa Limestone. This basal horizon of bauxite-bearing rocks in the Vargach Formation is traceable within an area of several tens of square kilometers.

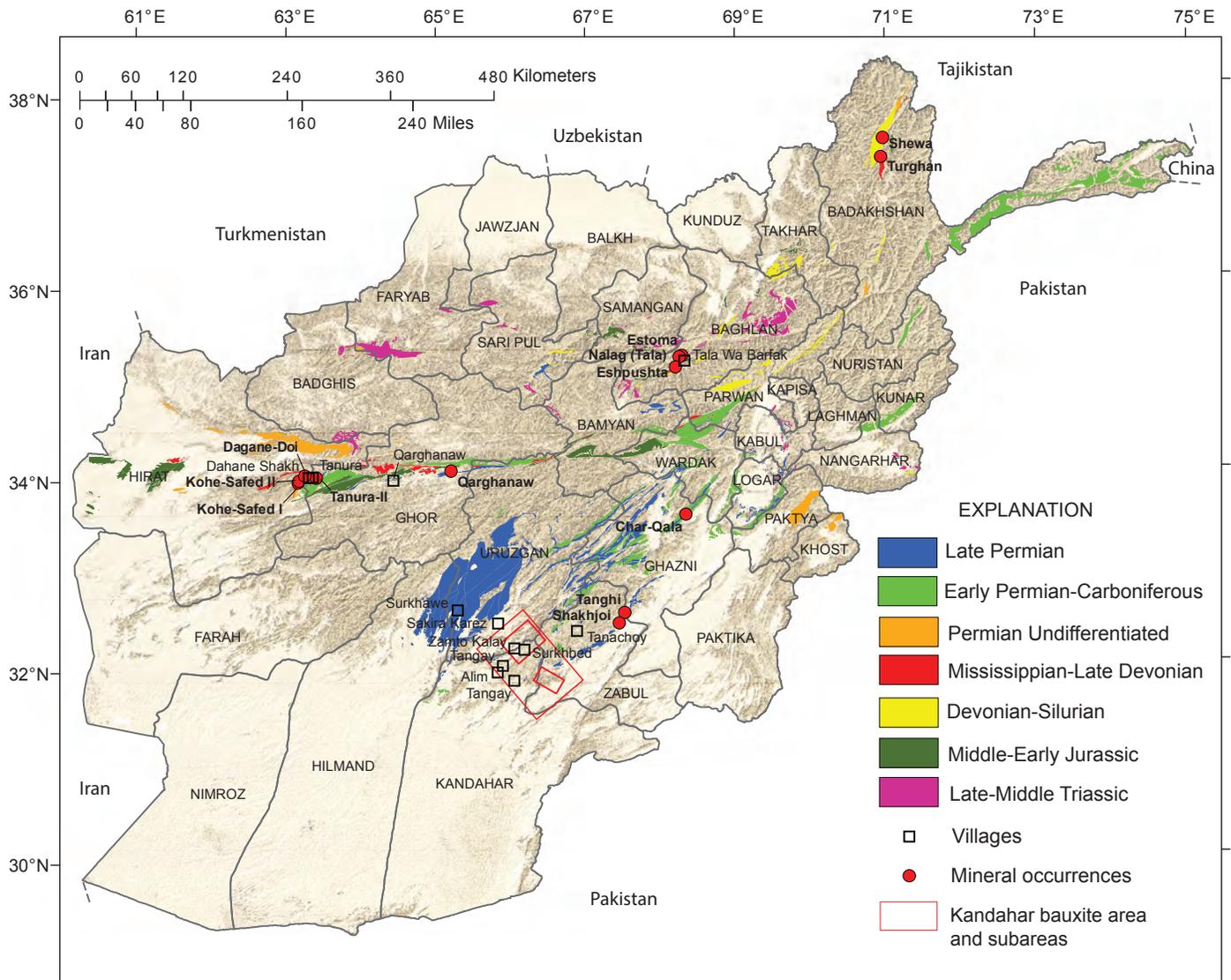


Figure 3. Map of bauxite deposits and occurrences based on map units (Dovgal and others, 1971).

## Description of Bauxite Deposits

Known bauxite deposits of Afghanistan are of two basic types—those found in karst and those in laterite. They occur in two general areas: laterite-type deposits are located northwest of Kabul, and karst-type deposits have been identified southwest of Kabul.

### Laterite-Type Bauxite

Laterite-type bauxites are composed of weathered residual material in subsoil that formed on weathered aluminous silicate rocks of sedimentary, metamorphic, or plutonic origin, including clay-rich sandstone, gneiss, granite, dolerite, and gabbro. The aluminous rocks are altered by intensive weathering to form bauxite. Bauxites are typically massive, pisolitic, nodular, and earthy. The deposits develop by surficial weathering of well-drained plateaus with warm to hot and wet climates. Locally, deposits may be present in poorly drained areas where iron is removed by organic complexing. The deposits are present on tectonically stable areas. Deposits may be overlain by a thin soil and usually are underlain by saprolite (parent rock in intermediate stages of weathering) (Bárdossy and others, 1990) as shown on figure 4.

Laterite-type bauxite consists mostly of gibbsite or a mixture of gibbsite and boehmite, as well as gangue minerals including hematite, goethite, anatase, and quartz. Residual kaolin deposits are associated with bauxite deposits (Patterson and others, 1967a).

### The Laterite-Type Bauxite Complete Profile

A “standard” profile does not exist because there are no identical laterite or bauxite profiles. Figure 4 illustrates two different profiles, which are based on studies by many scientists. Usually the weathering profile description starts at the top and proceeds downward. The profile shown in figure 4A is composed of five horizons, and the profile shown in figure 4B is composed of six horizons. The first (fig. 4A) is divided into the following (Bárdossy and Aleva, 1990):

1. *Soil*.—Forms the uppermost horizon; product of mechanical and chemical weathering, mixed with plant remains and humic matter; color depends on various factors.
2. *Duricrust horizon*.—Upper part, hard to very hard horizon, indurated, commonly concretionary, dark brown to almost black, can be enriched in iron or aluminum oxyhydroxide and kaolinite; in places it directly overlies the saprolite.
3. *Bauxite horizon*.—Lower section of lateritic part, can be homogeneous or inhomogeneous based on structure (massive beds or layers composed of concretions of various size in soft matrix), texture (aphanitic, pisolitic, gravelly, and breccia-like) and color (pinkish, yellowish, orange to tan, orange to reddish, gray, black); kaolinite is dissolved and replaced by gibbsite to form bauxite. This horizon is usually rich in aluminum and iron.
4. *Saprolite horizon*.—Composed of aluminum sheet silicate (clay) weathering of parent rock, with the texture and most of the volume of the primary rocks preserved; minerals include kaolinite, quartz, rutile, zircon; usually lighter in colors than the overlying laterite or bauxite; 2 to 100 meters (m) thick.
5. *Parent rock*.—Weathering profile is derived from this rock, which influences the nature of the weathering profile.

The profile shown in figure 4B is a more detailed profile, divided into several horizons and zones: (1) modern soil horizon, (2) lateritic paleosol and bauxite horizon, (3) saprolite which includes: (a) lateritic cuirasse (duracrust), (b) bauxite, (c) pallid zone and (d) molted zone, (4) lateritic pedolith, and (5) parent rock (Bárdossy and Aleva, 1990).

### Karst-Type Bauxite

Karst-type bauxite consists of weathered and transported materials that are present in or on carbonate-bearing rocks (fig. 5). The transported material commonly is composed of felsic volcanic ash from distant sources or any aluminous sediment (clay) that was washed into the basin of deposition. These types of bauxites tend to be concentrated in depressions on karst surfaces, and their texture is massive, pisolitic, and earthy. Age of the deposits can be from Paleozoic to Cenozoic. Associated common

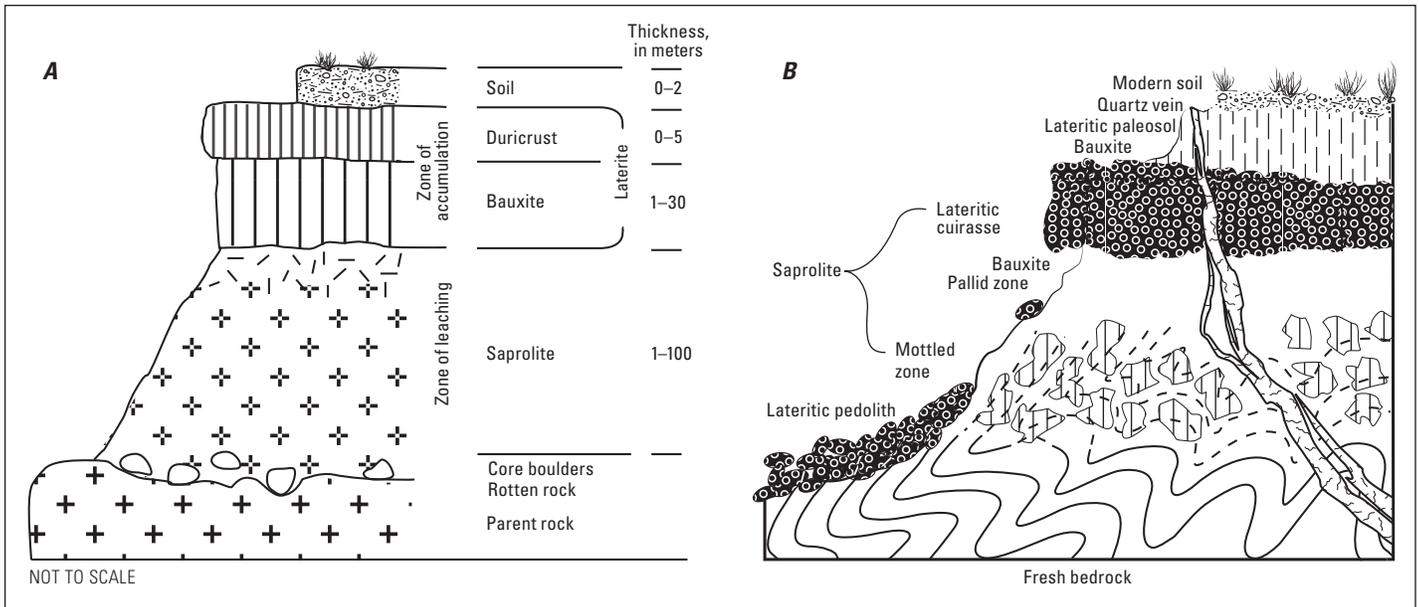


Figure 4. Lateritic bauxite profiles. A, Modified from Bárdossy and Aleva (1990). B, Modified from Retallack (2010).

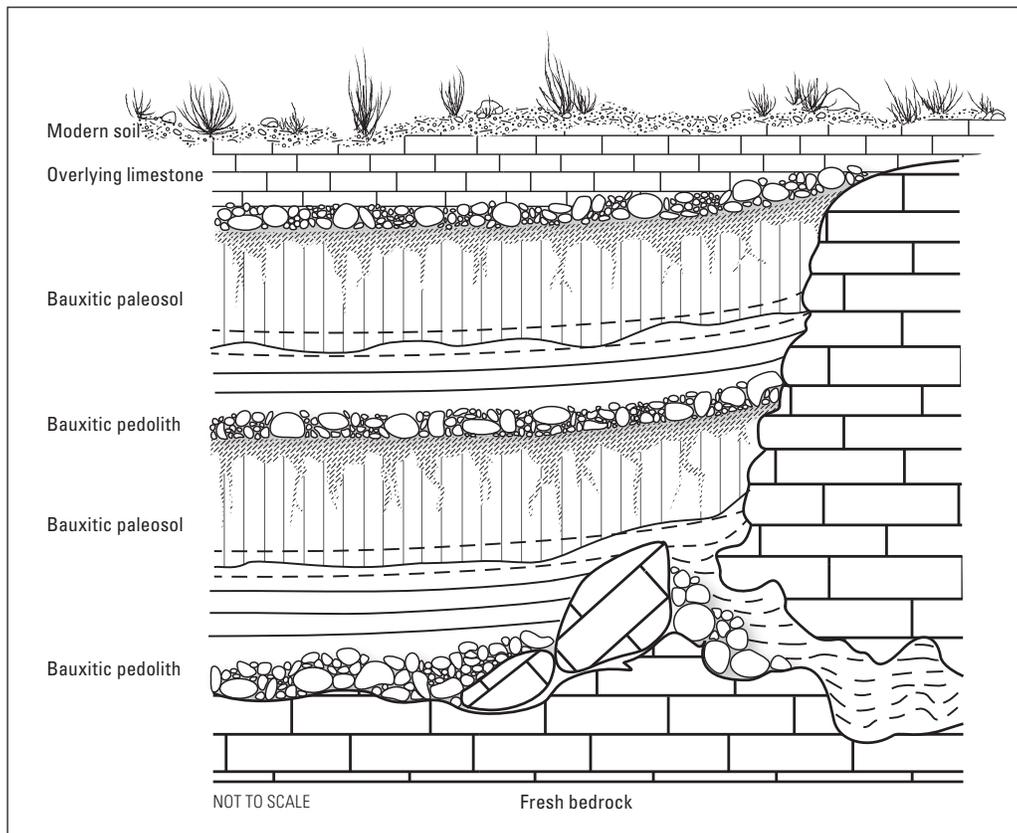


Figure 5. Karst-type bauxite profile (modified from Retallack, 2010).

rock types are limestone, dolomite, and shale. Some areas are associated with minor coal and are low in iron because of organic complexing and removal of iron during formation (Patterson, 1967b). Karst-type bauxites form from the alteration of aluminous sediments and from continuous intensive weathering, mainly in wet tropical areas. The land masses in those areas were stable, which allowed time for weathering and for protection from erosion.

Karst-type bauxite deposits typically contain mainly gibbsite. Boehmite and gibbsite mixtures also are present in some deposits. Boehmite is more common in Mesozoic and Paleozoic deposits. Gangue minerals in karst-type bauxite deposits are hematite, goethite, anatase, kaolinite, and minor quartz. Geochemically, these deposits are recognized by anomalous aluminum and gallium values (Patterson and others, 1973). A karst-type bauxite deposit in Afghanistan is exemplified by the Obatu Sheila deposit (figs. 2, 3, and 14).

## **Weathering Products**

Weathering products such as kaolinite are good indicators for residual soils and easy to map by using remote sensing ASTER images. Kaolinite can also be a good indicator for gibbsite formation during the intensive weathering. Gibbsite is an important end product constituent of bauxite deposits because it is easy and cheap to process.

Iron oxide minerals commonly are the end products of weathering of mafic and felsic rocks. Aluminum oxide and hydroxide minerals are an end product of weathering of felsic rocks. Of the aluminum ore minerals, gibbsite has the lowest specific gravity, is the softest, and is more soluble in the Bayer alumina extraction process than boehmite and diasporite. Therefore, gibbsite bauxite is cheaper to process than boehmite and diasporite bauxite (Patterson, 1984).

## **Kaolinite**

Kaolinite is a clay produced in tropical to subtropical conditions by the intense chemical weathering of aluminum silicate minerals, the most common being feldspars. Kaolinite also has a unique spectral signature, so is easily recognizable in satellite imagery. Mapping the distribution of kaolinite-rich sediments is a critical step in understanding the distribution of these residual soils in Afghanistan.

High-quality kaolin clays are present where the main Lower Jurassic clay bed is 5 m thick and several hundred meters long (Mikhailov and others, 1965). Near Tala Wa Barfak village, there is a large deposit of foundry clays (mixed clays) and refractory clays (kaolinite) represented by two beds, 2.6 and 4 m thick and 220 m in strike length, in the Lower through Middle Jurassic sequence. The clays are of medium plasticity and high caking and dispersion ability. The clay reserves are 385 thousand tons (Mikhailov and others, 1965).

## Description of Bauxite Areas by Region

### Afghanistan-South Pamir Folded Region (Herat (Hirat)-Ghor)

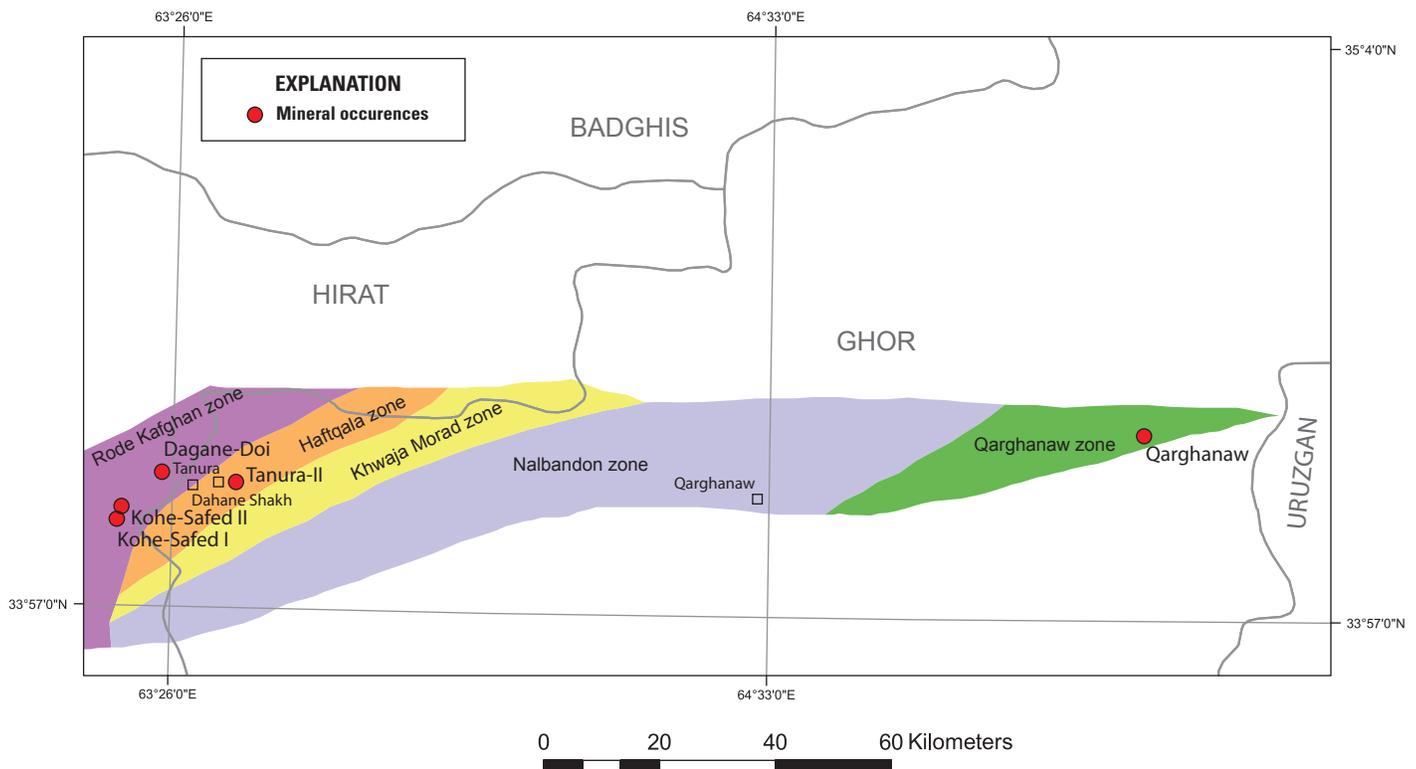
The Afghanistan-South Pamir folded region includes Haftqala (also spelled Haftkala), Rode Kafgan, and Qarghanaw in the western part of Afghanistan.

#### Haftqala, Rode Kafghan, Khwaja Morad and Qarghanaw Zones

The Haftqala zone is in western Afghanistan, in Herat (Hirat) and Ghor Provinces (fig. 2). The Haftqala zone contains the Dagane-Doi bauxite occurrences and the Rode Kafghan zone contains Kohe-Safed and Tanura II bauxite occurrences that are small, separate bauxite bodies and bauxite-bearing rocks, which were identified during construction of roads. They are far away from each other (Dronov and others, 1970, 1973, 1976).

The Haftqala zone is a complex folded structure consisting of rows of anticlines and synclines, which expose a 1,500-m-thick Devonian-Triassic carbonate-bearing section of rocks. The western side of the Haftqala zone is bounded by a thrust fault. The eastern border of the Haftqala uplift is more clearly defined along a fault that defines the transitional boundary to the adjacent Khwaja Morad zone (fig. 6) (Dronov and others, 1970, 1973, 1976).

The Haftqala zone contains Middle Carboniferous through Permian deposits disconformably above Lower Carboniferous strata. The Permian deposits are represented predominantly by quartz sandstone in the lower parts and contain carbonate rocks that include limestone, dolomite, and limy sandstone in the upper parts and are capped by bauxite. The total thickness of the section shown below is 250 to 280 m (Dronov and others, 1970, 1973, 1976). This section is overlain by Lower Triassic red limestone.



**Figure 6.** Location of bauxite occurrences in Haftqala, Rode Kafghan, Khwaja Morad and Qarghanaw zones, Herat (Hirat) and Ghor Provinces (bauxites from Dronov and others, 1970; tectonic zones from Peters and others, 2007).

12 Assessment of Bauxite, Clay, and Laterite Deposits in Afghanistan—Part A. Description of Bauxite Areas

Bed	Description	Thickness (meters)
10	Multicolored limestone and dolomite of Early Triassic age with bivalves including <i>Claraia aurita</i> , <i>C. cf. C. stachei</i> , <i>C. cf. C. australasiatica</i> , and <i>Anodonotophora</i> sp.	10
9	Gray, milliolid-bearing, bedded limestone with profuse <i>Shanita</i> sp. (loc. 563)	40
8	Brown and green pisolitic, ferruginous bauxite lenses lying on an uneven scoured limestone surface on bed 7.	0–4
7	Light-colored, massive algal-foraminiferal limestone with oolitic limestone interbeds. The following foraminifer species are abundant: <i>Rausarella sphaeroidea</i> , <i>Pseudoendothyra</i> sp., <i>Staffella</i> sp., <i>Sphaerulina</i> sp., <i>Dunbarula</i> sp., <i>Neoschwagerina</i> cf. <i>N. haydeni</i> , <i>Tuberitina</i> sp., <i>Eotuberitina</i> sp., <i>Glomospira</i> sp., <i>Globivalvulina</i> sp., <i>Glomospirella</i> sp., <i>Neoendothyra</i> sp., <i>Dagmarita chanakchensis</i> , <i>Hemigordiopsis renzi</i> , <i>Kamurana</i> sp., <i>Shanita</i> sp., <i>Baisalina</i> sp., <i>Nodosaria</i> sp., <i>Langella</i> sp., <i>Fronicularia tumida</i> , <i>Pachyphloia</i> sp., <i>Cribronerina</i> sp. (loc. 561-3, 573-1–573-24).	6–12
6	Dolomite and dolomitic limestone with rare foraminifers including <i>Pseudoendothyra</i> sp. and <i>Staffella</i> sp., and the alga <i>Permocalcus</i> sp. (loc. 561-4, 575).	60–70
5	Dark-gray, medium- and thick-bedded, algal-foraminiferal limestone, overlying bed 4 disconformably. Fusulinids are represented by <i>Sphaerulina</i> sp., <i>Dunbarula</i> sp., <i>Schubertella</i> sp., <i>Rugososchwagerina geratica</i> , <i>Pseudofusulina haftkalensis</i> (loc. 561-5, 571-1–571-4). Smaller foraminifers include <i>Eotuberitina</i> , <i>Climacammina</i> , <i>Cribronerina</i> , <i>Tetrataxis</i> , <i>Globivalvulina</i> , <i>Langella</i> , <i>Pachyphloia</i> . The tabulate corals are <i>Michelinopora</i> aff. <i>M. sigangensis</i> and <i>M. grandispinosa</i> .	20
4	Light-colored, massive, bioclastic limestone formed of fusulinids, crinoid ossicles, bryozoans, and algae. Foraminifers include <i>Pseudoendothyra</i> sp., <i>Pseudoreichelina darvasica</i> , <i>Schubertella giraudi</i> , <i>Rugosofusulina valida</i> , <i>Pseudofusulina macilenta</i> , <i>P. cf. P. karapetovi</i> , <i>P. fabra grandiuscula</i> , <i>P. fabra fabra</i> , <i>P. peregrina</i> , <i>P. aff. P. postpedissequa</i> , <i>P. cf. P. paraconcessa</i> , <i>P. cf. P. parasecalica</i> (loc. 566-1–566-12).	10
3	Massive, coarse-grained dolomite.	15–30
2	Thin bedded, dark-gray marl and limestone with some silicified material. Fossils include bryozoans and brachiopods such as <i>Permundaria</i> sp., <i>Globiella rossiae</i> , <i>Linoproductus cora</i> , <i>Marginifera typica</i> , and the corals <i>Paracania</i> sp., <i>Bradyphyllum</i> sp., <i>Amplexus</i> sp., <i>Caninia</i> sp.	25–30
1	White, quartzose sandstone with well-rounded grains. Conglomerate interbeds and lenses occur within the sandstone. The matrix is calcareous and locally dominates the rocks which grade into sandy limestone composed of moderately rounded fragments of bryozoans, algae, crinoid ossicles, echinoids, and brachiopod spines. Foraminifera are rare and poorly preserved; those present are represented by species of <i>Pseudoendothyra</i> and <i>Tetrataxis</i> .	80

A columnar section for parts of the Haftqala zone is presented in figure 7.

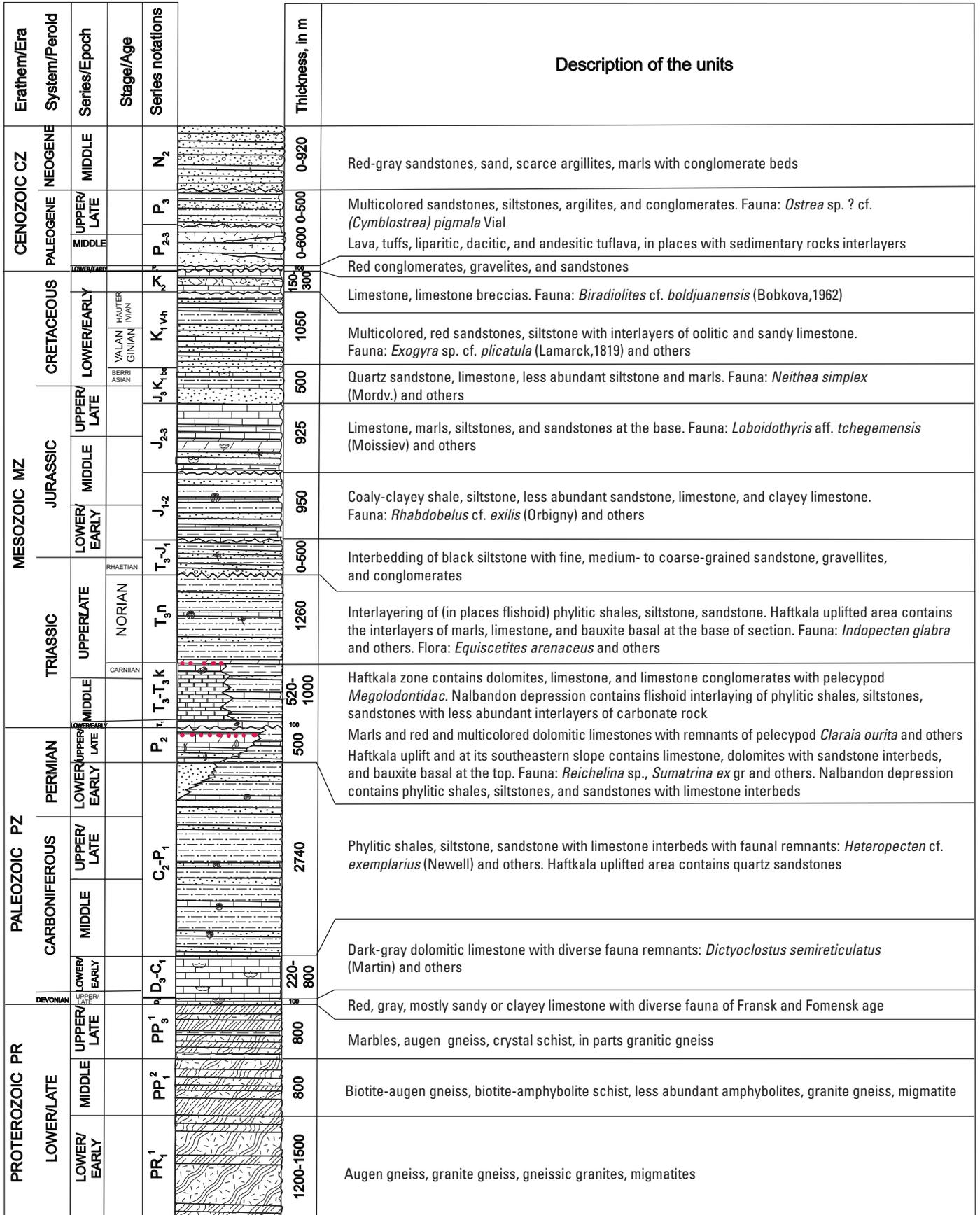


Figure 7. Stratigraphic column, Haftkala zone in Herat (Hirat) and Ghor Provinces (Tutubalin and others, 1979).

### Kohe-Safed I and II Bauxite Occurrences

The Kohe-Safed I and II bauxite occurrence (34°05' N., 63°20' E., 34°06' N., 63°20' E.) is in Ghor Province (figs. 2 and 3) and is confined to the Pamir (upper Permian) stratigraphic horizon (fig. 7). It contains two lens-shaped bauxites that are 1.5 and 2.5 m thick, respectively, and the exposed surfaces are from 15 to 20 m long (Dronov and others, 1970). The bauxite outcrops are 70 to 100 m apart from each other on top of early Permian white bioclastic limestone at the base of the upper Permian limestone. The bauxites are rusty red, brown, dull greenish, or greenish yellow and pisolitic. Each lens was channel sampled every 0.5 m along the strike, with three samples collected from each lens for a total of six samples (lens 1, samples 576/1–3; lens 2, samples 577/1–3). The contents are as follows: 40.16 to 48.66 wt %  $\text{Al}_2\text{O}_3$ , 6.88 to 23.32 wt %  $\text{SiO}_2$ , and 17.19 to 25.03 wt %  $\text{Fe}_2\text{O}_3$  (Dronov and others, 1970). The results of chemical analysis are in table 3.

The Kohe-Safed bauxite occurrence was recommended by Dronov and others (1970) as a prospective area for identifying more bauxite. Although  $\text{Al}_2\text{O}_3$ : $\text{SiO}_2$  ratios of the samples in table 3 are fairly high, the Kohe-Safed deposit falls slightly short of being compatible with industrial-grade bauxite (table 1).

**Table 3.** Results of chemical analysis of the Kohe-Safed bauxite occurrence (from Dronov and others, 1970).

[ID, identifier; —, no data; NI, not identified]

Sample ID	Content, in weight percent										
	$\text{SiO}_2$	$\text{Al}_2\text{O}_3$	$\text{Fe}_2\text{O}_3$	$\text{TiO}_2$	MnO	$\text{P}_2\text{O}_5$	CaO	MgO	Other	$\text{H}_2\text{O}$	$\Sigma$
576/1	8.49	46.87	22.60	6.63	0.07	0.02	7.11	—	12.92	0.555	99.71
576/2	12.70	40.16	25.03	5.70	0.04	—	2.87	0.43	12.41	0.90	99.54
576/3	15.64	43.95	19.77	5.85	0.07	0.03	2.11	1.4	12.18	1.09	100.32
577/1	23.32	40.44	17.19	5.63	NI	NI	NI	NI	NI	NI	NI
577/2	6.88	48.66	24.00	6.55	0.04	0.03	1.71	—	12.60	0.67	99.97
577/3	11.53	45.45	23.41	5.74	0.07	0.03	2.11	—	11.52	0.80	99.86

### Tanura-II Bauxite Occurrence

Tanura-II bauxite occurrence is northwest of Tanura village (34°09'41" N., 63°24'50" E.; figs. 2 and 3; Dronov and others, 1970). Aluminum-bearing rocks are in small irregular bodies (0.5 by 1 m) in upper Norian (Triassic) sandy-silty beds, which are on the erosion surface on top of middle through lower Norian bioclastic limestone. Macroscopically, the rocks are similar to the Kohe-Safed rocks. The bauxite-bearing rocks are greenish yellow and rusty and pisolitic. The results from geochemical analysis are listed in table 4.

### Dagane-Doi Bauxite Deposit

The Dagane-Doi deposit lie in a transitional zone between the Haftqala zone and the Khwaja Morad zone (34°09'37" N., 63°32'54" E.; figs. 2 and 3). This transitional zone was named the Sange Doshah zone by Abdullah and others (2008) but was included in the Haftqala zone by Peters and others (2007). The mineralization consists of two outcrops of rusty-red and green-yellow, pisolitic, dense, sandy rocks. The two lens-shaped bauxites (3 by 5 m and 4 by 10 m) are developed on an erosion surface on top of lower Permian bioclastic limestone, conformably overlain by upper Permian sandstone. Geochemical results of samples collected in a 3- by 5-m area and in a 4- by 10-m area in the small gully at the depth 3.4 m (lens I, sample 633/3; lens II, sample 633/6) are listed in table 5 (Dronov and others, 1970).

**Table 4.** Geochemical results for the Tanura-II bauxite occurrences (from Dronov and others, 1970).

[ID, identifier]

Sample ID	Content, in weight percent			
	$\text{SiO}_2$	$\text{Al}_2\text{O}_3$	$\text{Fe}_2\text{O}_3$	$\text{TiO}_2$
576/B	7.91	10.74	1.57	1.37
576/v	11.81	11.36	2.86	1.55
576/2	15.64	43.95	19.27	5.85
577/1	37.59	36.31	7.29	3.05

**Table 5.** Geochemical results of samples from the Dagane-Doi bauxite occurrences (from Dronov and others, 1970).

[ID, identifier]

Sample ID	Content, in weight percent			
	$\text{SiO}_2$	$\text{Al}_2\text{O}_3$	$\text{Fe}_2\text{O}_3$	$\text{TiO}_2$
633/3	41.18	29.64	9.15	3.35
633/6	36.99	28.65	18.02	5.62

The  $Al_2O_3$  content and  $Al_2O_3:SiO_2$  ratio (table 5) indicate that the rocks from the Dagane-Doi and Tanura-II bauxite occurrences may not be industrial-grade deposits (table 1). Kohe-Safed mineralization is closer to the industrial mark but still slightly below. It was proposed by Soviet geologists that the Haftqala zone may contain many more bauxite bodies similar to the described bauxite bodies that remain undiscovered (Dronov and others, 1970). This inference is based on paleogeographic conditions during the Permian and Triassic periods (tropical climates, common exposure surfaces, dominant carbonate deposition). This area is recommended for further investigation.

The section was described in detail by Russian geologists is near Dane Shah village. The lower parts of the section begin with a carbonate bed unconformably overlain by largely terrigenous deposits of Middle Carboniferous through lower Permian age. The stratigraphy in this area is as follows:

Bed	Description	Thickness (meters)
10	Sandstone and siltstone with bioclastic, agal limestone interbeds containing fusulinids and small foraminifers <i>Reichelina</i> cf. <i>R. changhsingensis</i> , <i>Staffella</i> cf. <i>S. zisonzhengensis</i> , <i>Codonofusiella</i> sp., <i>Globivalvulina</i> sp., <i>Paraglobivalvulina</i> sp., <i>Glomospira</i> sp., <i>Hemigordius reicheli sigmoidalis</i> , <i>Baisalina</i> sp., <i>Dagmarita</i> sp., <i>Spirulina</i> sp., <i>Pachyphloia</i> sp., <i>Froncina</i> sp., <i>Partisanina</i> sp., <i>Rectostipulina</i> sp. (loc. 633-1; sample of Leven, 1997). The siltstone contains fossil leaf impressions which include <i>Pecopteris orientalis</i> and <i>P. nerinii</i> .	100
9	Feriferous red and green-gray bauxite-like rock of pisolitic texture.	0.5–5
8	Limestone, white, massive, bioclastic algal, bearing the fusulinids <i>Kahlerina</i> sp., <i>Pseudokahlerina compressa</i> , <i>Schubertella</i> cf. <i>S. silvestri</i> , <i>Codonofusiella</i> sp., <i>Chusenella pseudocompacta</i> , <i>C. schwageriniformis</i> , <i>Neoschwagerina</i> sp., <i>Verbeekina</i> sp. and the small foraminifers <i>Neoendothyra parva</i> , <i>Abadehella biconvex</i> , <i>Dagmarita chanakchensis</i> , <i>Climacammina</i> sp., <i>Deckerella</i> sp., <i>Nodosaria</i> sp., <i>Pachyphloia</i> sp., <i>Partisanina</i> sp. (loc. 633-2 and 633-4, samples of Leven, 1997).	20
7	Dolomite, gray, thick-bedded.	100
6	Limestone, gray and black, interbedded with sandstones and siltstones, bearing the fusulinids <i>Nankinella</i> sp., <i>Staffella zisonzhengensis</i> , <i>Dunbarula ardagdensis</i> , <i>Boultonia</i> sp. <i>Skinnerella multiseptata</i> , <i>Neoschwagerina simplex simplex</i> , <i>N. simplex tenuis</i> , <i>N. verae</i> , <i>Presumatrina neoschwagerinoides</i> , <i>Pseudodoliolina</i> aff. <i>P. oliviformis</i> (loc. 631-1 to 631-17; samples of Leven, 1997).	100
5	Limestone, gray, massive and thick-bedded, containing Early Murghabian fusulinids including <i>Boultonia ogbinensis</i> , <i>Pseudofusulina quasifusuliniformis</i> , <i>Parafusulina</i> sp. (loc. 630, 630-1; samples of Leven, 1997).	30
4	Limestone, gray and black, interbedded with sandstones and siltstones and bearing Late Permian brachiopods of <i>Leptodus nobilis</i> . Fusulinids include <i>Schubertella kingi</i> , <i>Yanchienia</i> sp., <i>Parafusulina</i> sp., <i>Armenina</i> sp., <i>Cancellina</i> sp. (loc. 629-17 to 629-25; samples of Leven, 1997).	60
3	Limestone, massive, lumpy.	10
2	Limestone, bioclastic and clastic, bearing fusulinids including <i>Schubertella</i> sp., <i>Yanchienia</i> sp., <i>Skinnerella yabei asiatica</i> , <i>Skinnerella cincta</i> , <i>Chusenella brevis</i> , <i>Armenina</i> sp. (loc. 629-1 to 629-15; samples of Leven, 1997, from beds 2 and 3).	8
1	Limestone, gray, medium- and thick-bedded, detrital. The clasts are composed of bryozoans, crinoids, algae, and fusulinids. From the upper part of the bed the fusulinids are <i>Schubertella</i> sp., <i>Kubergandella</i> cf. <i>K. sarykolensis</i> , <i>Pseudofusulina heratica</i> , <i>P. postkraffii</i> , <i>Misellina (Misellina) ovalis</i> , <i>Armenina</i> cf. <i>A. pamirica</i> (loc. 628-16 to 628-41, samples of Leven, 1997). Fusulinids in the lower half of the bed include <i>Schubertella giraudi</i> , <i>S. kingi</i> , <i>S. longiuscula</i> , <i>Toriyamaia laxiseptata</i> , <i>Chalartoschwagerina vulgariformis</i> , <i>Pseudofusulina kraffii</i> , <i>P. postkraffii</i> , <i>Misellina (Brevaxina) dyhrenfurthi</i> , <i>M. (B.) olgae</i> , <i>M. (Misellina) parvicostata</i> (loc. 628-1 to 628-15; samples of Leven, 1997).	70

## Qarghanaw Bauxite Occurrence

The Qarghanaw zone lies to the east of the Haftqala zone (34°15'20" N., 65°15'18" E.; figs. 2 and 3). Two stratigraphic sections were measured, one Permian (Leven, 1997) and the other Triassic (Dronov and others, 1973). The Permian sequence in the Qarghanaw zone, located southeast of the Nalbandan zone, is generally similar to others in western middle Afghanistan. A minor difference is that the upper part of the siliciclastic Carboniferous through lower Permian group is altered volcanic rocks up to 400 m thick. North of the village of Qarghanaw, the volcanic rocks are overlain, apparently conformably, by the following sequence (Leven, 1997; Dronov and others, 1973):

Bed	Description	Thickness (meters)
6	Dolomite, thick-bedded.	40
5	Siltstone and limestone with hydroid-algal limestone bioherms and biostromes.	50
4	Dirty, green-gray, pisolitic siliceous rocks lying on a rough limestone surface [a soil].	10
3	Black, bioclastic, detrital limestone with rare chert nodules and sandstone and siltstone interbeds. Limestone contains foraminifers including <i>Staffella</i> sp., <i>Nankinella</i> sp., <i>Pseudofusulina</i> aff. <i>P. solita</i> , <i>Parafusulina</i> sp., <i>Neoschwagerina</i> sp., <i>Yabeina</i> sp., <i>Armenina</i> sp., <i>Pseudodoliolina</i> sp., and <i>Sumatrina</i> sp. (loc. 1405-8).	40
2	Thick-bedded, gray limestone.	40
1	White, massive reefal limestone with the foraminifers <i>Stafella zisongzhengensis</i> , <i>Nankinella inflata</i> , Schwagerinidae gen. indet., <i>Hemigordiopsis</i> sp., and the algae <i>Mizzia velebitana</i> , <i>Permocalculus tenellus</i> (loc. 837, 837-1). A fault separates beds 1 and 2.	100

In the Qarghanaw zone, the Induan-Carnian (Triassic) sequence exhibits a different succession of beds as compared to Nalbandan and Khwaja Morad. The section described from the Mene Bum Ravine is as follows. Permian dolomites are overlain disconformably by the following beds (Leven, 1997; Dronov and others, 1973):

Bed	Description	Thickness (meters)
6	Dolomite, thick-bedded.	20
5	Bauxite of pisolitic and fine-grained texture, variegated, with a well-defined horizon of gray limestone abounding in gastropod and pelecypod remains of Carnian appearance in the middle part.	30
4	Dolomite, gray and dark, layered, occasionally fragmental.	30
3	Limestone, black, layered, argillaceous with rare chert nodules, lenses and bands.	20
2	Limestone, gray, occasionally lumpy, with crinoid and pelecypod remains in the upper portion.	40
1	Limestones, dark and gray, thin-bedded with abundant remains of mud-eaters and algae at the bedding surfaces.	200

The thickness of the sequence is 340 m. By the position in the section and by comparison with similar deposits from other zones, bed 1 (200 m) corresponds to Lower Triassic to Anisian deposition and beds 2 to 6 (140 m) to Ladinian to Carnian deposition. The distinctive feature of the Lower Triassic through Carnian beds from the Qarghanaw zone as compared with those of the Nalbandan zone is the greater thickness of the beds (and particularly that of the Lower Triassic through Anisian flaggy limestones), the absence of limestone conglomerates at the base, a gap in the Carnian sequence, and the presence of bauxite and dolomite (Leven, 1997; Dronov and others, 1973).

## Afghanistan-North Pamir Folded Region (Badakshan)

### Faydz Abad and Safed Hers Bauxite Zones

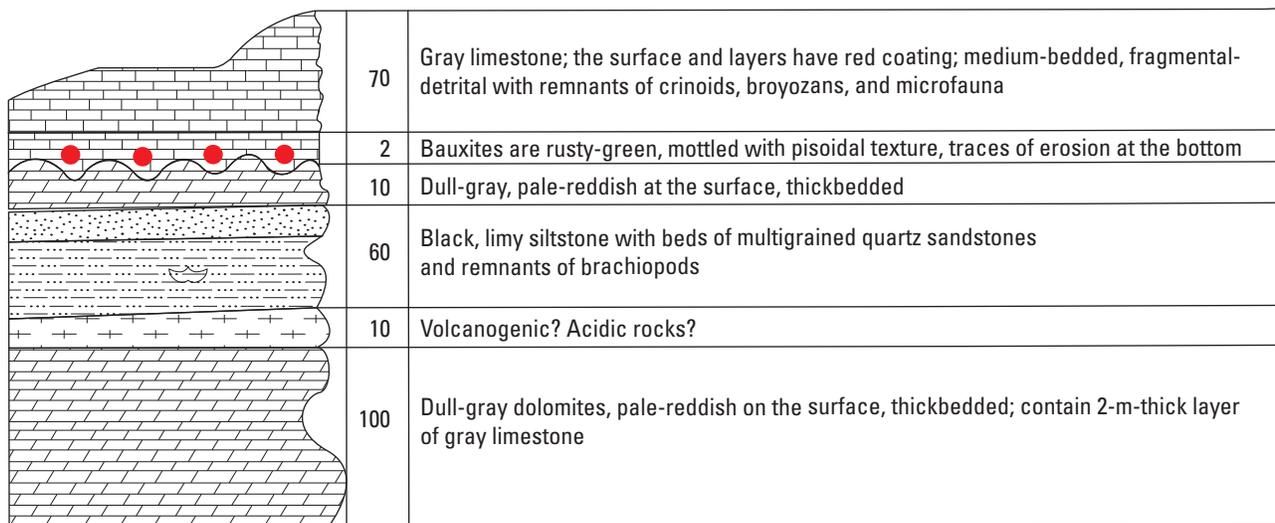
The Faydz Abad and Safed Hers bauxite zones are in central Badakshan Province, and are characterized by a complex structural setting. The bauxite zone contains many faults of different scales and genesis; specifically, overthrust sheets in different allochthonous complexes. In places the lithological relations among sections is unclear. Many formations in the zone, especially the Paleozoic stratigraphic sections, appear to be allochthonous; the facies are juxtaposed by strong horizontal movement in Alpine-style thrusting. The Faydz Abad and Safed Hers bauxite zones are in the form of a wedge that pinches out southward. Neoproterozoic and Vendian formations form the basement in the northeast side of the Faydz Abad zone (Sborshchikov and others, 1973).

### Shewa Bauxite Occurrence

The Shewa bauxite occurrence (Sborshchikov and others, 1973; 37°38'25" N., 70°53'05" E.; figs. 2 and 3) is in the Faydz Abad zone. The bauxite layer is 1.0 m thick and lies in the middle parts of the Permian section. The bauxite is tan-green, mottled, dense, and pisolitic. The bauxite beds lie on a faintly expressed erosion surface on top of dolomite and are overlain by a thick gray limestone. The fossiliferous Permian rocks are present in a narrow thrust sheet, which extends for 13 kilometers (km) from north to south along the confluence of the Shewa and Turghan Rivers. The Permian deposits in this area are typified by a stratigraphic section on the west slope of the Shewa River Valley near the confluence with the Turghan River (Sborshchikov and others, 1973). The Permian beds in this area are overturned. They lie in fault contact with Lower Ordovician limestone in the east and Upper Triassic sandstones and siltstones in the west. The Permian stratigraphic section in this area has the following succession from east to west (the rocks were described by Dronov and others, 1975, and Sborshchikov and others, 1973):

Bed	Description	Thickness (meters)
6	Gray limestone, medium-bedded, detrital; has red-colored coating on the surface and contains crinoids, bryozoans, and Schwagerinidae fusulinids.	70
5	Rusty-green bauxite, mottled, with pisoidal texture dense with an erosional surface at the base.	2
4	Dull-gray, pale-reddish at top, thick-bedded dolomite.	10
3	Black, calcareous siltstone with interbedded quartzose sandstone that contains the Lower Permian brachiopod <i>Reticularia</i> sp.	60
2	Volcanic tuff?	10
1	Dull-gray, thick-bedded dolomite with a 2-m pale rusty limestone at the top.	100

The total thickness of this section is 252 m. The age of the beds of the described section is lower Permian, based on the brachiopod fauna below and the fusulinid fauna above the bauxite bed. The lower Permian rocks in this area formed in a nearshore environment indicated by the mixture of thin layers of rock, an erosion surface, a bauxitic soil, marine fossils, and quartz sandstone (Sborshchikov and others, 1973; fig. 8).



NOT TO SCALE

**Figure 8.** Section of Permian deposits in Shewa River Valley (Sborshchikov and others, 1973).

### Turghan Bauxite Occurrence

The Turghan bauxite occurrence (Sborshchikov and others, 1973; 37°26'16" N., 70°50'55" E.) lies in the same zone as the Shewa bauxite occurrence, 10 km from the Shewa occurrence. The bauxite-bearing bed is 2.0 m thick and occurs in a multi-colored Permian section (Sborshchikov and others, 1973).

### South Afghanistan Region (Kandahar, Zabul, Ghazni, and Uruzgan)

Bauxites in the South Afghanistan structural region lie within the Tirin and Arghandab blocks of the Central Afghan Massif in Kandahar, Zabul, Ghazni, and Uruzgan Provinces (fig. 2). The Central Afghan Massif is elongated, contains large faults, and is covered by Neogene deposits in the Seistan Valley. The massif consists of two sections. The eastern section (Helmand (Hilmand)-Arghandab block) is uplifted. The western section consists of folded volcanic, carbonate, terrigenous deposits (Dovgal and others, 1971; Karapetov and others, 1970; Dronov and others, 1972).

The Arghandab block extends through Kandahar, Zabul, and Ghazni Provinces. It contains bauxite deposits and occurrences. The Arghandab block in Ghazni Province contains the Char-Qala bauxite occurrence; in Zabul Province the occurrences are the Sakhjoi and Tanghi. The Arghandab block in Kandahar Province contains the largest deposits: Obatu Sheila, Archa Ghar, and Zamto Kalay. Deposits related to the Obatu Sheila occur in the Tirin block.

The Arghandab block was first defined by Dovgal and others (1971) and Karapetov and others (1970). The outlines of the block were revised by Dronov and others (1972), who included in the block the peripheral part of the Helmand (Hilmand)-Arghandab Uplift, which is southeast of the granitoid massifs of the Arghandab Complex. The northwest boundary of the block is bounded by granitoids, and the southeast boundary is the Mukur-Tarnak fault. The Arghandab block is lensoidal in shape, extending for 250 km in length and up to 40 km in width. It has a northeast strike (Dovgal and others, 1971; Karapetov and others, 1970; Dronov and others, 1972).

The Arghandab block consists of lower and upper sections. The lower section consists of two Neoproterozoic folded complexes (Malakhel and Malestan). The folded basement consists of Mesoproterozoic and Neoproterozoic rocks. In the present structural pattern, the basement rocks crop out in a number of antiformal structures, the largest of which is the Malakhel arch. Sedimentary rocks are common in this block as compared to other uplifts. The upper section of the Arghandab block consists of uppermost Proterozoic through Cretaceous sedimentary deposits, 9,000 m thick. The block is highly dislocated and includes isoclinal folds. Vendian through Cambrian carbonate beds (870 m) are overlain by Ordovician to lower Permian fine-terrigenous beds (4,335 m), which are in turn overlain by upper Permian through Jurassic carbonate rocks (3,870 m) that are disrupted by a Rhaetian through Liassic terrigenous interval (40–600 m). The Cretaceous is represented by Barremian through Aptian coarse- and fine-grained terrigenous beds (450–1,365 m). The total thickness of the sedimentary strata ranges from 6,250 to 10,000 m. Quartz sandstone is abundant in the Silurian, Devonian, and Carboniferous rocks, and dolomite is abundant in the upper Permian and Middle through Upper Triassic parts of the sequence. Indications of erosion are observed at three levels: inside the Frasnian, at the base of the Artinskian, and at the base of the Upper Jurassic. Bauxite is present in this section at the second and third erosional levels. The Barremian-Aptian sequence lies unconformably on all the older formations. As in other areas of the uplift, the sedimentary strata are deformed to folded in short, broad, linear, gently dipping, shallow folds. Monoclinical bedding is observed in many areas, and angles of the limbs of the folds and monoclines range from 15° to 20° up to 50° to 70°. Disharmonic folding is traceable in the more ductile stratigraphic intervals. Devonian, Permian, and Jurassic sections contain major erosional surfaces, with bauxite having developed in the latter two periods (Karapetov and others, 1970; Dovgal and others, 1971; Dronov and others, 1972).

The Tirin block is between the Helmand (Hilmand) and Arghandab blocks. The sedimentary cover consists of Upper Devonian to Jurassic carbonate-terrigenous rocks that total 4,300 m in thickness, separated by an erosional surface from an upper complex that consists of a Lower Cretaceous, continental, thin terrigenous section which is 600 m thick. Bauxite is developed on an unconformable surface between Middle and Upper Jurassic sediments (Karapetov and others, 1970; Dovgal and others, 1971; Dronov and others, 1972).

## Ghazni (Ganzi) Province, Arghandab Block

### Char-Qala Bauxite Occurrence

Char-Qala bauxite occurrence is located in Ghazni Province (33°46' N., 68°12' E.; figs. 2 and 3). The bauxite layers are on an erosional surface at the top of Lower Permian terrigenous beds. They are immediately overlain by Artinskian limestone. Five lens-shaped bauxites, ranging in thickness from 8 to 25 m and exposed over 100 m of the strike length, with individual outcrop lengths of 10 to 30 m, have been discovered at the bottom of the Artinskian limestone in the section of Carboniferous through lower Permian sequence (Karapetov and others, 1970). The bauxites are brown, greenish-gray, red, and dirty green; pisolitic; and massive, locally exhibiting vague bedding. The samples taken by Russian geologists contain 40.37 wt % and 49.95 wt %  $\text{Al}_2\text{O}_3$  and 2.74 wt % and 5.88 wt %  $\text{SiO}_2$ , respectively (Dronov and others, 1972). Based on chemical analysis from the channel samples, the content of  $\text{Al}_2\text{O}_3$  ranges from 40 to 50 wt %.

## Zabul Province, Arghandab Block

In this area the Arghandab block contains two bauxite occurrences: Sakhjoi and Tangi. Both occurrences are in the Permian Chohan Formation. The Chohan Formation contains dark-gray (gray at the surface), laminated, and thick-bedded dolomitic limestone, 900 m thick. The bottom of Chohan Formation limestone (10–15 m) contains foraminifera similar to Darwazian and Murgabian stages (Middle Permian): *Ammodiscidae* gen. indet., *Pachyphloia* sp., and *Nankinella* sp. To the south from Sakhjoi, rugose corals were determined: *Yatsengia* aff. *Y. bukiensis*, *Y. cf. asiatica*, *Carinthiaphyllum* cf. *maclayi*, *Waagenophyllum* aff. *wengchengense*, and *W. aff. indicum*, which characterize the Darwaz and Murgab Formations. In the upper beds of the Chohan the following fossils were collected: *Reichelina* cf. *media*, *Geinitzina* cf. *caucasica*, *Nodosaria* aff. *acera*, *Pachyphloia* cf. *multiseptata*, *P. aff. robusta*, and *Colaniella* cf. *cylyndrica*. These fossils indicate a Pamirian (upper Permian) correlation. On the basis of the fossils, the Chohan is middle to late Permian in age (Dronov and others, 1972).

The Chohan Formation has a transgressive unconformable lower contact; it is conformably overlain by Triassic beds. The Chohan formation rocks rest on various horizons including Precambrian and lower and upper Paleozoic beds. The content of Permian basal layers varies according to the horizon they overlie. The unconformity between Permian basal beds and

Precambrian metamorphic beds to the south of Davlatel is sharp and angular. The basal beds of the Chohan Formation contain 1 m of granular, brown-yellow conglomerate, followed by green siltstones, 2 m thick. The siltstones grade into laminated light-gray and yellow limestone beds, 10 m thick, with interbeds of granular conglomerate, 0.3 m thick (Dronov and others, 1972).

Permian limestone overlies carbonate rocks of the Cambrian through Lower Ordovician Zargaran Formation with an angular unconformity that shows 15 to 200 m of relief. The basal bed contains bright-colored bauxite from 2 to 5 m thick that is pisolitic and contains rock fragments. The content of  $\text{Al}_2\text{O}_3$  in the samples from several pit holes is low, from 23 to 24 wt %. The bauxites grade along the strike into iron-rich pebble conglomerates (5 to 7 m) with well-rounded quartz and chert grains (Dronov and others, 1972).

Where the Chohan Formation overlies Carboniferous quartz sandstone beds, the angular unconformity is absent. The basal beds are coarse pebble and cobble conglomerates from 4 to 5 m thick. The quartz sandstone cobbles are from 30 to 40 cm in diameter and well rounded (Dronov and others, 1972).

The Chohan Formation is present in many areas including upstream of the Arghandab River and along the west bank of the Tirin River. In the middle reaches of the Arghandab River, the Chohan Formation crops out as a narrow elongate broken strip for more than 160 km, from Lar village in the northeast to Mukrak village to the southwest. Isolated outcrops occur near Faten Mohammad village, Malikhel village, Shal Kalay, Dewkhana, Hajian, and Takhamak. The Chohan Formation overlies dolomites of the Cambrian(?), and contains conglomerates, bauxite, and bauxitic rocks 2 to 3.5 m thick at its base above the Zargaran Formation (Dronov and others, 1972).

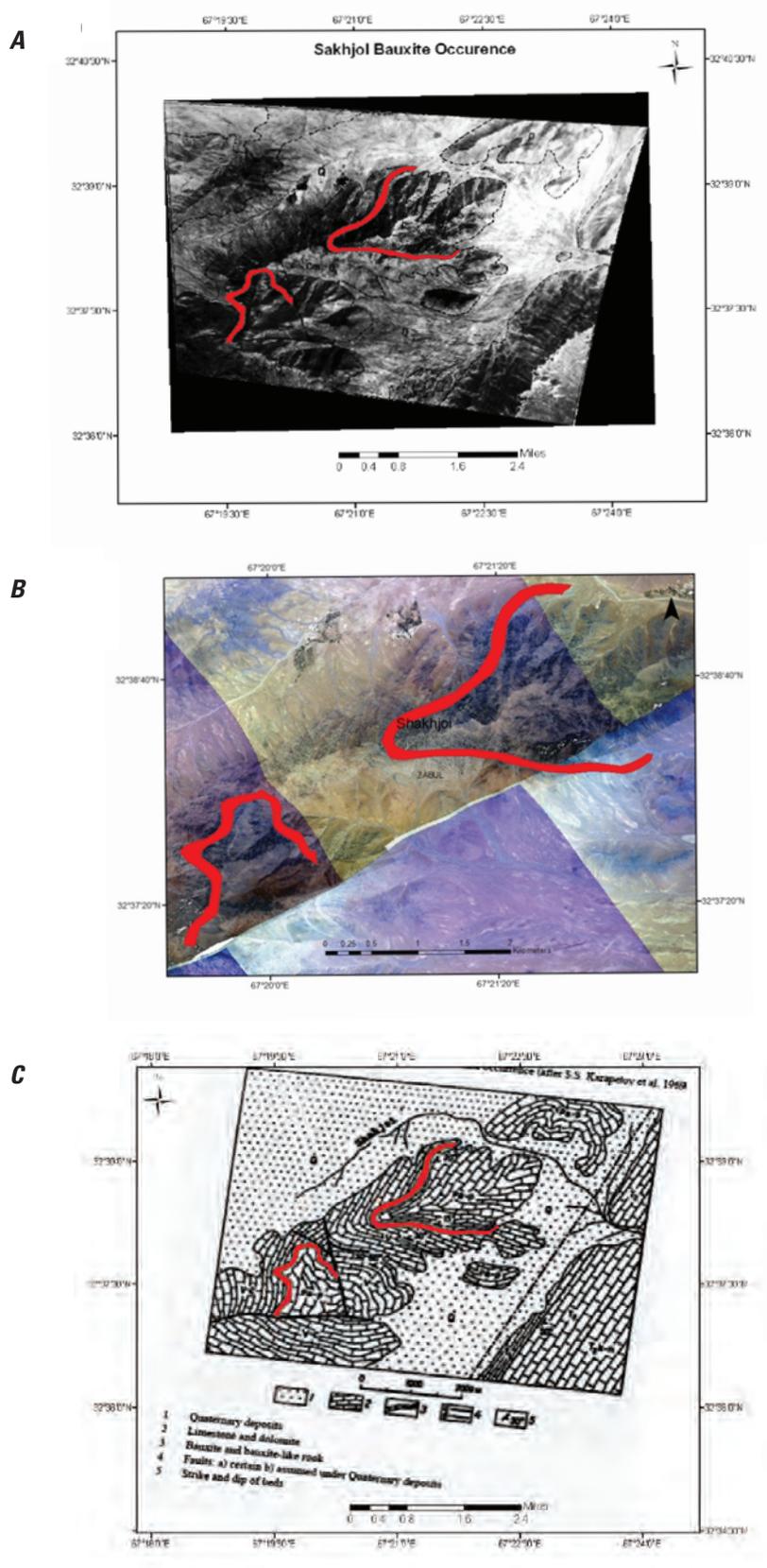
### Sokhjai Bauxite Occurrence

The Sokhjai bauxite occurrence (32°38'27" N., 67°21'8" E.) is within the Chohan Formation, which unconformably overlies a weakly karsted dolomitic limestone surface of the Zargaran Formation. There are two outcrops of bauxite to the northeast and southeast of each other (fig. 9). The northeastern outcrop extends as far as 4 to 5 km and gently dips at 15° to 20°. The northeastern outcrop is described by Karapetov and others (1970). The southwestern outcrop extends as far as 2 to 3.5 km.

The bauxites range from 0 to 5 m and average 3 to 4 m in thickness. The bauxites are brownish, greenish-yellow, and jasperlike and ferruginous in places, with pisolites and rock fragments. The pisolites range from 1.0 to 1.5 cm up to several centimeters in diameter. The pisolites gradually disappear upwards in the section. The upper part of the section contains greenish, layered, clayey bauxite. The clayey bauxites locally are completely replaced by conglomerates with chert, quartz, and limestone pebbles. The basal bauxites have been sampled along the strike (Karapetov and others, 1970). The 14 channel samples were chemically analyzed, and they showed an  $\text{Al}_2\text{O}_3$  content that did not exceed 27 wt %. The occurrence does not represent any potential interest because of the low  $\text{Al}_2\text{O}_3$  content (Karapetov and others, 1970).

### Tangi Bauxite Occurrence

Tangi bauxite occurrence is located in Zabul Province (32°45' N., 67°25' E.; figs. 2 and 3). Several lens-shaped bauxite bodies have been identified in the base of the Chohan Formation overlying the Proterozoic through Cambrian Zargaran Formation. Bodies 5 to 70 m long and 1 to 15 m thick were sampled. The bauxite is massive, either ferruginous, greenish-gray bauxite with a small amount of pisolites or brown, cryptocrystalline bauxite. The  $\text{Al}_2\text{O}_3$  content varies from 11.57 to 46.72 wt %, and the  $\text{SiO}_2$  content from 11.28 to 66.79 wt % (Karapetov and others, 1970).



**Figure 9.** Sokhjo bauxite occurrence, Arghandab block, Zabul Province; red polygons represent bauxite occurrences. *A*, Aerial photograph (Karapetov and others, 1970). *B*, Image provided by the U.S. Naval Research Laboratory. *C*, Geologic map (Abdullah and others, 2008).

## Kandahar Province, Arghandab and Tirin Blocks

Jurassic bauxites of the Vargach Formation have been discovered in many areas of the southern part of the Arghandab and Tirin blocks in the Obatu Sheila River Basin and in the region of Tanachay village, including Obatu Sheila I, II, and III, Surkhbet (I and II), Zamto-Kalay, Tor Ghar, Archa Ghar, and Surkhob. The Vargach Formation is composed of terrigenous and carbonate rocks 200 to 350 m thick. The Vargach Formation is divided into two subdivisions. The lower subdivision consists of irregular interlayers of siltstone, limestone, arenaceous limestone, calcareous sandstone, and quartz-feldspar sandstone and conglomerate. The green to rusty-red bauxitic rocks and bauxite are present at the base of the lower subdivision. The subdivision is 20 to 130 m thick. The Vargach lower subdivision was deposited on the eroded surface of Paynawa Limestone. The contact between the lower and upper subdivisions is a sharp transition from carbonate-terrigenous deposits of the lower subdivision into carbonates of the upper subdivision. The lower subdivision of Vargach Formation has been described from a section 7 km to the northeast of Sah Karez village, on the northern slope of Vargach Ridge. The section of this lower subdivision is as follows (Dovgal and others, 1970):

Bed	Description	Thickness (meters)
11	Irregular interbeds (1–2.5 m) of sandstones and limestone. The limestone dominates. Quartz feldspar sandstones are fine-grained, pinkish-gray and gray. Dark-gray, almost black limestone is laminated at the upper horizon and is arenaceous.	22
10	Gray and ash-gray siltstone.	3
9	Fine-grained, pinkish-gray calcareous sandstone.	4
8	Bioclastic-detrital, dark-gray and rusty-brown laminated limestone.	9
7	Fine-feldspar, laminated, pinkish-gray and gray sandstone.	4
6	Ash-gray siltstone with red coating at the surface (0.5 m).	2
5	Fine-grained, laminated, pinkish-gray quartz-feldspar sandstone.	2.5
4	Reddish-gray and gray siltstone.	5
3	Fine-grained, laminated, pinkish-gray and gray quartz-feldspar sandstone.	5.5
2	Greenish-ash-gray siltstones with scarce pisolites.	3
1	Dark-green, pisolitic bauxites. Pisolites occupy 20–30 % of the rock volume (size varies from 0.2 to 0.6 cm).	3

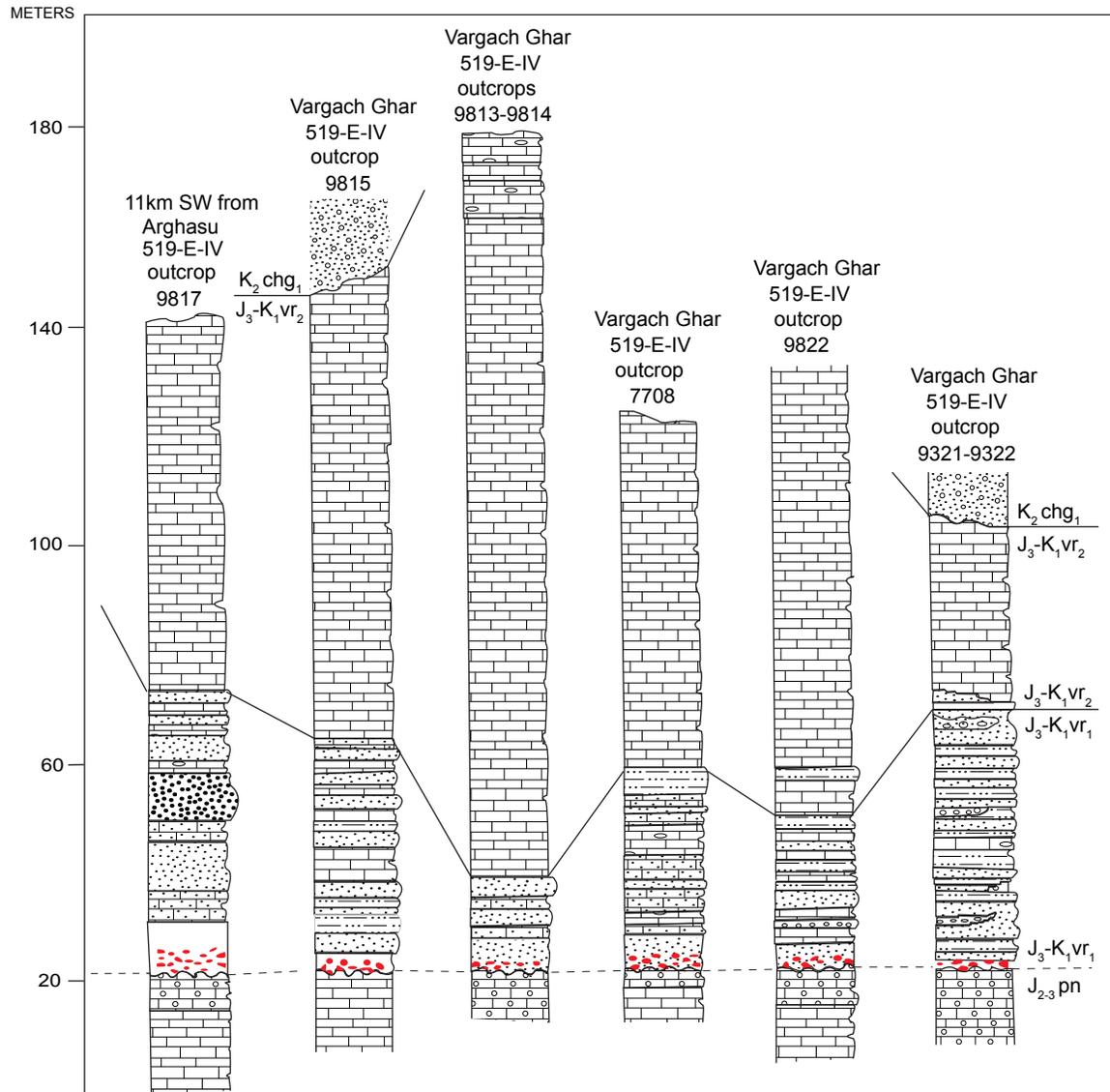
The upper subdivision of the Vargach Formation lies conformably on the lower subdivision. The total thickness of the lower subdivision is 22 m. The entire thickness of the section is 63 m.

The lower subdivision of the Vargach Formation varies greatly over short distances. For instance, the lower subdivision in the Vargach Ridge area consists of terrigenous deposits, 25 to 130 m thick. In Tangay and Alim villages, the lower subdivision also consists of terrigenous deposits but is consistently thicker (120 to 140 m). Near Surkhbet village, the lower subdivision consists mostly of carbonate rocks, 20 to 100 m thick (Dovgal and others, 1971).

Bauxite and bauxitic rocks at the bottom of the lower subdivision appear as continuous beds on the eroded and slightly karsted limestone surface of the Middle through Upper Jurassic Paynawa Limestone. The contact between lower subdivision of Vargach Formation and Paynawa Limestone is sharp, uneven, and wavy (fig. 10). This uneven surface is responsible for the variable thickness of the bauxite beds from 1 to 10 m. The beds are composed of clayey, sandy bauxites; clayey bauxites; and lens-shaped bauxites. Sandstone and conglomerate are interbedded with the bauxitic beds. The bauxite-bearing rocks grade upward into sandstone and siltstone (Dovgal and others, 1971).

The bauxite and bauxitic rocks are traceable within an area of several tens of square kilometers. The horizon comprises lenses and sheet-like bodies of bauxite and bauxitic rocks, described by the Soviet workers (Karapetov and others, 1970) as clayey bauxite and clayey, sandy bauxite: these mixtures are predominant over pure bauxite. The bauxite lenses and interbeds are up to 250 m long and 6 m thick. The bauxite and bauxitic rock are interlayered and show gradual transitions and thus can only be clearly identified by chemical analysis (Karapetov and others, 1970).

The bauxitic horizons are subhorizontal and contain branching folds that plunge 20°. The bauxitic interval in this formation is continuous. The structure and geometry of the ore is complicated by a high degree of faulting. The faulting strikes northeast, but locally the faults strike northwest and are near vertical (Karapetov and others, 1970).



## EXPLANATION

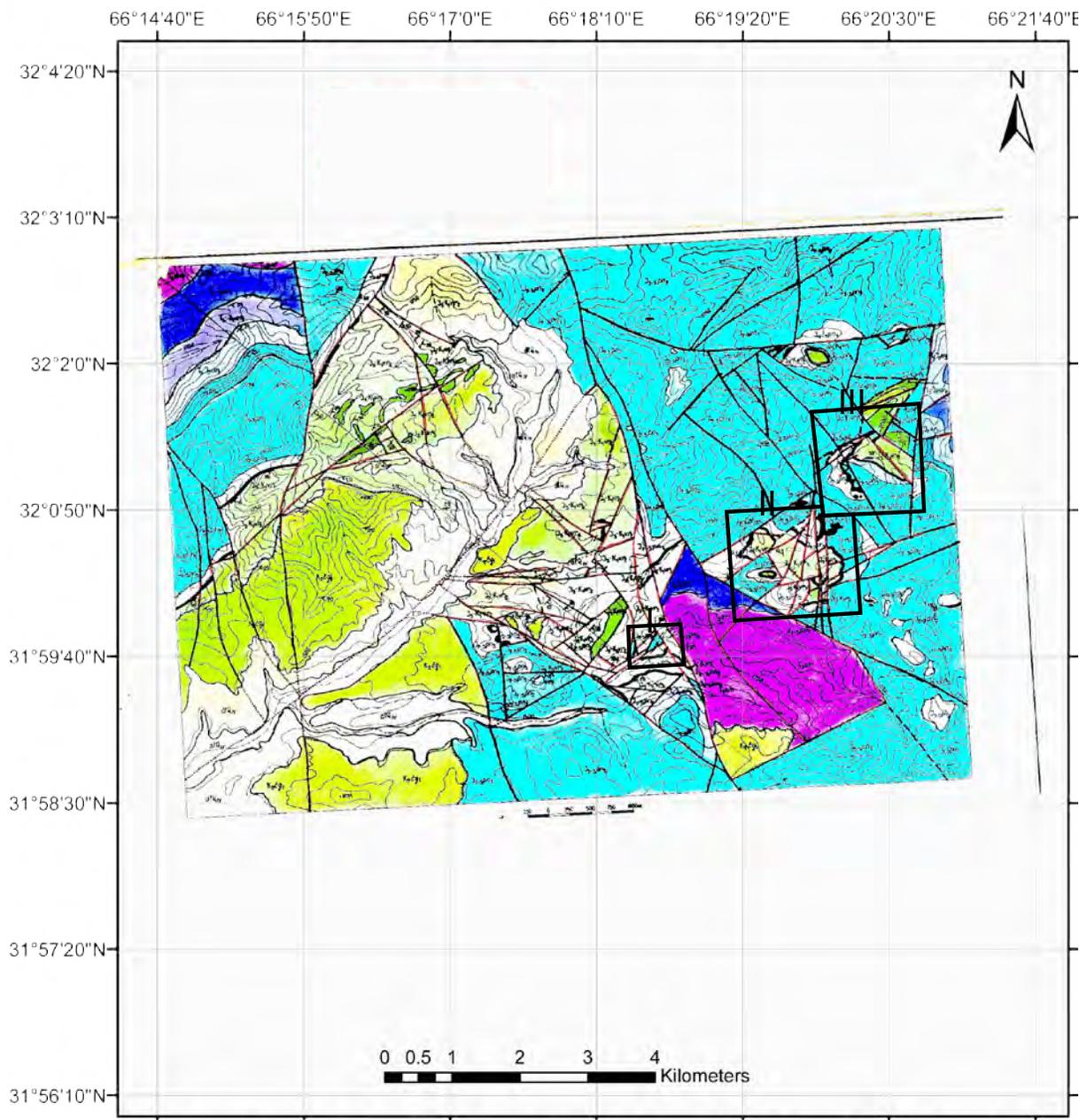
NOT TO SCALE

-  Dark-green, pisolitic. Pisolites occupy 20–30% of the rock volume (size varies from 0.2–0.6 cm)
-  Quartz-feldspar sandstone (Jurassic-Cretaceous Lower Subdivision)—thin-grained, massive, pinkish-gray
-  Siltstone (Jurassic-Cretaceous Lower Subdivision)—rusty-gray and gray, ash-gray
-  Clastic sandstone (Jurassic-Cretaceous Lower Subdivision)—composed of quartz and feldspar
-  Limey sandstone (Jurassic-Cretaceous Lower Subdivision)—fine-grained, pinkish-gray
-  Platy limestone (Jurassic Upper Subdivision)—bioclastic-detrital, dark-gray and rusty-brown
-  Conglomerate (Cretaceous Lower Subdivision of Chagai Formation)—medium to fine-grained, gray color with violet tint. Pebbles composed of gneiss and crystalline schists, migmatite, amphibolite, diabase, phyllites, polymictic sandstones and siltstones; well sorted and rounded, in places shingled
-  Limestone (Jurassic-Cretaceous Lower Subdivision)—massive, gray with scarce amount of pebbles of other material
-  Oolitic limestone (Jurassic Upper subdivision to Lower Subdivision)—massive, light-gray

**Figure 10.** Correlation of Vargach Formation in the Tirin block, Kandahar Province (from Dovgal and others, 1971); pisolitic bauxite highlighted in red.

Obatu Sheila Bauxite Deposit

The Obatu Sheila bauxite deposit (31°58'31" N., 66°12'30" E. and 32°02'58" N., 66°21'54" E.) is the largest known deposit and includes bauxite bodies I, II, and III (fig. 11). The area lies in the syncline of the Sar-e-Koh Mountain, which is 2,500 m high. The reserves of the resource is 7,247,000 tons (table 6) (Han, 1964).



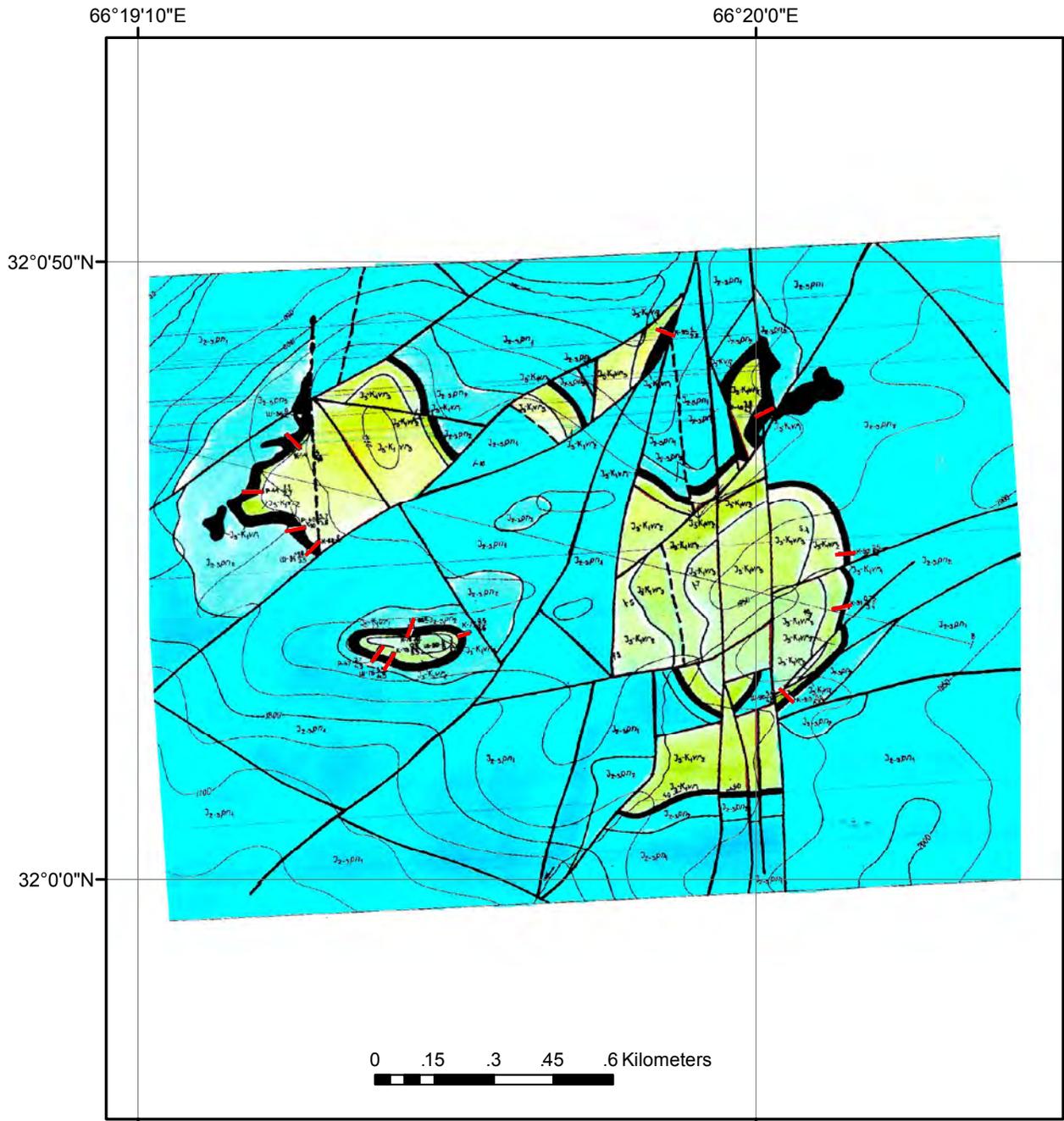
**Figure 11.** Structural map of the Obatu Sheila bauxite deposit. Red boxes and numbers indicate the location of Obatu Sheila I, II, and III (modified from Dovgal and others, 1971).

**Table 6.** Total reserves of the Obatu Sheila bauxite deposit (Han, 1964).

Ore reserves of the Obatu Sheila deposit	Tons
Minaible ore by open-casting	1,322,000
Extension of the above as probable ore reserves	5,925,000
<b>Total</b>	<b>7,247,000</b>

The Obatu Sheila bauxite deposit is about 80 km from Shah-Kharez to the north of Kandahar City. The altitude of the area is from 1,600 to 2,000 m above sea level. The most intensively studied part of the Obatu Sheila bauxite deposit was Obatu Sheila II (fig. 12). The bauxite body in this area has been sampled in 13 trenches, 5 pits, and 95 channels (fig. 13).

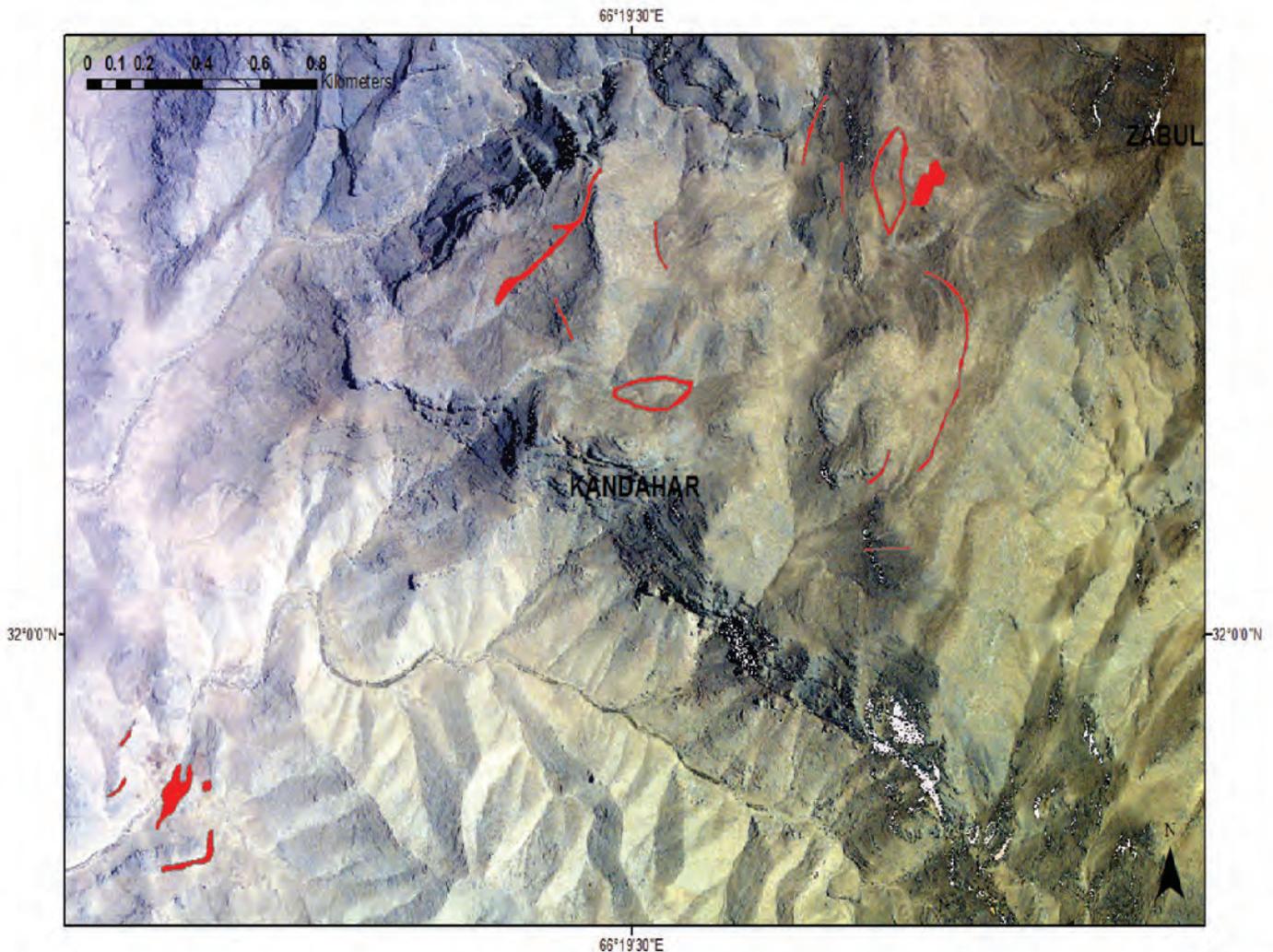
Jurassic rocks and the base of the Early Cretaceous rocks are highly dislocated and folded by an Early Cretaceous orogeny. Bauxite is present in lens-shaped and lenslike interbeds, extends as far as 250 m, and is as much as 5 to 6 m thick. According to X-ray diffraction analysis by Mitsui Central Laboratory in Tokyo (Horita and others, 1971, unpublished laboratory report), the primary bauxite mineral in the Obatu Sheila deposit is diaspore.



**Figure 12.** Schematic geologic map of Obatu Sheila II exposed ore, Kandahar Province; red lines mark trenches (modified from Dovgal and others, 1971).

Soviet geologists studied and mapped the Obatu Sheila deposit in detail. The first type of bauxite at Obatu Sheila is karst-type bauxite that is concentrated in karst holes, fissures, and cavities on the surface of Jurassic limestone of the Paynawa Limestone. The bauxites are underlain by conglomerate containing sharp, angular fragments and blocks of limestone, and these are overlain by sandy, clayey bauxite that contains no pisolites.

The second type of bauxite at Obatu Sheila appears as “hanging” bodies of bauxite between bauxitic rocks. The “hanging” body of bauxite comes in contact in some places with the weathered and karsted surface of limestone of the Paynawa Limestone. This deposit is in a graben that occurred as a result of multiple faulting. The height is approximately 2,000 m. Outwardly, the bauxite is dense and massive, exhibits conchoidal fracture, and is pisolitic, 1 to 5 m thick. The color of bauxite is mainly green and red-brown; however, dark-gray, gray, and lilac colors were also observed. The pisolites (0.5 to 1 cm in diameter) are composed of aluminum oxide (including diasporite or boehmite), exhibit concentric-wavy texture, and constitute 50 to 85 wt % of bauxite. The  $\text{Al}_2\text{O}_3$  content in the bauxite of area II varies from 45 to 50 wt %, and  $\text{SiO}_2$  content is from 2 to 4.5 wt %. Accumulation of muscovite has also been observed. The pisolites are cemented by mixtures of hydromica, ferric oxide hydrates, and alumina and contain quartz fragments, rutile, and zircon. In places, only boehmite and diasporite are present (Dovgal and others, 1971).



**Figure 13.** Map of ore-reserves calculation for the Obatu Sheila bauxite deposit in Kandahar Province (derived from Dovgal and others, 1971, and shown in red) placed on photography taken by U.S. Naval Research Laboratory in 2006 and 2008.

The third type of bauxite at Obatu Sheila is confined to a folded (pleated) zone, which is the eastern wing of an anticline (graben-synclinal structure) in the center of a synclinal fold. The height varies from 2,000 to 2,500 m. This zone was not studied in detail. The major chemical components of the bauxite are listed in tables 7 and 8 below. The  $Al_2O_3$  range is from 27 to 54 wt %. The clayey bauxite contains from 15 to 35 wt % of  $Al_2O_3$ , and pisolites compose approximately 50 wt % of the rock (tables 7 and 8; Dovgal and others, 1971).

The bauxites contain from 42 to 58 wt %  $Al_2O_3$ , from 12 to 20 wt %  $SiO_2$ , between 12 and 20 wt %  $Fe_2O_3$ , 0.03 wt % of  $TiO_2$ , 12 wt % of ignition loss, and the  $Al_2O_3:SiO_2$  ratio varies between 2.7 and 6.8. The speculative reserves of the industrial grade bauxite are 30 to 35 million tonnes (Dovgal and others, 1971). Samples with less than 42 wt %  $Al_2O_3$  are considered clayey or sandy clayey bauxites or bauxitic rocks (with very low alumina percentage) (Dovgal and others, 1971).

Even though the Obatu Sheila bauxite deposit is estimated to be several million tons, there are several issues that may impede development, such as (1) mountainous location, (2) lack of industrial water, (3) shape of ore bodies, which would require underground mining, and (4) mineral character of bauxite, consisting of diaspore and boehmite rather than gibbsite (Dovgal and others, 1971).

**Table 7.** Chemical analysis for Obatu Sheila I (modified from Dovgal and others, 1971).

[ID, identifier; m, meter]

Number	Sample ID	Sample type	Length (m)	Location	Content, in weight percent		Ratio
					$Al_2O_3$	$SiO_2$	
1	B-45-1	Channel	2.5	#45	28.98	22.60	1.28
2	B-45-2	Channel	2.5	#45	27.18	22.06	1.23
3	B-45-3	Channel	2.0	#45	45.48	11.81	3.85
4	B-45-4	Channel	2.5	#45	42.96	12.07	3.56
5	B-45-5	Channel	2.5	#45	31.81	13.59	2.34
6	B-49-1	Trench	5.0	#49	36.90	20.35	1.81
7	B-49-2	Trench	5.0	#49	36.73	20.23	1.81
8	B-49-3	Trench	2.0	#49	45.15	13.02	3.47
9	B-49-4	Trench	2.0	#49	43.32	12.06	3.59
10	B-49-5	Trench	2.0	#49	43.13	11.65	3.70
11	B-49-6	Trench	2.1	#49	37.61	15.83	2.38
12	B-67-1	Trench	1.0	#67	24.65	24.16	1.02
13	B-67-2	Trench	2.3	#67	26.80	31.71	0.85
14	B-67-3	Trench	1.3	#67	27.55	31.88	0.86
15	B-67-4	Trench	0.4	#67	27.78	26.80	1.04
16	B-67-5	Trench	2.2	#67	28.78	34.30	0.84
17	B-67-6	Trench	2.0	#67	29.26	36.77	0.80
18	B-67-7	Trench	1.0	#67	28.83	36.60	0.79
19	B-67-8	Trench	1.8	#67	24.34	26.53	0.92
20	B-68-1	Trench	1.5	#68	33.84	28.22	1.20
21	B-68-2	Trench	1.0	#68	30.36	32.50	0.93
22	B-68-3	Trench	0.8	#68	28.05	30.78	0.91
23	B-68-4	Trench	1.2	#68	25.05	30.20	0.83
24	B-68-5	Trench	2.8	#68	29.88	38.55	0.78
25	B-68-6	Trench	1.3	#68	28.00	35.22	0.80
26	B-68-7	Trench	1.3	#68	24.53	33.53	0.73
27	B-68-8	Trench	1.2	#68	20.30	28.18	0.72
28	B-68-9	Trench	2.0	#68	22.12	28.07	0.79

**Table 7.** Chemical analysis for Obatu Sheila I (modified from Dovgal and others, 1971).—Continued

[ID, identifier; m, meter]

Number	Sample ID	Sample type	Length (m)	Location	Content, in weight percent		Ratio
					Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	
29	B-68-10	Trench	2.0	#68	25.46	22.90	1.11
30	B-68-11	Trench	2.0	#68	29.86	21.68	1.38
31	B-68-12	Trench	2.0	#68	24.06	27.10	0.89
32	B-68-13	Trench	1.8	#68	23.20	29.95	0.79
33	B-68-14	Trench	2.8	#68	18.24	20.04	0.91
34	B-68-15	Trench	2.8	#68	18.24	20.04	0.91
35	B-69-1	Trench	0.6	#69	43.17	25.42	1.70
36	B-69-2	Trench	0.3	#69	30.07	30.00	1.00
37	B-69-3	Trench	1.6	#69	36.52	37.90	0.96
38	B-70-1	Trench	1.4	#70	13.78	45.26	0.30
39	B-70-2	Trench	2.6	#70	19.17	30.31	0.63
40	B-70-3	Trench	3.9	#70	24.32	31.49	0.77
41	B-70-4	Trench	1.6	#70	28.49	39.93	0.71
42	B-70-5	Trench	1.9	#70	25.27	30.13	0.84
43	B-70-6	Trench	1.6	#70	23.83	25.78	0.92
44	B-71-1	Trench	2.4	#71	43.12	21.31	2.02
45	B-71-2	Trench	3.4	#71	46.11	14.19	3.25
46	B-71-3	Trench	3.0	#71	41.79	19.61	2.13
47	B-71-4	Trench	3.2	#71	38.56	27.39	1.41
48	B-72-1	Trench	2.8	#72	29.58	40.56	0.73
49	B-72-2	Trench	0.75	#72	29.18	33.17	0.88
50	B-72-3	Trench	2.4	#72	25.65	26.95	0.95
51	B-72-4	Trench	2.6	#72	27.49	30.89	0.89
52	B-72-5	Trench	2.0	#72	29.49	24.79	1.19
53	B-73-1	Pit hole	1.1	#73	30.07	25.48	1.18
54	B-73-2	Pit hole	1.2	#73	27.57	36.03	0.77
55	B-73-3	Pit hole	1.3	#73	28.47	32.62	0.87
56	B-73-4	Pit hole	0.75	#73	36.75	30.91	1.19
57	B-73-5	Pit hole	1.45	#73	48.07	19.44	2.47
58	B-74-1	Pit hole	0.7	#74	46.45	13.43	3.46
59	B-74-2	Pit hole	1.1	#74	23.41	39.79	0.59
60	B-74-3	Pit hole	1.1	#74	37.70	41.22	0.91
61	B-74-4	Pit hole	1.0	#74	22.13	39.27	0.56
62	B-74-5	Pit hole	1.4	#74	5.86	54.16	0.11
63	B-74-6	Pit hole	0.5	#74	38.29	36.08	1.06
64	B-74-7	Pit hole	0.5	#74	38.89	37.66	1.03
65	B-74-10	Pit hole	1.3	#74	31.59	38.10	0.83
66	B-74-12	Pit hole	1.4	#74	31.94	38.55	0.83
67	B-75-1	Pit hole	0.5	#75	27.09	30.22	0.90
68	B-75-2	Pit hole	1.15	#75	20.21	24.08	0.84

**Table 7.** Chemical analysis for Obatu Sheila I (modified from Dovgal and others, 1971).—Continued

[ID, identifier; m, meter]

Number	Sample ID	Sample type	Length (m)	Location	Content, in weight percent		Ratio
					Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	
69	B-75-3	Pit hole	1.55	#75	21.50	23.56	0.91
70	B-75-4	Pit hole	1.8	#75	22.82	44.29	0.52
71	B-75-5	Pit hole	1.0	#75	24.28	47.20	0.51
72	B-75-6	Pit hole	1.0	#75	27.65	39.30	0.70
73	B-75-7	Pit hole	1.0	#75	29.56	39.88	0.74
74	B-75-10	Pit hole	1.0	#75	20.42	<sup>1</sup> 220.59	0.99
75	B-86-1	Pit hole	1.2	#86	25.17	37.93	0.66
76	B-93-1	Pit hole	1.0	#93	51.29	10.16	5.05
77	B-93-2	Pit hole	1.0	#93	58.18	8.49	6.85
78	B-96-2	Pit hole	1.0	#96	32.07	42.77	0.75
79	B-96-3	Pit hole	1.8	#96	33.06	33.26	0.99
80	B-96-4	Pit hole	1.5	#96	40.45	31.69	1.28
81	B-96-5	Pit hole	1.2	#96	38.46	24.92	1.54
82	B-96-10	Pit hole	1.0	#96	1.58	2.56	0.62
83	B-97-1	Pit hole	1.0	#97	54.23	20.15	2.69
84	B-97-2	Pit hole	2.8	#97	54.80	19.83	2.76
85	B-97-3	Pit hole	2.8	#97	13.67	54.53	0.25
86	B-97-4	Pit hole	1.4	#97	26.85	35.60	0.75
87	B-97-5	Pit hole	1.1	#97	14.70	53.38	0.28
88	B-97-6	Pit hole	2.0	#97	7.89	71.30	0.11
89	B-97-7	Pit hole	1.9	#97	10.85	71.40	0.15
90	B-97-8	Pit hole	2.0	#97	16.42	53.30	0.31
91	B-97-9	Pit hole	2.6	#97	33.10	36.90	0.90
92	B-98-1	Trench	1.0	#98	9.78	76.80	0.13
93	B-99-1	Trench	1.0	#99	34.65	30.84	1.12
94	B-99-2	Trench	1.0	#99	35.39	33.55	1.05
95	B-99-3	Trench	0.75	#99	49.89	23.27	2.14
96	B-99-4	Trench	0.65	#99	32.21	37.76	0.85
97	B-99-5	Trench	0.85	#99	32.88	31.03	1.06
98	B-99-6	Trench	1.0	#99	10.52	41.67	0.25
99	B-99-7	Trench	1.75	#99	9.42	68.83	0.14
100	B-99-10	Trench	1.0	#99	1.94	2.18	0.89
101	B-101-1	Trench	1.0	#101	20.03	23.97	0.84
102	B-101-2	Trench	1.0	#101	21.36	24.83	0.86
103	B-101-3	Trench	1.3	#101	15.86	18.25	0.87
104	B-101-4	Trench	1.8	#101	29.75	32.86	0.91
105	B-101-5	Trench	0.9	#101	36.85	28.66	1.29
106	B-101-6	Trench	0.8	#101	25.51	27.70	0.92
107	B-101-7	Trench	1.5	#101	2.68	30.60	0.09

<sup>1</sup>This value was obviously erroneous in the source document. The actual value is likely either 20.59 or 22.59 wt %.

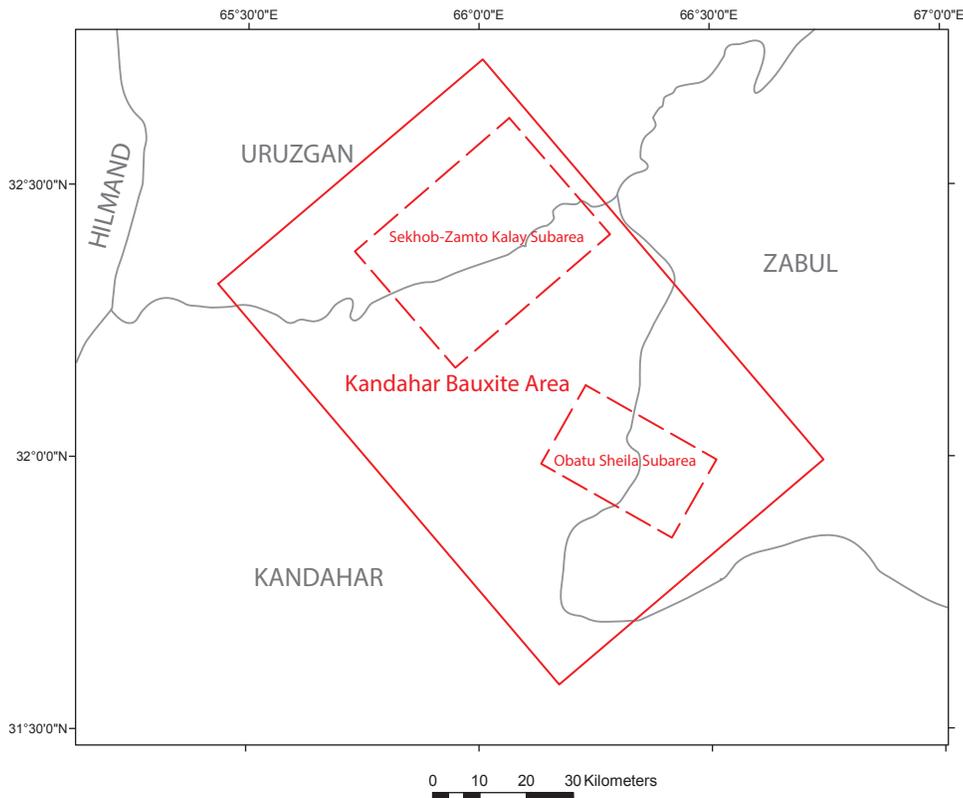
**Table 8.** Chemical analysis for Obatu Sheila II and III (modified from Dovgal and others, 1971).

[ID, identifier; m, meter]

Number	Sample ID	Sample type	Length (m)	Location	Content, in weight percent		Ratio
					Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	
1	B-44-1	Channel	1.0	#44	44.95	13.50	3.33
2	B-44-2	Channel	1.0	#44	46.67	9.57	4.88
3	B-44-3	Channel	1.0	#44	46.66	11.95	3.90
4	B-44-4	Channel	1.0	#44	46.08	11.57	3.98
5	B-44-5	Channel	1.0	#44	44.06	13.13	3.36
6	B-44-6	Channel	2.5	#44	44.34	12.32	3.60
7	B-44-7	Channel	2.5	#44	51.94	9.40	5.53
8	B-44-8	Channel	3.0	#44	50.87	11.14	4.57
9	B-44-8a	Channel	1.0	#44	34.07	28.70	1.19
10	B-44-9	Channel	3.5	#44	31.37	33.41	0.94
11	B-44-11	Trench	2.2	#44	32.01	28.60	1.12
12	B-44-12	Trench	2.5	#44	35.53	27.09	1.31
13	B-44-13	Trench	2.5	#44	28.56	32.04	0.89
14	B-44-14	Trench	1.7	#44	35.98	20.55	1.75
15	B-44-15	Trench	1.7	#44	41.59	15.12	2.75
16	B-44-16	Trench	1.6	#44	45.44	21.50	2.11
17	B-44-17	Trench	3.5	#44	46.83	15.56	3.01
18	B-47-1	Channel	3.0	#47	34.16	18.08	1.89
19	B-47-2	Channel	3.0	#47	32.25	27.00	1.19
20	B-47-3	Channel	3.0	#47	47.58	7.07	6.73
21	B-47-4	Channel	1.0	#47	44.42	11.28	3.94
22	B-47-5	Channel	1.0	#47	48.40	14.04	3.45
23	B-47-6	Channel	3.5	#47	31.44	29.83	1.05
24	B-48-1	Channel	2.0	#48	48.18	22.85	2.11
25	B-48-2	Channel	3.0	#48	51.75	14.38	3.60
26	B-48-3	Channel	1.5	#48	49.00	15.08	3.25
27	B-48-4	Channel	1.5	#48	47.72	9.81	4.86
28	B-48-5	Channel	2.2	#48	32.53	29.17	1.12
29	B-77-1	Trench	1.9	#77	40.00	18.94	2.11
30	B-77-2	Trench	2.4	#77	42.33	21.16	2.00
31	B-77-3	Trench	3.6	#77	50.59	13.18	3.84
32	B-77-4	Trench	3.9	#77	31.41	25.92	1.21
33	B-78-1	Trench	2.5	#78	52.10	15.07	3.46
34	B-78-2	Trench	2.5	#78	50.18	12.45	4.03
35	B-78-3	Trench	2.0	#78	45.97	18.21	2.52
36	B-79-1	Trench	2.5	#79	36.76	28.27	1.30
37	B-80-1	Trench	0.65	#80	27.37	39.00	0.70
38	B-80-2	Trench	0.5	#80	25.78	35.05	0.74
39	B-84-1	Pit hole	0.37	#84	5.26	3.70	1.42
40	B-84-2	Pit hole	0.1	#84	4.47	4.57	0.98
41	B-84-3	Pit hole	0.1	#84	54.20	15.15	3.58

### Tor Ghar Bauxite Deposit

The Tor Ghar bauxite deposit (Abdullah and others, 2008; Dovgal and others, 1971; 32°15'44" to 32°18'19" N., 66°00'19" to 66°03'07" E.) is within the Sekhab-Zamto Kalay subarea as shown in figure 14. The development area of productive bauxitic deposit of Vargach Formation is 8 km<sup>2</sup>. The bauxite-bearing layer is 3.5 to 4.0 m thick along the strike and extends 1.5 km. The bauxite-bearing rocks are greenish gray and stony. Chemical analysis of three composite ore samples from bauxitic rocks yielded variable alumina and silica content: Al<sub>2</sub>O<sub>3</sub>, 10.6 to 58 wt %; SiO<sub>2</sub>, 42.71 to 69.77 wt % (Dovgal and others, 1971).



**Figure 14.** Location of Kandahar Bauxite Area and subareas in Kandahar, Uruzgan, and Zabul Provinces (from Abdullah and others 2008; Dovgal and others, 1971).

### Archa Ghar Bauxite Deposit

The Archa Ghar bauxite deposit (Abdullah and others, 2008; Dovgal and others, 1971, 32°24'55" to 32°28'00" N., 66°12'02" to 66°09'28" E.) is on the southeastern slope of the Archa Ghar Ridge, also within the Sekhab-Zamto Kalay subarea as shown in figure 14. The developed area of productive bauxitic deposits is 3.0 km<sup>2</sup>. The thickness of the bauxite-bearing layer is 2.5 to 8 m along the strike and extends as far as 4.0 km (based on aerial photography). The bottom of the layer (0.5 to 2.0 m) contains pisolitic, brown-, claret-, and green-colored bauxite-bearing rocks with clayey cement. The amount of pisolites is 10 to 15 wt % of the rock mass. The top part of the layer (2.0 to 6.0 m) contains bauxite-bearing sandstone and conglomerate with local pisolites. Two composite samples were collected from the bauxite-bearing rocks. Chemical analysis showed Al<sub>2</sub>O<sub>3</sub> at 7.95 to 23.62 wt % and SiO<sub>2</sub> at 10.87 to 28.30 wt % (Dovgal and others, 1971).

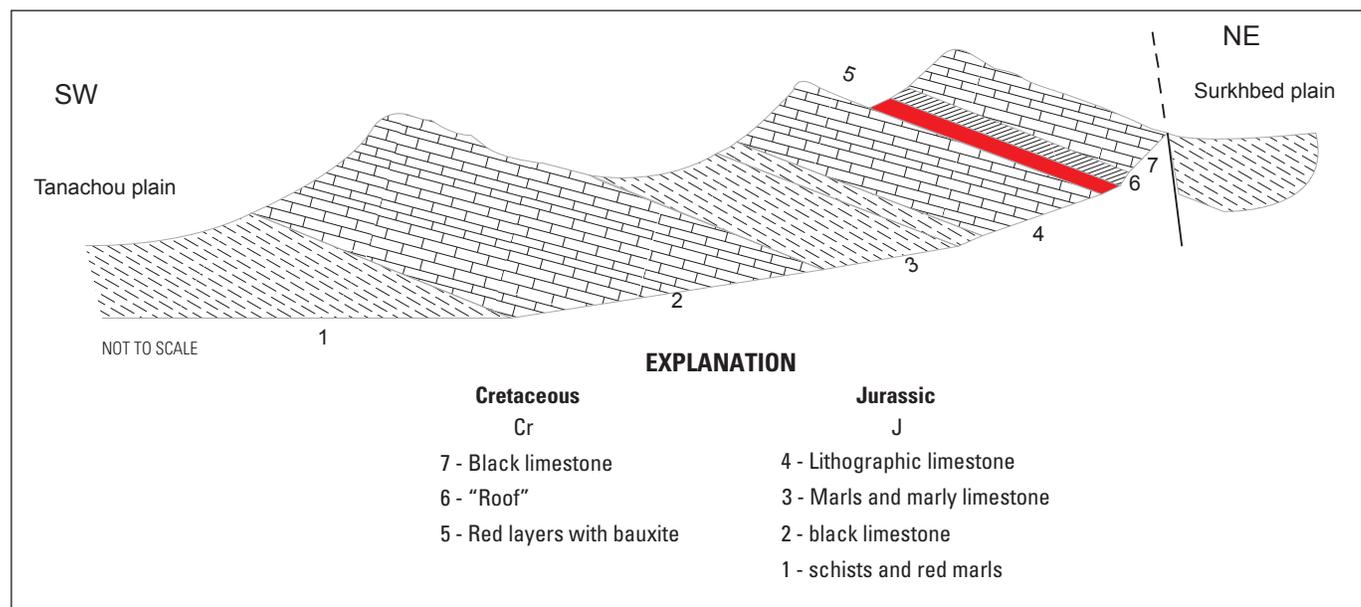
### Zamto Kalay Bauxite Deposit

The Zamto Kalay bauxite deposit (Abdullah and others, 2008; Dovgal and others, 1971; 32°22'19" to 32°23'26" N., 66°10'06" to 66°08'42" E.; fig. 14) is 2 km to the northwest from Zamto Kalay village. The area of productive bauxitic deposits of Vargach Formation is 1.7 km<sup>2</sup>. The bauxite-bearing layer is 7.5 to 10 m thick along the strike and extends as far as 0.6 km. Bauxite-bearing rocks are greenish-gray, stony, and pisolitic. The bottom of the layer (1.5 to 4 m) is composed of bauxite-bearing rocks with 10 to 15 wt % of pisolites cemented by clay cement. The top of the layer (approximately 6.0 m) contains sandstones with scarce pisolites. The bauxite-bearing rocks were not sampled in this area (Dovgal and others, 1971).

## Uruzgan Province, Tirin Block

## Surkhbet Bauxite Deposits

The Surkhbet bauxite area consists of two deposits, Surkhbet I and Surkhbet II, which are 50 km from Tirin and 130 km from Kandahar, at 2,000 m altitude, in Uruzgan Province. The area is mountainous, with moderate relief and large lowlands. Water resources are scarce in this area. The ridge between Tanachou and Surkhbet plains, as shown in figure 15 (Dovgal and others, 1971).



**Figure 15.** Profile of section of Surkhbet bauxite deposit in Uruzgan Province (modified from Lapparent, 1969).

The Surkhbet I bauxite deposit (Abdullah and others, 2008; Dovgal and others, 1971; 32°20'11" to 32°22'50" N., 66°03'21" to 66°01'18" E.) is within the Sekhob-Zamto Kalay subarea as shown in figure 14 and is 2 km to the south from Surkhbet village. The area of productive deposits for bauxite is 3 to 4 km<sup>2</sup>. The bauxite-bearing layer is 1 to 3 m thick along the strike and extends as far as 6 km. Bauxite-bearing rocks are greenish gray, greenish-olive black and claret red, stony, and pisolitic. The rocks are made up of 15 to 30 vol % pisolites (2 to 10 millimeters [mm] in diameter). The top of the layer is eroded, and bauxite-bearing rocks are included as fragments in the overlying limestone. Two composite samples were collected from bauxite-bearing rocks. The chemical analysis showed Al<sub>2</sub>O<sub>3</sub> from 19.04 to 27.96 wt % and SiO<sub>2</sub> from 19.08 to 28.36 wt % (Dovgal and others, 1971).

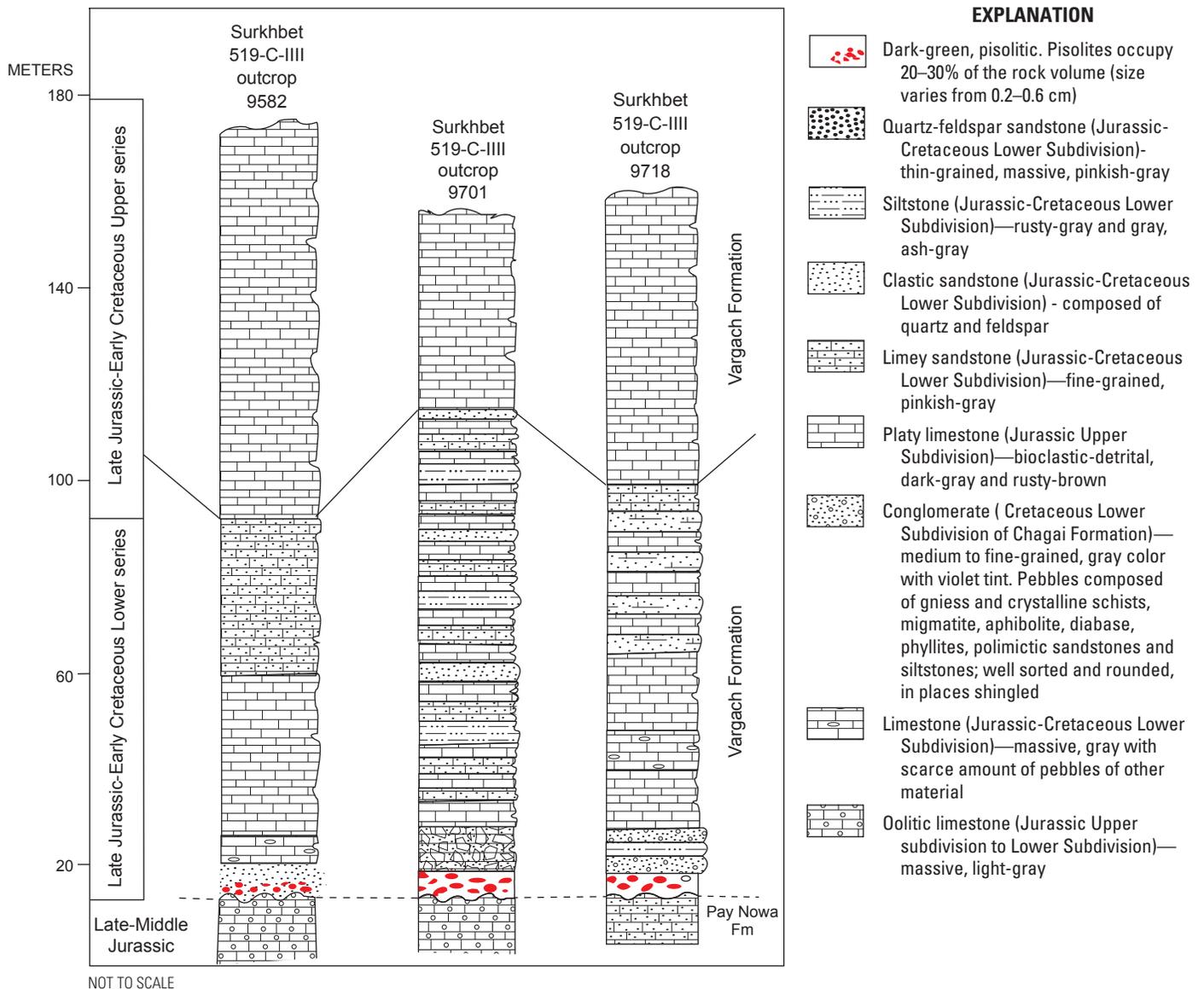
The description of beds by Lapparent (1969) is modified here as follows (chemical analyses from Lapparent, 1969, are in table 9):

Bed	Description
7	Massive recrystallized black limestone with corals and other fossil remains.
6	Black limestone beds.
5	Brecciated white felsic rhyolite that is present throughout the syncline.
4	Cretaceous red conglomerates with angular Jurassic limestone blocks. This unit thickens from northeast to southwest and is apparently concordant with the bauxite-bearing beds below.
3d	Black limestone.
3c	Beds with ripple marks.
3b	Yellowish limestone.
3a	Black calcareous limestone with traces of aluminum.
2	Red sand with calcareous limestone and pisolitic bauxite.
1	Early Jurassic, calcareous white and red lithology, forms cliff. The surface of the Early Jurassic layer is corroded and is iron stained.

**Table 9.** Analysis of three samples from the Surkhbet bauxite deposit (from Lapparent, 1969).

Loss on ignition	Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	Fe <sub>2</sub> O <sub>3</sub>	TiO <sub>2</sub>	CaO (carbonate)
23.90	9.90	9.60	27.80	0.50	28.00
7.70	38.00	37.80	10.80	2.10	Traces
14.80	17.50	16.80	34.00	1.30	15.60

The Surkhbet II bauxite deposit (Abdullah and others, 2008; Dovgal and others, 1971; 32°22'29" to 32°23'14" N., 66°04'18" to 66°03'49" E., figs. 14 and 16) is 1.5 km to the east of Surkhbet village. The area of productive bauxitic deposits is 0.6 km<sup>2</sup>. The bauxite-bearing layer is 2 to 5 m thick along the strike and extends as far as 1.2 km. The color, the texture, and the amount of pisolites are similar to those of bauxite-bearing rocks of the Surkhbet I bauxite deposit. The bauxite-bearing rocks were sampled by six composite samples. Chemical analysis showed Al<sub>2</sub>O<sub>3</sub> from 12.0 to 38.32 wt % and SiO<sub>2</sub> from 10.93 to 45.26 wt % (Dovgal and others, 1971).



**Figure 16.** Correlation of Vargach Formation for Surkhbet deposits in Kandahar Province (from Dovgal and others, 1971).

Doubalagh Bauxite Deposit

The Doubalagh area near Surkhbet deposit was visited and trenched by Technoexport engineers in November 1969. The dip is approximately 25°. The variation in facies was observed in the northern part of the valley. The red layer is approximately 15 m thick and contains red limestone, and bauxite is enriched in ferruginous pisolites (fig. 17). The ore appears in lenticular shape and of poor quality. It does not appear interesting from an industrial point of view (Dovgal and others, 1971).

Sekhab Bauxite Deposit

The Sekhab bauxite deposit (Abdullah and others, 2008; Dovgal and others, 1971; 32°24'08" to 32°25'29" N., 65°55'59" to 65°58'11" E.) is 2.5 km east of Sekhab village. The area of productive bauxitic deposits is 3.0 km<sup>2</sup>. The basal bauxite bed is 0.8 to 1.0 m thick and contains bauxite fragments which grade along strike into dolomites and sandy limestone of rusty-claret and cherry color. The basal bauxite bed does not have any potential for high grade bauxite (Dovgal and others, 1971).

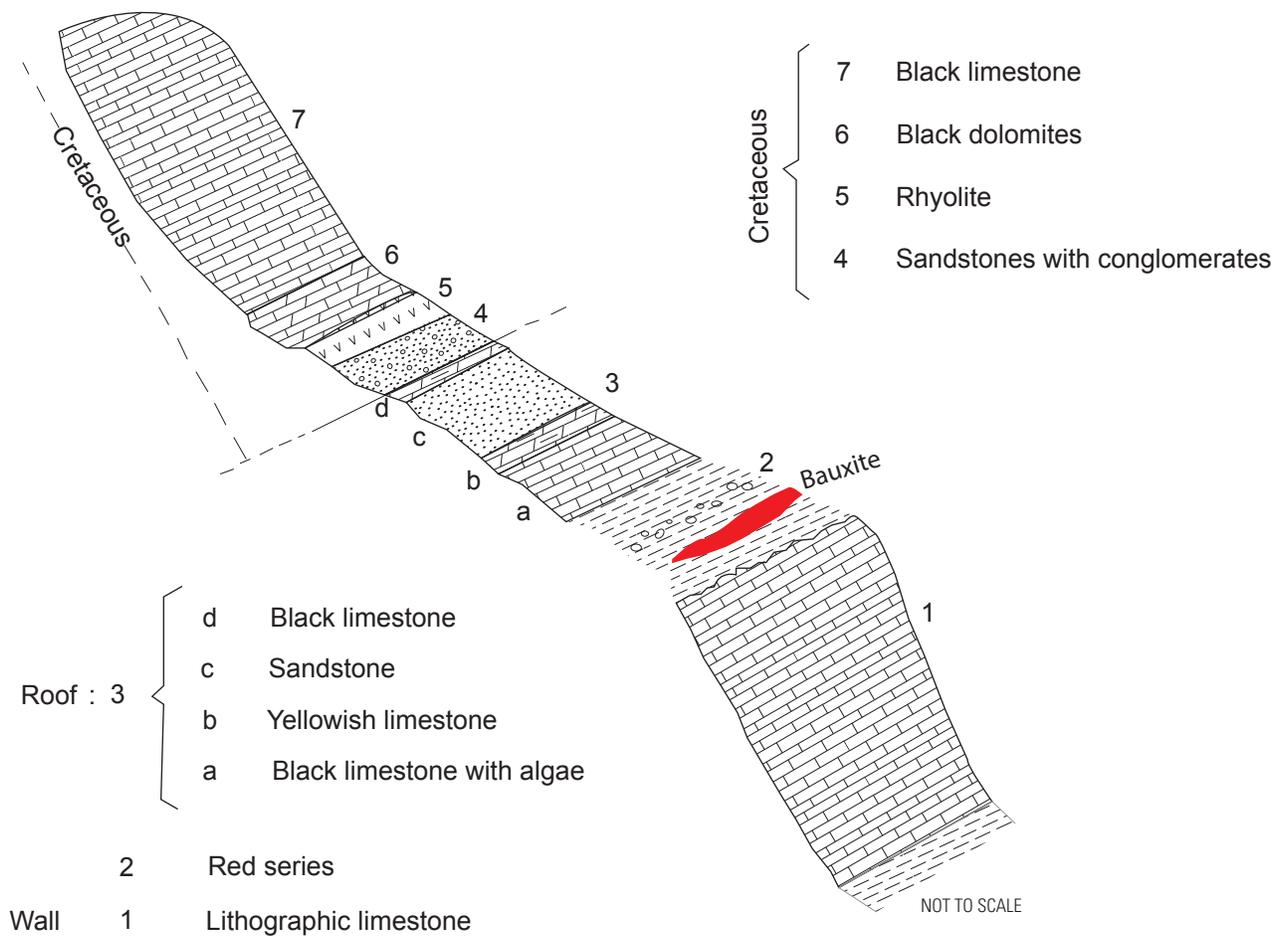


Figure 17. Detailed profile of Surkhbet and Doubalagh (modified from Lapparent, 1969).

## Northern Afghanistan Platform

The Northern Afghanistan Platform occupies the northern part of the country, beginning from Firuz-Koh to Hindukush Ridges, extending through Badakshan to the Amu-Dariya River, and ending in the southeast at the Hari Rod fault system. The platform is characterized by Hercinian folding and Jurassic to Paleogene sedimentary cover.

### Baghlan Province, Surkhob Zone

#### Tala Barfak (Nalag) Bauxite Occurrence

The Tala Barfak (Nalag) bauxite occurrence (Abdullah and others, 2008; 35°25'16" N., 68°09'20" E.) is slightly to the northwest from the Tala Wa Barfak village in Baghlan Province (figs. 2 and 3). The paleosol is developed on an erosion surface on Triassic volcanic rocks, is irregular in thickness, and is overlain by Lower Jurassic sediments. The lower part of the stratigraphic section is up to 5 m thick (usually 0.3 to 1.5 m) and is a saprolite with altered ferruginous brown volcanic rocks. This altered saprolite is overlain by bleached, lumpy, dense clays. The clays are up to 5 m thick (usually 3 m) and contain primary structure in places. The clays are overlain by dense foliated, lumpy, pisolitic bauxite (1.5 to 2 m thick), which is interbedded with pink, dense, limy bauxite, 0.6 to 1 m thick. The deposits are overlain by 0.5 m of gray, foliated, clayey bauxite with small pisolites (Sborshchikov and others, 1973).

The lower and middle part of the paleosol are enriched in silica and iron oxide. The aluminum oxide increases toward the top. The thickness of the alumina rich rocks does not exceed 3 m. The bauxite occurs as at least 10 separate lenses at the top of the paleosol: each lense is as much as 4 m thick and as much as 200 m long (Sborshchikov and others, 1973).

The text of the report by Abdullah and others (2008) indicated that 18 samples enriched in aluminum oxide were collected in this deposit and recorded in the table; however, the table is in the Russian version of the report, which is missing.

According to the  $\text{SiO}_2$  calculation, (1) two of the samples are referred to as low-iron sandy bauxites, (2) five of the samples are referred to as low-iron clayey bauxites, and (3) one sample (5138) with silicic modulus ( $\text{Al}_2\text{O}_3:\text{SiO}_2$  ratio) 2.62 is bauxite of industrial grade (Sborshchikov and others, 1973). The gray to pink bauxite is pisolitic. The pisolites are 2 to 4 mm in diameter and consist of boehmite cemented by a mixture of cryptocrystalline kaolinite with boehmite. This bauxite bed is in the upper part of the paleosol and is overlain by Jurassic coal-bearing deposits. The lower part of the bed contains a bauxitic kaolinite. The bauxite contains 52.34 wt % alumina, 19.9 wt % silica, 16.5 wt % iron oxide, 1.4 wt % calcium oxide, and 0.75 wt % magnesium oxide, with the  $\text{Al}_2\text{O}_3:\text{SiO}_2$  ratio being 2.6. Chemical analyses of the other varieties of clayey rocks from the bauxite-bearing unit suggest that these are partly low-iron, clayey bauxites with a 0.98 to 2.17  $\text{Al}_2\text{O}_3:\text{SiO}_2$  ratio and partly low-iron, sandy bauxites with 0.82 wt % and a lower  $\text{Al}_2\text{O}_3:\text{SiO}_2$  ratio. Because of the small size, this occurrence is of no practical value (Sborshchikov and others, 1973).

The Tala Barfak (Nalag) occurrence is not recommended for further investigation based on the low percentage of  $\text{Al}_2\text{O}_3$ . However, it can serve as an indication of finding more occurrences of higher quality. The suggested areas for further work are (1) areas adjacent to the confluence of Ashraf River south bank of Surkhob River to the northeast from Tala Wa Barfak village, (2) in the basin of Geryrud River, and (3) the area along both sides of Surkhob River in the area of Kaushandos-Ishpushtagan (Sborshchikov and others, 1973).

## Estoma Bauxite Occurrence

The Estoma bauxite occurrence (Sborshchikov and others, 1973; 35°26'08" N., 68°11'16" E.; fig. 18) is at the mouth of the Estoma River, which is the north tributary of Surkhob River in Baghlan Province. The bauxite deposits are at the base of Jurassic coal-bearing deposits. Bauxites compose four layers, which are 2 to 4 m thick and as much as 70 m long. The bauxite is gray and light pink and contains fine pisolites. The pisolites have the following chemical content:  $\text{Al}_2\text{O}_3$ , 52.34 wt %, and  $\text{SiO}_2$ , 19.95 wt %. The paleosol is approximately 20 to 25 m thick. The weathered paleosol is widespread on top of the volcanics. The paleosol was trenched at two intersections over 2 km apart and channel sampled (fig. 18). The section of the trenches from bottom to top follows (Sborshchikov and others, 1973):

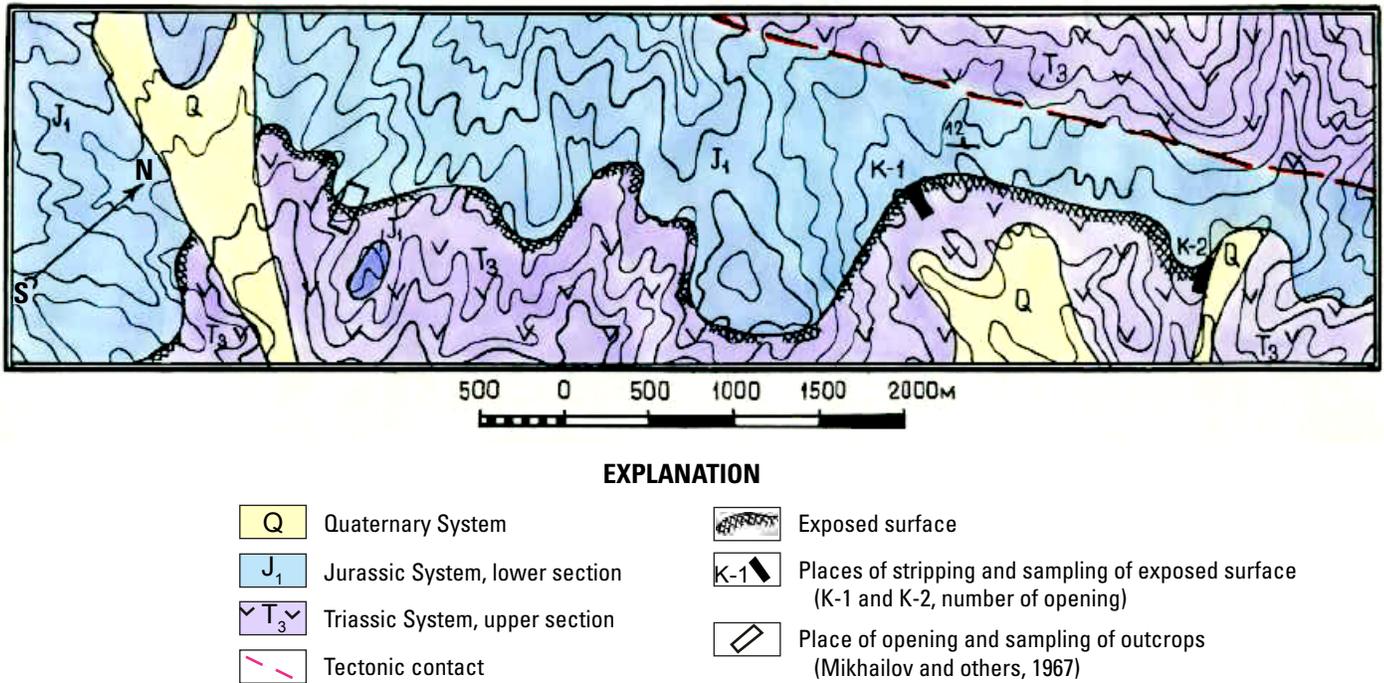
Bed	Description	Thickness (meters)
4	Lower Jurassic conglomerates overlie the soil profile.	
3	Paleosol is mostly white with gray-bluish, bluish and brownish tints interbedded with 6- to 8-cm-thick, flaky-loamy clay. The weathering intensifies upward with increase of clay layers.	4–6
2	Light-gray to white with bluish tint, paleosol with enclosing 8- to 10-cm-thick dark-gray to black rocks. The dark-gray to black rocks are probably the weathered volcanic tuffs.	3–5
1	Light-gray to white volcanic rocks, in highly weathered saprolite; in places the primary structure appears in uneven forms.	5–12

The chemical analyses of channel samples that were collected from the weathered crust are listed in table 10. A high concentration of alumina was not identified in the sampled rocks.

**Table 10.** Geochemical results from Estoma bauxite occurrence (Sborshchikov and others, 1973).

[ID, identifier]

Number	Sample ID	Content, in weight percent				
		$\text{SiO}_2$	$\text{Al}_2\text{O}_3$	CaO	MgO	S
1	52	62.26	13.38	2.68	0.42	0.30
2	53	63.85	13.03	2.68	0.57	0.35
3	54	60.16	14.69	0.78	2.10	0.35
4	55	40.64	10.62	15.82	8.42	0.14
5	56	65.78	14.23	1.87	0.53	0.28
6	57	60.17	13.71	1.85	1.35	0.17
7	58	58.81	15.56	2.55	0.45	0.28
8	59	64.54	12.88	2.52	0.39	0.39
9	60	62.90	12.13	4.02	0.87	0.18
10	61	63.90	11.35	4.27	0.63	0.11
11	62	62.57	11.81	4.91	0.68	0.08
12	63	65.36	12.99	2.92	0.20	0.12
13	64	63.71	12.78	3.78	0.86	0.12
14	65	63.71	12.32	3.90	0.37	0.15
15	66	65.45	13.05	3.04	0.18	0.03
16	67	63.13	11.73	4.62	0.39	0.06
17	68	63.80	12.97	3.92	0.22	0.06
18	69	65.43	12.82	3.62	0.36	0.06



**Figure 18.** Schematic geologic map of the Estoma bauxite occurrence (Mikhailov and others, 1967).

### Eshpushta Bauxite Occurrence

The Eshpushta bauxite occurrence (Abdullah and others, 2008, 35°18'44" N., 68°06'22" E.) is in Baghlan Province. The bauxite occurs at the top of a paleosol developed on an erosion surface on top of Upper Triassic volcanic rocks. It occurs as a layer 300 to 400 m long and 1 to 3 m thick. The bauxites are light gray and pink and contain small pisolites (Salah and others, 1977), very similar to those in the Estoma occurrence.

## Summary

Table 11 summarizes the previous discussions of locations, types, and quality of the bauxite occurrences and deposits that were compiled and analyzed in this report. The known resources of bauxite-bearing rocks are widespread in Afghanistan; the possibility of high grade bauxite deposits is low. There may be undiscovered bauxite-bearing rocks. Future exploration for mineral resources in Afghanistan may help to identify additional undiscovered bauxite-bearing deposits of economic value.

**Table 11.** Summary characteristics of selected bauxite occurrences and deposits in Afghanistan.

[—, unknown]

Name	Province	Structural zone	Age	Formation	Occurrence/deposit	Reserves (million tons)	Geo-chemistry data available?	Grade (Al <sub>2</sub> O <sub>3</sub> content, in weight percent)
Kohe-Safed	Ghor	Haftkala	Upper Permian	Pamir	Occurrence	—	Yes	<50
Tanura-II	Ghor	Haftkala	Triassic	Limestone	Occurrence	—	Yes	<50
Dagane-Doi	Ghor	Haftkala	Lower Permian	Limestone	Occurrence	—	Yes	<30
Qarghanaw	Ghor	Qarghanaw	Triassic	Dolomite	Occurrence	—	No	—
Shewa	Badakshan	North Pamir	Lower Permian	Dolomite	Occurrence	—	No	—
Char-Qala	Ghazni	Arghandab	Lower Permian	—	Occurrence	—	Yes	<50
Turghan	Zabul	Arghandab	Permian	Chohan	Occurrence	—	No	—
Sokhjai	Zabul	Arghandab	Permian	Chohan	Occurrence	—	No	—
Tangi	Zabul	Arghandab	Permian	Chohan	Occurrence	—	No	—
Obatu Sheila I	Kandahar	Arghandab	Jurassic	Vargach	Deposit	7.247	Yes	<50
Obatu Sheila II	Kandahar	Arghandab	Jurassic	Vargach	Deposit	—	Yes	<50
Obatu Sheila III	Kandahar	Arghandab	Jurassic	Vargach	Deposit	—	Yes	<50
Surkhbet I	Kandahar	Tirin	Jurassic	Vargach	Occurrence	—	Yes	<35
Surkhbet II	Kandahar	Tirin	Jurassic	Vargach	Occurrence	—	Yes	<40
Zamto-Kalay	Kandahar	Arghandab	Jurassic	Vargach	Occurrence	—	No	—
Tor Ghar	Kandahar	Arghandab	Jurassic	Vargach	Occurrence	—	Yes	—
Archa Ghar	Kandahar	Arghandab	Jurassic	Vargach	Occurrence	—	Yes	<25
Sekhab	Kandahar	Tirin	Jurassic	Vargach	Occurrence	—	No	—
Doubalagh	Kandahar	Tirin	Jurassic	Vargach	Occurrence	—	No	—
Nalag	Baghlan	Surkhob	Triassic	Volcanic rocks	Deposit	4.5	Yes	52
Estoma	Baghlan	Surkhob	Triassic? Jurassic?	Volcanic rocks	Occurrence	—	Yes	<20
Eshpushta	Baghlan	Surkhob	Triassic	Volcanic rocks	Occurrence	—	No	—

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