Chapter 16A. Introduction to Industrial Minerals

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Abstract

This chapter is a synopsis of the industrial minerals summary chapters (chapters 17A through 26A) that follow. Each of those chapters includes an assessment of selected industrial mineral resources in specific areas of interest (AOIs) in Afghanistan, including barite, carbonatite, celestite, clay, fluorite, gypsum, limestone (industrial grade), magnesite, pegmatite, talc, and travertine. Chapters on cement and coal are also included (although coal is not a nonfuel mineral, it is included with the assessments of industrial minerals because of its importance to cement production). This chapter provides a brief overview of the geologic settings of the AOIs that are described in the following chapters. The summary chapters provide more detailed information on what industrial minerals are present in these areas of interest, the nature of their respective depositional settings, and which commodities may offer significant economic potential for Afghanistan.

All the chapters on industrial minerals (chapters 17 through 26) summarize and interpret results from studies of industrial minerals in Afghanistan that began in the mid-20th century and that culminate with this report. They contain updated hyperspectral data and geohydrologic assessments. This study has been a cooperative effort of the U.S. Geological Survey, the U.S. Department of Defense Task Force for Business and Stability Operations, and the Afghanistan Geological Survey. Supporting data and other information on industrial minerals in Afghanistan are available from the Ministry of Mines in Kabul.

16A.1 Introduction

This chapter is a guide to subsequent chapters that provide updated information on the assessment of industrial mineral resources in Afghanistan. Much of the material summarized here and in subsequent chapters has been gleaned from an array of reports written since the early 1950s. These early studies, which provide much of the factual basis for the updates reported here, were conducted by collaborations between geoscientists from the former Union of Soviet Socialist Republics (USSR), the British Geological Survey, the U.S. Geological Survey (USGS), countries of Eastern Europe, and the Afghanistan Geological Survey (AGS). Data on fundamental Afghanistan geology generated during this early period, combined with a preliminary assessment by the USGS in 2007 (Peters and others, 2007), provided the framework for this updated report.

Throughout the period 2009–11, the USGS, in collaboration with the AGS, integrated newly acquired geochemical, geologic, geophysical, hydrologic, and remote sensing data into comprehensive information packages focused on specific areas of interest (AOIs) defined according to near-term economic potential for mineral resource development. These AOI packages contain information on mineral prospects and occurrences, some of which have been quantitatively assessed for grade and tonnage, and most of which are genetically related to known deposits elsewhere. Digital data and archival information on nonfuel minerals for each of the 24 AOIs are available through the AGS Data Center in Kabul (Afghanistan Ministry of Mines). Of the 24 AOIs, 10 AOIs have been identified as hosting industrial minerals of potential economic value to Afghanistan; the data on industrial minerals in the 10 AOIs are reviewed in this introductory chapter. An additional chapter covering the cement sector in Afghanistan is included with the chapters on specific AOIs; the cement sector is not associated with a specific AOI. It should be noted that areas outside of the identified AOIs could also have mineral resource potential, but the potential is not directly measurable currently because field work at many of the sites has been limited or not possible.

Industrial minerals are broadly defined as nonfuel nonmetallic geologic minerals of potential economic value. Among the large set of generally recognized industrial minerals, those reported in the chapters reviewed here include barite, bauxite, carbonatite, celestite, clay, coal, fluorite, gypsum, halite limestone, magnesite, pegmatites, salt, sulfur, talc, and travertine. Some metallic minerals, such as aluminum and titanium, are also regarded as industrial materials, depending on their application, and especially when used in their nonmetallic form, such as aluminum oxide and titanium oxide. Although coal does not qualify as a nonfuel mineral, it is covered in chapter 19A (Dudkash AOI) because of its importance to cement production in the region. Figure 16A–1 shows the locations of the AOIs identified for industrial minerals.

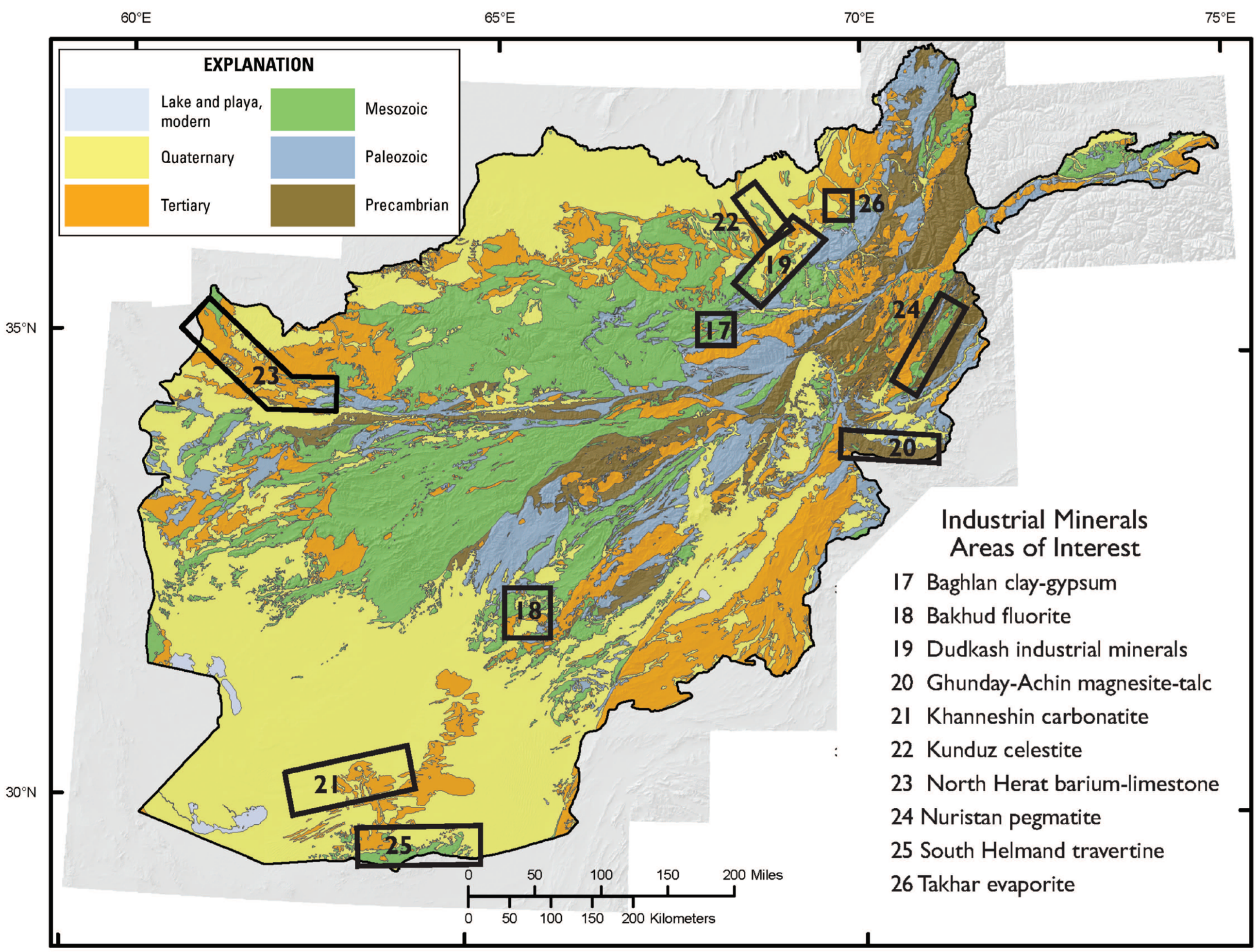

Figure 16A–1. Index map showing locations of areas of interest for industrial minerals. Map from U.S. Geological Survey, Western Mineral and Environmental Resources Science Center, Digital Information and Analysis Project; base maps from Doebrich and Wahl, 2006).

The summary chapters that discuss the AOIs for industrial minerals are as follows:

16B	Cement in Afghanistan	22A	Kunduz Celestite
17A	Baghlan Clay-Gypsum	23A	North Herat Barium-Limestone
18A	Bakhud Fluorite	24A	Nuristan Pegmatite
19A	Dudkash Industrial Minerals	25A	South Helmand Travertine
20A	Ghunday-Achin Magnesite-Talc	26A	Takhar Evaporite
21A	Khanneshin Carbonatite		

16A.1.1 Geologic Setting

Figure 16A–2 shows a highly simplified tectonic map of the major blocks and faults in Afghanistan. Of the 10 industrial mineral AOIs, one-half are located north of the Herat fault system (chapters 17, 19, 22, 23, and 26) and one-half are distributed along a wide southwest-to-northeast trending zone defined by the complex that includes the Helmand, the Kabul, and the Nuristan blocks and the Tirin-Arghandab accretionary zone (chapters 18, 20, 21, 24, 25). Of the five AOIs located south of the Herat suture zone, the Khanneshin carbonatite AOI (chapter 21) and the south Helmand travertine AOI (chapter 25) are located along the south-central margin of the Helmand block, and the Bakhud fluorite AOI (chapter 18) is located on the southeastern margin of the Helmand block where it is intersected by the southwest-to-northeast trending Tirin-Arghandab interfluves; the Ghunday-Achin magnesite-talc AOI (chapter 20) and the Nuristan pegmatite AOI (chapter 24) are located on the Nuristan block.

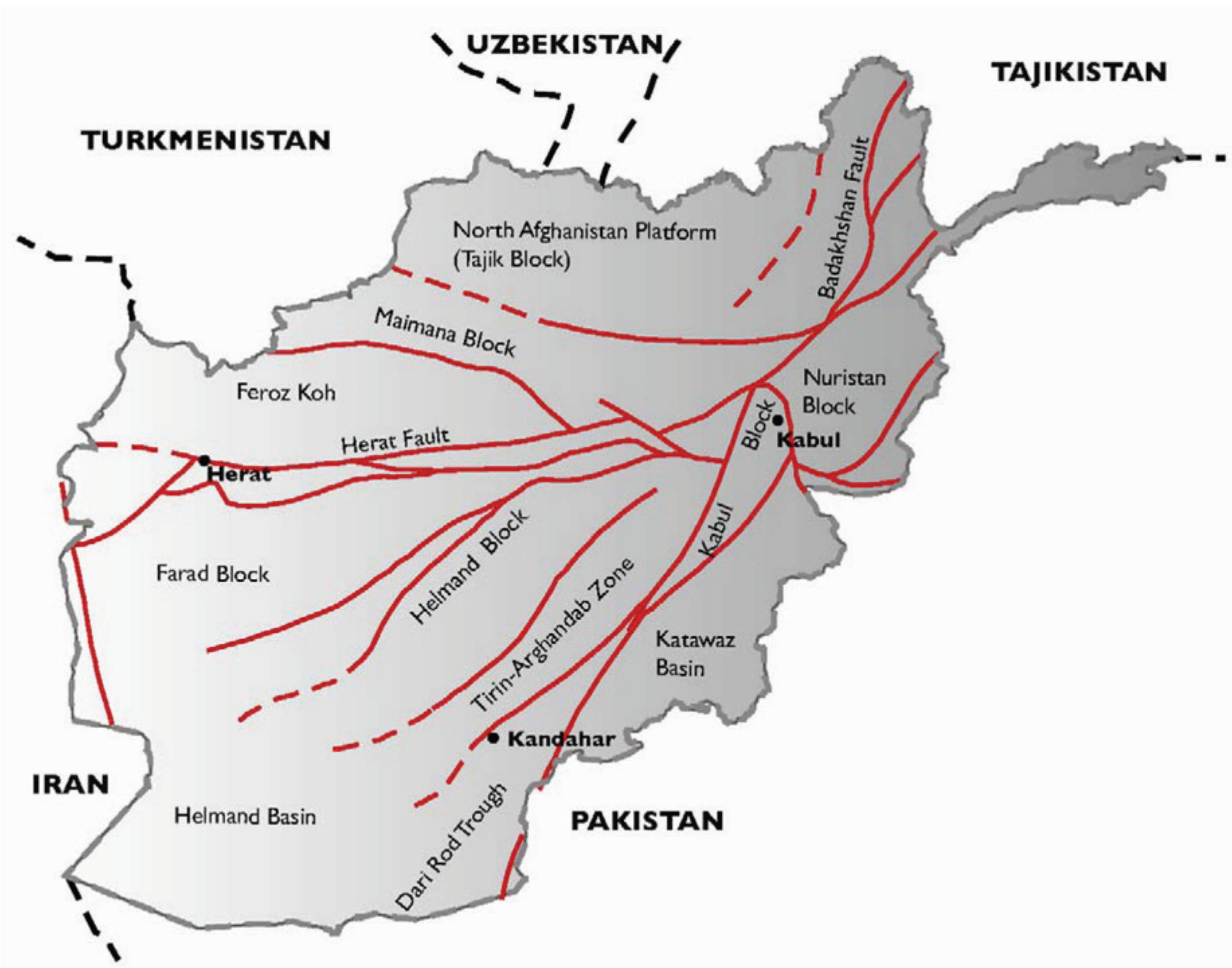

Figure 16A–2. Map showing major blocks and faults in Afghanistan.

It has been proposed that the Tirin-Arghandab zone and the highly fractured terrane proximal to the zone emerged as a consequence of the Cimmeride Orogeny (Sengor, 1990). During the Triassic Period, the northern edge of the Gondwanaland supercontinent broke away and drifted north, resulting in at least two distinct collisions that closed the ancient Paleo-Tethys Ocean (Whitney, 2006). The first collision brought the Farad block against the Tadjik block and created the Paropamisus Range that defines the northern boundary of the Helmand Basin and the suture recognized as the Herat fault system (which comprises the main Hari Rod fault and the Qarghanaw fault). This collision was completed in the

Early Cretaceous Period. The second collision, most likely completed by the Late Cretaceous Period, brought the Helmand block against the Farad block. The Panjao Suture, which is a zone of ophiolitic mélange that separates the Farad and Helmand blocks, verifies this conjunction (Moores and Fairbridge, 1997). The extent of the suture zone suggests that a sizable ocean existed at one time between the Farad and the Helmand blocks.

After a period of relative quiescence, tectonic activity continued during the Cretaceous Period to early Tertiary Period. During this time, India drifted north from Gondwanaland and collided with the Afghan block at its southern margin, producing the Tirin-Arghandab accretionary zone and the Dari Rod Trough. Evidence of this is preserved as the Kandahar volcanics, which mark the beginning of a volcanic arc on the margins of the Eurasian plate (Debon and others, 1987). The active Eurasian continental margins were intruded by subduction-related I-type granitoids in the Helmand and the Nuristan blocks. As a consequence, the geologic settings in the Khanneshin carbonatite AOI (chapter 21), the south Helmand travertine AOI (chapter 25), and the Tirin-Arghandab/Nuristan complex in southeastern Afghanistan are highly prospective for a number of different mineralization styles, most of which involve hydrothermal fluids as a source of mineral components in ore genesis. In particular, the Bakhud fluorite AOI (chapter 18), framed as it is by the Tirin-Arghandab zone and the Helmand block, has been reported to host a variety of mineral occurrences, among which include barite ($BaSO_4$), chalcopyrite ($CuFeS_2$), fluorite (CaF_2), galena (PbS), sphalerite (ZnS), and tennantite ($Cu_{12}As_4S_{13}$) (Avtonomov and Polvanov, 1976).

The geologic situation of the AOIs located north of the Herat fault and the mineralization of the industrial ores in the area are related to the Cimmeride Orogeny by virtue of the closing of the Paleo-Tethys Ocean. The Tadjik block of northern Afghanistan formed the southern margin of the Eurasian continental plate during the Permian and Triassic Periods. During this time, the paleo-latitude of the region was equatorial, giving it a tropical climate. The Paleozoic Era basement was intruded by Triassic granitoids as a result of subduction related to the first stages of the closure of the Paleo-Tethys Ocean during the Cimmeride Orogeny (Moores and Fairbridge, 1997). The pre-Jurassic basement of the North Afghan platform is unconformably overlain by a Jurassic to Middle Tertiary sedimentary rock platform cover, unconformably overlain by Neogene syn- and post-orogenic continental clastics. This cover has three units that are relevant to the industrial mineral AOIs—

1. A Late Triassic to Middle Jurassic rift succession is dominated by continental clastics. This includes thick, coarse, lenticular formations hosting coal, which is one of the commodities discussed in chapter 19A;
2. A Middle to Late Jurassic transgressive–regressive succession consisting of mixed continental and marine clastics and carbonates overlain by regressive Late Jurassic evaporite-bearing clastics; and
3. A Cretaceous succession consisting of Lower Cretaceous red beds with evaporites resting unconformably on Jurassic and older deposits. These beds are overlain (usually unconformably) by Upper Cretaceous shallow marine limestone, which forms a fairly uniform transgressive succession across most of Afghanistan. A Paleogene succession rests on the Upper Cretaceous limestones, with a minor break marked by bauxite in places. Stratigraphically, thin Paleocene to Upper Eocene limestones with gypsum are overlain by thin conglomerates; these transition up-section into shales.

The Neogene succession consists of a variable thickness of coarse continental sediments derived from the rising Pamir Mountains and adjacent ranges. Almost all the deformation of the North Afghan platform began in the Miocene Epoch (Brookfield and Hashmat, 2001). Thus, orogenesis north of the Herat suture zone is expected to favor the formation of different types of mineral deposits than occur south of the suture zone.

A given commodity may occur in any of a number of AOIs. Figuress 16A–3 and 16A–4 cross-reference target commodities with AOIs. Entries in figure 16A–3 represent commodities associated with the North Afghan Platform and entries in figure 16A–4 represent commodities associated with hydrothermal fluids.

	17.0A Baghlan	19.0A Dudkash	22.0A Kunduz	23.0A North Herat	26.0A Takhar Evaporite
Area (km2) →	1,800	4,922	2,266	9,684	1,148
Bauxite	Platform				
Barite				Platform	
Celestite		Platform	Platform		Platform
Clay/Brick	Platform	Platform		Platform	Platform
Clay/Fire				Platform	Platform
Clay/Porcelain					Platform
Coal	Platform	Platform			Platform
Gypsum	Platform	Platform	Platform	Platform	Platform
Limestone	Platform	Platform	Platform	Platform	Platform
Salt					Platform
Sulfur			Platform		Platform

Figure 16A–3. Target commodities in areas of interest on the North Afghan platform cross-referenced to areas of interest. km2, square kilometers.

	Bakhud and Daykundi	Ghunday-Achin	Khanneshin	Nuristan	South Helmand-Travertine
Area (km2) →	3,638	5,844	6,628	3,490	1,365
Fluorite	Hydrothermal				
Magnesite		Hydrothermal			
Talc		Hydrothermal			
Carbonatite			Hydrothermal		
Pegmatite				Hydrothermal	
Travertine					Hydrothermal

Figure 16A–4. Target commodities in areas of interest south of the Herat suture zone cross-referenced to areas of interest. km2, square kilometers.

16A.1.2 Assessment Methods

The purpose of the mineral assessment is the delineation of geographical tracts that are permissive, favorable, or prospective for the presence of undiscovered mineral deposits. The assessment was conducted by a team that included scientists from the USGS and the AGS. To begin the assessment, the team reviewed the geology of Afghanistan and selected appropriate deposit models. They then delineated permissive tracts for each type of deposit.

The permissive tracts were defined by the environments of formation described in the deposit model such that the probability of deposits of the type delineated occurring outside the tract is negligible (that is, less than 0.00001 to 0.000001) (Singer, 1993). Geologic maps and location maps showing the distribution and types of existing mineral deposits and occurrences were used in outlining these permissive tracts. Geophysical and geochemical maps, as well as knowledge about the exploration history, were used in tract delineation and estimation. One important factor in assessment of a particular tract was the degree of previous and current exploration activity.

The team reviewed the descriptive characteristics and grade and tonnage data for known deposits in all defined tracts and decided which deposit type and grade and tonnage models were appropriate for the tract. Reasoning by analogy to other parts of the world where similar deposits are present, the undiscovered deposits estimated in the area were assumed to be similar in grade and tonnage to known examples. Whenever possible, the team then estimated the number of undiscovered deposits in the permissive tract. These estimates are subjective and are expressed in terms of the least number of deposits for specified cumulative probabilities. Commonly, subject matter experts were asked for the least number of deposits at a specified cumulative probability, and the answer is a specific number of deposits. A series of these questions for several quantiles (generally 0.9, 0.5, 0.1, and 0.05) was used to develop a cumulative probability distribution. Teams used a variety of methods to arrive at a consensus. The most common method was simply to continue the discussion until all agreed; however, many tools, including deposit density estimates and assumptions about exploration adequacy, were used to guide the final estimates (Singer, 1993).

The result of the estimation process is a probability distribution of numbers of undiscovered deposits that are consistent with the grade and tonnage model for a given deposit type. Estimates can be guided by counting mineral occurrences, geochemical anomalies, or exploration “plays” and assigning to each a probability of its being a member of the grade and tonnage distributions for a given deposit type. Estimates can also be guided by analogy with well-explored areas that contain known numbers of deposits and that are geologically similar to the study area. More details and the theoretical basis for these procedures can be found in Singer (1993).

As a general rule, current methods of estimating undiscovered resources are made to a depth of 1 kilometer (km) beneath the surface of the earth. Thus, if an area of permissive rock is covered by more than 1 km of rock known to be barren, or by younger sediment, it was excluded from the tract. This rationale is consistent with mining practice; direct exploration is seldom conducted at depths greater than 1 km, although extensions of mineral deposits may be explored and developed deeper (up to 3 km) once they have been discovered at shallower depths.

The most important data sources used for this assessment were the digital geologic map of Afghanistan (Doebrich and Wahl, 2006), the mineral deposit database for Afghanistan (Doebrich and Wahl, 2006), which was based on the earlier studies of Abdullah and others (1977) and the United Nations Economic and Social Commission for Asia and the Pacific (1995), along with new geophysical data collected by the USGS that is in the process of being published.

16A.2 Guide to Summary Chapters

16A.2.1 Chapter 16B—Cement in Afghanistan

Cement is the most basic of all modern building materials; hence, the availability of fairly priced cement to the construction industry in Afghanistan is of the highest priority for reconstruction of the country’s infrastructure. The demand for cement in Afghanistan is projected to exceed 5 million metric tons per year by 2012 (S.S. Sharma, Chief Financial Officer, Ghori Cement Works, written commun., November 2007); the demand is currently being met by imports from neighboring countries at prices set by foreign suppliers. The essential resources for cement production include raw materials, thermal power, electrical power, water, physical infrastructure, and human resources (skilled labor, management, finance, marketing, sales). Assessments of the raw minerals used in cement production are considered in subsequent chapters, including limestone (chapters 17A, 19A, 22A, 23A, and 26A); clay (chapters 17A, 19A, 23A, and 26A); bauxite (chapter 17A); gypsum (chapters 17A, 19A, 22A, and 26A); and coal (chapters 17A, 19A, and 26A) (fig. 16A–3). In addition to providing an assessment of the availability of industrial minerals used for cement production, chapter 16B also provides an assessment of the state of indigenous cement production in Afghanistan within the context of the country's geographical and geopolitical setting.

There are currently two potential facilities for cement production in Afghanistan; one is located south of the Hindu Kush at Jabal-e Sharaj in Parwan Province and the other is located north of the Hindu Kush at Pul-e Khumri, Baghlan Province. The plant at Pul-e Khumri has the potential to produce up to 1,800 metric tons per day, but it has insufficient electrical power and coal. The facility at Jabal-e Sharaj has not produced cement for some years, and the technology installed at the plant is 40 years old. Modernizing and completing facilities at Pul-e Khumri and upgrading facilities at Jabal-e Sharaj, redeveloping the coal mines near Pul-e Khumri, upgrading power lines for both plants, and setting up a sustainable training program for cement engineers, chemists, plant managers, and technicians would require an initial capital outlay.

16A.2.2 Chapter 17A—Summary of the Baghlan Clay-Gypsum Area of Interest

Area	1,800.32 km^2.
Provinces, districts	Baghlan and Samangan Provinces and Ruyi Du Ab, Kamard, and Tala Wa Baak districts.
Deposit type(s)	Bauxite, clay, and gypsum.
Geology	The southeastern parts of the AOI contain Paleozoic sedimentary rocks, which are overlain by Triassic, Jurassic, and Cretaceous sedimentary rocks, which are in turn overlain in the central parts of the AOI by Eocene and Neogene sedimentary rocks. Triassic granitic plutons and stocks intrude the older rocks in the eastern part of the AIO. Gypsum, clay, and bauxite deposits are most abundant in the Jurassic sedimentary rocks associated with coal. Some Eocene sedimentary rocks also contain gypsum.
Known deposits	Examples of potentially important clay, gypsum, and bauxite deposits in the AOI—with brief descriptions—are included below. Additional details and data on grade, reserve tonnage, and operational information for the deposits identified here, and for other deposits in the AOI, are provided in chapters 17A, 17B, and 17C. The listing of example deposits below is nonexclusive of other significant deposits and prospects that may be in the AOI.
Clay	Rafak, Samangan Province (35°31'49"N, 67°51'09"E). A 5-meter (m)-thick clay bed occurs in Lower Cretaceous siltstone. The clay is suitable for refractory products manufacturing.
Gypsum	Kahmard, Bamyan Province (35°18'32"N, 67°54'E). Beds consisting of massive gypsum up to 2.5 m thick and stratified gypsum ranging in thickness from 20 to 40 centimeters (cm) have been found in Upper Cretaceous-Paleocene clay and dolomite deposits. The total thickness of the gypsum unit is 20 m and the average gypsum content is 98 weight percent (wt. %).
Bauxite	Eshpushta, Baghlan Province (35º18'44"N, 68°06'22"E). A bed-shaped bauxite body that varies in thickness between 1 and 3 m and extends for 300 to 400 m has been distinguished in the weathering crust on Upper Triassic extrusive rocks. The bauxites are light gray and pinkish and contain few iron terrigenous rocks of Early to Middle Jurassic age that are 20 m thick and extend for 300 m.

16A.2.3 Guide to Chapter 18A—Summary of the Bakhud Fluorite Area of Interest

Area	3,637.53 km^2.
Provinces, districts	Kandahar and Daykundi Provinces and Nesh, Dihrawud, Tirin Kot, Chera, Sha Wali Kot, and Khakere Ghorak districts.
Deposit type(s)	Sedimentary rock-hosted fluorite and fluorite vein deposits; prospects include

	copper, iron, polymetallic skarns, and tin.
Geology	The main cluster of deposits lies in southern Daykundi Province and northern Kandahar Province and is hosted in unconformities in Triassic and Jurassic limestone sequences. A permissive tract was constructed in the Bakhud area near the settlements of Tirin Kot and Nesh in Daykundi Province and parts of northern Kandahar Province. The tract was partially defined using aeromagnetics (Sweeney and others, 2006).
Known deposits	An example of a potentially important fluorite depositional complex in the AOI—with a brief description—is included below. Additional details and data on grade, reserve tonnage, and operational information for the fluorite deposit identified below, for other styles of fluorite deposits, and for prospects of iron, copper, tin, and polymetallic skarns in the AOI, are provided in chapters 18A, 18B, and 18C. The description below is not exclusive of other potentially significant deposits and prospects that may be in the AOI.
Fluorite	Bakhud carbonate-hosted fluorite (32°27'17"N, 65°53'58"E). This example represents a hydrothermal replacement-style fluorite depositional complex that consists of tabular orebodies hosted in Upper Triassic to Lower Jurassic argillaceous-marly sediments and limestones. The deposit consists of a number of tabular zones located at the base of the angular unconformity between Upper Triassic dolomitic limestone of the Arghasu Formation and Upper Triassic to Lower Jurassic clay-marly sediments of the Arghasu Formation. There are four discontinuous mineralized zones in the north, south, east, and west that are 80 to 860 m long, 10 to 200 m wide, and 1.1 to 2.8 m thick. Alteration consists of recrystallized dolomite with silicification that is restricted to limestone in the basal Alamghar Formation. Fluorite mineralization consists of abundant calcareous fluorite associated with lead and zinc sulfide minerals and less-abundant siliceous fluorite. Accessory minerals are sphalerite, galena, chalcopyrite, tennantite, and molybdenite. Gangue minerals are pyrite, barite, ankerite, dolomite, and silica. Supergene accessory minerals are common (Avtonomov and Palvanov, 1976).

16A.2.4 Guide to Chapter 19A—Summary of the Dudkash Industrial Minerals Area of Interest

Area	4,922 km^2.
Provinces, districts	Baghlan Province in the south and main part of the AOI and Kunduz and Takhar Provinces in the north, and including the following districts: Dahana-i-Ghori, Ddushi, Pul-e Khumri, Naharin, Baghlan, Burkha, Baglani Jadid, Khost Wa Firing, Ishkamish, and Alibad.
Deposit type(s)	Brick clay, coal, celestite, dolomite, gypsum, limestone (cement grade) covered by Upper Paleozoic and Lower Mesozoic sedimentary rocks
Geology	The Dudkash Industrial Minerals AOI is underlain by Upper Paleozoic and Lower Mesozoic sedimentary rocks in the southeastern and southwestern parts of the area. These rocks are uncomformably overlain by Upper Cretaceous and Paleogene and some Jurassic sedimentary rocks that contain evaporite, limestone, and clay deposits. The rocks, in turn, are covered in large parts of the area by Quaternary basins.
Known deposits	Examples of potentially important limestone, dolomite, celestite, gypsum, brick clay, and coal deposits in the AOI—with brief descriptions—are included below. Additional details and data on grade, reserve tonnage, and operational information for the deposits identified here, and for other deposits in the AOI, are provided in chapters 19A, 19B, and 19C. The listing of example deposits

below is nonexclusive of other significant deposits and prospects that may be in the AOI.

Limestone (cement grade)	Pul-e Khumri-limestone, Baghlan Province (35°58'24"N, 68"40'56"E). Upper Cretaceous-Paleocene 300- to 500-m-thick limestone occurs over an area of several thousand square kilometers. The rock is light colored, thick bedded, and fine crystalline. A large limestone deposit has been mined to supply raw material for a cement plant located close to Pul-e Khumri This deposit consists of Danian (Paleocene) limestone beds that are 300 to 400 m thick and exposed over an area of several thousand square kilometers. The limestone is pure, containing 52 to 53 wt. % lime, 0.8 to 1.3 wt. % magnesium oxide, and 1.3 wt. % insoluble residue.
Dolomite	Dudkash-dolomite, Baghlan Province (36°00'47"N, 68°47'20"E). A 3.9-m-thick dolomite bed occurs in Lower Cretaceous siltstone, limestone, and gypsum units. In composition, the rock is almost chemically pure dolomite.
Celestite	Tangi Murch, Baghlan Province (36°16'13"N, 69°12'24"E). The Bukhara and the Suzak carbonate rock formations of Paleogene age crop out in the area. The deposit is characterized by smaller dimensions of the workable bed, and the celestine content is approximately equal to that of the Kortaw deposit. The host rock is bituminous limestone. The ore beds consist of fine- to coarse-crystalline celestite-bearing rock. Four ore beds have been located; their thicknesses range from 0.4 to 1.67 m and they have a maximum length of 170 m. The celestite content is from 29 to 77 vol. % and the specific gravity is from 3.00 to 3.94 grams per cubic centimeter (g/cm^3). The speculative reserve of the celestite ore is 85,600 metric tons (t) with an average celestite content of 53.96 vol. % and a specific gravity of 3.43 g/cm^3.
Gypsum	Dudkash-Gypsum, Baghlan Province (36°00'55"N, 68°47'30"E). The name of the Dudkash Industrial Minerals AOI is taken from the name of this mine. The occurrence comprises massive 1.5-m-thick to as much as 6-m-thick gypsum beds, which occasionally extend for 12 km in Upper Jurassic clay, siltstone, sandstone, and dolomite. The gypsum has been mined.
Brick clay	Kawkpar-clay, Baghlan Province (35°56'55"N, 68°52'36"E). Clay beds that are between 2 and 17 m thick have been found between Neogene sandstone and conglomerate beds. The clay is lumpy and slightly gypsiferous.
Coal	Karkar and Dudkash (36°02'07"N, 68°46'16"E). Four mines (Karkar, Dudkash, Ahandara, and Khurdara) and a cement works at Pul-e Khumri were privatized during 2006 and 2007. All movable and fixed assets were transferred to the private Afghan Investment Company (AIC) in April 2007 (Erreck, 2011). The mines are now operated by an AIC subsidiary, Afghan Coal LLC, with the intention to provide fuel for a proposed 25-megawatt thermal powerplant as well as to provide fuel in limited quantities for the AIC Ghori-I cement plant in Pul-e Khumri.

16A.2.5 Guide to Chapter 20A—Summary of the Ghunday-Achin Magnesite-Talc Area of Interest

Area	4,922 km^2.
Provinces, districts	The Ghunday-Achin magnesite-talc AOI lies along the border with Pakistan approximately 16 km south of Jalalabad in Nangarhar and Paktiya Provinces. The Achin and the Sherzad districts are located in southern Nangarhar Province. The Ghunday mine is located in the Sherzad district.
Deposit type(s)	Magnesite and talc
Geology	The magnesite and talc deposits are hosted within the east-west trending

Spinghar Zone, which consists mainly of Early Proterozoic metamorphic rocks (Abdullah and Chmyriov, 2008). The area in the northern part of the Ghunday-Achin magnesite-talc AOI is covered mainly by Pliocene and Quaternary conglomerate and sandstone (Doebrich and Wahl, 2006). Rocks of the Spinghar Zone may extend under the Pliocene and Quaternary cover.

Known deposits Examples of potentially important magnesite and talc deposits in the AOI—with brief descriptions—are included below. Additional details and data on grade, reserve tonnage, and operational information for the deposits identified here, and for other deposits in the AOI, are provided in chapters 20A, 20B, and 20C. The description below is nonexclusive of other significant deposits and prospects that may be in the AOI.

Talc Ghunday (Mamahel), Nangarhar Province (34°21'00"N, 70°43'12"E). This deposit consists of the northern and southern talc-bearing zones located within Proterozoic dolomitic marble. The dolomitic marble is intruded by numerous sill-like and dike-like andesite and diabase bodies, which are metamorphosed to amphibolites. Each talc zone consists of a series of elongated lenticular talc bodies, clusters of nests, and veinlets.

Achin, Nangarhar Province (34°7'12"N, 70°42'00"E). This deposit consists of a 2-km-long talc-bearing zone in Proterozoic dolomitic marble. The talc zone consists of a series of closely spaced en-echelon talc veins, pods, or deformed sheet-like bodies that are oriented subparallel to the layering in the marble.

Magnesite Achin, Nangarhar Province (34°7'12"N, 70°42'00"E). This deposit consists of two magnesite orebodies that average 33 to 70 m in thickness and 328 to 765 m in length. These orebodies are lens shaped and consist of magnesite with talc, dolomite, calcite, and quartz inclusions (United Nations Economic and Social Commission for Asia and the Pacific, 1995; Adullah and Chmyriov, 2008). Large bodies of magnesite are present at Achin but not at Ghunday.

16A.2.6 Guide to Chapter 21A—Summary of the Khanneshin Carbonatite Area of Interest

Area 5,628 km^2.

Provinces, districts The Khanneshin carbonatite AOI is located in the Rig District of Helmand Province. It is located relatively close to the Helmand River and 168 km southwest of Lashkar Gah.

Deposit type(s) Two types of rare earth elements (REE) mineralization were observed.

Type 1 REE mineralization consists of semiconcordant, symmetrically banded veins enriched in khanneshite, barite, strontianite, and secondary REE minerals (synchysite and parisite). The dark central zone, which consists primarily of ankeritic dolomite, barite, apatite, and strontianite, also has trace amounts of khanneshite.

Type 2 REE mineralization occurs in discordant dikes and tabular sheets up to tens of meters thick and hundreds of meters long, which are filled with primary igneous minerals that crystallized directly from magma or another fluid. These REE-enriched igneous rocks are of two types: those enriched in fluorine and those enriched in phosphorus.

Geology The Khanneshin carbonatite is a deeply dissected igneous complex of Miocene-Pliocene age that rises about 700 m above the flat-lying Neogene sediments of the Registan Desert, Helmand Province. The complex consists almost exclusively of carbonate-rich intrusive and extrusive igneous rocks that are crudely circular in outline. The complex is divisible into a central intrusive vent (or massif) that is approximately 4 km in diameter, a thin (less than 1-km wide) marginal zone of outwardly dipping (5 to 30 degrees) Neogene sedimentary strata, and a peripheral apron of volcanic and volcaniclastic strata that extends another 3 to 5 km away from the central intrusive massif.

Known deposits	Examples of potentially important REE deposits in the AOI—with brief descriptions—are included below. Additional details and data on grade, reserve tonnage, and operational information for the deposits identified here, and for other deposits in the AOI, are provided in chapters 21A, 21B, and 21C. The description below is nonexclusive of other significant deposits and prospects that may be in the AOI.
Rare earth elements	Khanneshin, Helmand Province (34°26'49"N, 63°38'44"E). Type 1 mineralized rocks—Symmetrically banded veins and seams are defined by a yellow-weathering zone symmetrically disposed about a dark central zone. In some veins, the REE carbonate minerals form dense crystal aggregates, presumably crystallizing from immiscible droplets, which compose up to 30 vol % of the vein. Type 1 mineralized rocks average 19.9 wt. % barium, 3.61 wt. % strontium, and 2.78 wt. % ∑ LREE (lanthanum, cerium, praseodymium, neodymium). The values of ∑ LREE for eight average whole-rock analyses range between 2 and 6 wt. %. Type 2 mineralized rocks—Both types of REE-enriched rocks are comparable in grade to the world-class Bayan Obo (China) and Mountain Pass, California, (USA) deposits, which are also greatly enriched in the LREE. The USGS field team estimates that at least 1 million metric tons (Mt) of LREE may be present in the Khanneshin carbonatite AOI. This comports well with the probabilistic estimate of 1.4 Mt of undiscovered REE resources in all of south Afghanistan (Peters and others, 2007). In addition to the LREE, the Khanneshin carbonatite is greatly enriched in barium (> 10 wt. %), strontium (> 6 wt. %, phosphorus (~ 2 wt. %), and uranium (> 0.05 wt. %).

16A.2.7 Guide to Chapter 22A—Summary of the Kunduz Celestite Area of Interest

Area	2,266 km^2.
Provinces, districts	The Kunduz celestite AOI is located mainly in the Kunduz Province of northern Afghanistan. The southwestern part of the AOI, which makes up about one-third of the total area, lies in Baghlan Province.
Deposit type(s)	Celestite ($SrSO_4$).
Geology	Paleogene rocks conformably overlie Cretaceous rocks in northern Afghanistan. Structural movements of the Afghan-Tajik Basin during the basinal stage of development (Jurassic through Paleogene) are characteristic of block-type platform tectonics (Klett and others, 2006). In northern Afghanistan, Paleogene sediments are classified as part of the Bukhara series and the slightly younger Suzak Formation (Debon and others, 1987; Klett and others, 2006). These sediments were deposited in marine to lagoon environments and are as much as 650 m thick in the southeasternmost part of the Afghan-Tajik Basin. It is not clear from the available literature which member(s) of the Bukhara series hosts the celestite deposits of northern Afghanistan, although the gypsum-bearing Akdzhar and Aruktau members are the most likely candidates.
Known deposits	An example of a potentially important celestite deposit in the AOI—with a brief description—is included below. Additional details and data on grade, reserve tonnage, and operational information for the deposit identified here, and for other deposits in the AOI, are provided in chapters 22A, 22B, and 22C. The description below is nonexclusive of other significant deposits and prospects that may be in

	the AOI.
Celestite	Kortau deposit [Chahar Dara], Kunduz Province (36°42'00"N, 68°35'00"E). Celestite is found in folded sediments of the Paleogene Bukhara series sediments, specifically in a horizon of gypsum and light gray bituminous limestone (Lim and Hyupperen, 1976).

16A.2.8 Guide to Chapter 23A—Summary of the North Herat Barium-Limestone Area of Interest

Area	9,684 km^2.
Provinces, districts	Herat Province and the following districts: Gulran, Kusuk, Khosan, Zind Jau, Injil, Herat, Karukh, Kushi Kuhna, Obe, and Pashtun Zarghun.
Known deposits	Examples of potentially important bedded barite, vein barite, brick clay, limestone (cement grade), marble, and iron skarn deposits in the AOI—with brief descriptions—are included below. Additional details and data on the grade, reserve tonnage, and operational information for the deposits identified here, and for other deposits in the AOI, are provided in chapters 23A, 23B, and 23C. The description below is nonexclusive of other significant deposits and prospects that may be in the AOI.
Bedded barite, Gardani-Burida prospect	Barite occurrences near the city of Herat are hosted in terrigenous Paleogene sedimentary rocks; the prospect contains five milky-white to pink, coarse to fine-grained, lenticular barite-bearing bodies that are 5 to 20 m long and 0.2 to 0.6 m thick (Abdullah and others, 1977).
Vein barite	The Gulron-barite occurrence lies along a fault zone that is 30 to 700 m long and 0.15 to 0.7 m thick and cuts Eocene sedimentary rocks. The occurrence contains 8 barite veins with transparent Iceland spar crystals that are 10 by 20 cm in size, 15 barite calcite veins, and 2 calcite veins. The barite veins assay 80 to 95.5 wt. % barite and the barite-calcite veins grade 12 to 26 wt. % barite.
Limestone (cement grade)	Benosh Darrah-limestone, Herat Province (34°34'30"N, 62°46'20"E). Lower Triassic limestone that is 464 m thick and outcrops in an area of 3 km^2.
Clay (brick)	Maluma-clay, Herat Province (34°29'N, 62"44'E). The area is underlain by Quaternary clays that vary in lime content and that are rich in silty and sandy material.
Iron scarn	Tagab-iron, Herat Province (34°36'11"N, 62º57'12"E). Lenses and irregular bodies of magnetite ore in epidote-garnet skarns that are 1 to 3 m thick; the skarns are formed in Upper Permian rocks at their contact with a small granodiorite massif of Late Triassic age. Magnetite is partially replaced by martite.

16A.2.9 Guide to Chapter 24A—Summary of the Nuristan Pegmatite Area of Interest

Area	3,490 km^2.
Provinces, districts	The Nuristan rare-metal pegmatite AOI includes parts of the Nuristan, Kunar, Badakhshan, and Laghman Provinces. The main districts are Matal, Kamdesh, Kuran Wa Munjan, Wama, Waygal, Pech, Chapa Dara, and Nuristan. The Nuristan rare-metal pegmatite AOI lies in the Hindu Kush Mountains in northeastern Afghanistan approximately 135 km northeast of Kabul.
Deposit type(s)	Rare-metal pegmatites.
Geology	The Nuristan rare-metal pegmatite AOI and surrounding areas are characterized by northeast-trending structures and similar trending belts of rocks. The belts are composed of Early Proterozoic, Carboniferous to Early Permian, and Late Triassic rocks that are bounded by northeast-trending faults. Oligocene-age granite intrusions are also elongate along the same structural trends. Because the

rare-metal pegmatites in the AOI are genetically and spatially related to the Oligocene-age granitic intrusions, this chapter describes the Oligocene-age granitic intrusions in some detail.

Known deposits Examples of a potentially important rare-metal pegmatite deposits in the AOI—with brief descriptions—are included below. Additional details and data on the grade, reserve tonnage, and operational information for the deposit identified here, and for other deposits in the AOI, are provided in chapters 24A, 24B, and 24C. Chapter 24A includes an indepth discussion of Oligocene and older intrusions; pegmatite metallogeny; the economic geology of pegmatite provinces, belts, fields, groups; gemstone-bearing pegmatites; six specific deposits located in Kunar Province; and known prospects in the AOI. The description below is nonexclusive of other significant deposits and prospects that may be in the AOI.

Pegmatite (gem) Nilaw pegmatite field, Nuristan Province (35°12'7"N, 70°20'9"E). Gently dipping pegmatite sills, which are characteristic of the Nilaw, Kulam, and Darrahe Pech fields and some other fields, are developed mainly in gabbroic and diorite bodies of the Nilaw Complex (figs. 24A–5, 24A–6, 24A–8, 24A–9). Some gently dipping and cross-cutting sills occur in Proterozoic gneiss in the Paran pegmatite field also. Steeply dipping pegmatite veins in the Paran pegmatite field occur in schists and form linearly elongated zones that are conformable with the schistosity and fold patterns of the enclosing rocks (figs. 24A–9). Small intraformational lenticular bodies are associated with the contact zones of the Alingar granite. Observations suggest that the steeply dipping veins contain most of the important lithium deposits and occurrences. The gently sloping to flat lying pegmatites contain important concentrations of beryllium, tantalum, precious stones, piezo-quartz, and tourmaline. Those pegmatites that are closely associated with the granites are considered to be noneconomic (Abdullah and Chmyriov, 2008).

16A.2.10 Guide to Chapter 25A—Summary of the South Helmand Travertine Area of Interest

Area 6,628 km^2.

Provinces, districts South Helmand Province; the three districts, from west to east, are Dishu, Gamser, and Reg.

Deposit type(s) Travertine/onyx, porphyry copper, porphyry copper gold and skarn copper (gold) deposits.

Geology The South Helmand (Chaigai Hills) AOI encompasses an east-northeast-trending belt of Oligocene(?) intrusive bodies (Peters and others, 2007) that consist of granite, granite porphyry, granodiorite, quartz syenite, and granosyenite. These rocks have not been dated in Afghanistan, but, based on information about the ages of the porphyry copper deposits in nearby Pakistan, they are probably between about 22 and 12 million years. These rocks intrude felsic and mafic volcanic rocks, flint, fine- and coarse-grained continental sedimentary rocks, marl, and limestone. The tract extends from the border with Pakistan north to where the rocks are estimated to be covered by more than 1 km of Quaternary and Early Pliocene sedimentary and volcanic rocks. Where they are exposed, some of the plutonic and volcanic rocks exhibit areas of phyllic alteration mapped from Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) imagery (Mars and Rowan, 2007).

Known deposits There are five reported travertine deposits in the AOI. An example of a potentially important travertine deposit in the AOI—with a brief description—is included below. Additional details and data on the grade, reserve tonnage, and operational information for the deposit identified here, and for other deposits in the AOI, are provided in chapters 25A, 25B, and 25C. The description below is nonexclusive of other significant deposits and prospects that may be in the AOI.

Travertine Arbu deposit, Helmand Province (29°49'N, 68°58'E). The deposit contains numerous tabular and predominantly high-grade aragonite veins ranging from 100 to 250 m long and 0.5 to 4.0 m thick that occur in a Lower Quaternary andesite-dacite vent surrounding Lower Quaternary clastic rocks. Speculative reserves are 170,000 t of aragonite. The deposit was being exploited in the 1970s (Slavin and others, 1972; Eriomenko and others, 1975).

16A.2.11 Guide to Chapter 26A—Summary of the Takhar Evaporite Area of Interest

Area 1,148 km^2.

Provinces, districts Takhar Province and the following districts: Kalatgan, Talugan, Banqi, Farkhar, Chal and Ishtamish.

Deposit type(s) The main commodities of interest within the Takhar AOI are evaporite-related commodities, such as salt, gypsum, celestite, and clay. There are also known coal and dimension stone occurrences and the possibility for deposits of mercury, sand and gravel, limestone, sulfur, and other commodities.

Geology The exposed geology of the Takhar AOI consists largely of Cretaceous to recent sediments. The lithologies of the Mesozoic and Early Cenozoic units consist of a mix of marine to lagonal to continental sediments with contained evaporates, such as anhydrite and gypsum. The evaporite deposits within the Takhar AOI are part of the Afghan-Tajik Basin fill, which in part is composed of the eastern portions of the Central Asia Jurassic Salt Basin. Additionally, the Cretaceous evaporites found farther north and northwest in the basin have relatively thin halite and a higher proportion of gypsum.

Known deposits Examples of potentially important halite deposits in the AOI—with brief descriptions—are included below. Additional details and data on grade, reserve tonnage, and operational information for the deposits identified here, and for other deposits in the AOI, are provided in chapters 26A, 26B, and 26C. The listing of example deposits below is nonexclusive of other significant deposits and prospects that may be in the AOI.

Halite (rock salt) On the north side of the salt core, the surrounding rocks are overturned by 45 degrees, but then straighten to a steep dip. The rock salt is reported to be finely crystalline, light gray to red-brown, and to have a highly variable texture. Impurities include anhydrite, clay, and dolomite. The salt has a low bromine content that may indicate that it has been recrystallized (Kulke, 1972).

Gypsum Taqca Khana, Takhar Province; Sary-Kan, Takhar Province (36.580N, 69.654E). Bedded gypsum is known to occur in sedimentary formations of Jurassic and Cretaceous age within the Takhar AOI. These formations are permissive for the occurrence of the bedded gypsum deposit type (Raup, 1991). There is also gypsum associated with the salt domes in the area that are believed to be Jurassic. Gypsum is also a significant component of several Paleogene and Neogene units in northern Afghanistan.

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