11.0 Dimension Stone

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Dimension stone is generally defined as natural rock quarried for the purpose of cutting and(or) shaping to a specific size (Barton, 1968; Dolley, 2004). It is one of the oldest and most durable building materials. The Egyptian pyramids were built from quarried stone in about 2800 B.C., and the Babylonians used cut stone in 600 B.C. to build the renowned Hanging Gardens, one of the Seven Wonders of the World. The Greeks and Romans also used cut and finished stone widely as construction, decorative, and statuary material. The Greeks quarried marble as early as 447 B.C. (*http://www.answers.com/topic/cut-stone-and-stone-products*).

The principal rock types used for dimension stone are granite, limestone, marble, sandstone, and slate. Of these, granite, limestone, and marble are the three main materials (*http://www.answers.com/topic/cut-stone-and-stone-products*). Other rock types, such as massive gypsum sold as alabaster and massive talc marketed as soapstone, are minor specialty types. Physical properties, such as durability, strength, and the ability of the stone to hold a surface finish, are important in the industry and to the customer as are esthetic properties such as color, texture and pattern, and surface finish (Dolley, 2004).

Scientific and commercial descriptions of the five dimension stone types overlap. The scientific description generally focuses on the mineral composition and its geographic locality; the commercial description focuses primarily on the color and locality of origin. Dimension rock type descriptions herein are mainly from Dolley (2004) where they were adapted from Currier (1960) and Barton (1968).

The dimension stone industry

A recent study by USAID, OTF Group, a competitiveness consulting firm that specializes in helping to build prosperity in developing economies, and Commercial Competitiveness Commission of Afghanistan found that the dimension stone industry has great potential to become one of the leading industries in the Afghan economy (USAID and others, 2006). That potential, however, is being held back by inefficient practices (*http://www.ccca.org.af/pdf/06%20Marble/04%20Concept%20Paper%20-%20Marble%20Investment%20Fund.pdf*). Much of this section is condensed from that study.

Difficulties begin at the quarry where black powder is used in blasting, which damages both the rock by causing it to micro fracture resulting in material being wasted. Some dimension stone deposits have been effectively ruined by fracturing resulting from overuse of explosives. Blasting produces small (8 to 10 metric tons) irregular pieces; over 50 percent of which is wasted in processing.

At the processing plant, lack of adequate equipment and processing techniques applied to stone that was previously damaged leads to more inefficiency. Efficient dimension stone production, however, requires special quarrying methods. Although some quarries use low powered or soft explosives to good effect, care must be taken in handling the large blocks so as to minimize breakage and waste. Equipment, such as wire saws and high-pressure water jets, are typically used for successful dimension stone quarrying. Wire saws can reduce wastage to about seven percent while producing blocks as large as 250 metric tons to customer specifications. Large multiblade block cutters can cut an entire block into 50 or more slabs at once. Each slab may be 2 to 3 cm thick and as wide and long as the original block. Typically, the strategy is to get a block of 20 tons or less and move it to a plant for sawing and further processing (*http://www.heritage.nf.ca/environment/dimension.html*). McReady (2006) reports that the Afghanistan dimension stone industry is poorly equipped, has little technical knowledge, and uses poor extraction methods, which often reduce the value of the harvested rock.

USAID and OTF Group conducted research on several industries from carpets and lambskins, to essential oils and nuts, to dimension stone. They found that the size of the Afghan dimension stone industry (the report uses the term "marble" to represent dimension stone types, such as marble, onyx, granite, travertine, limestone, and other stones used for tiles, cladding, etc.) was unknown, but the majority of exports are to Pakistan. The current level of development of the dimension stone industry in Afghanistan is greater than the essential oils industry but lags that of cashmere, cotton, lamb skins, dried fruit and nuts, and carpets. The potential opportunities for dimension stone are thought by USAID and OTF Group to be better than for cotton and lambskins but not as good as for the other industries in question. They determined that accessing foreign markets should lead to more export opportunities. Their research also noted that little processing for export markets is being done in Afghanistan. Most of the value is added abroad. Afghanistan exports raw dimension stone and imports cut and trimmed products. For example, Afghanistan exports uncut blocks and imports cut tiles for final cutting and polishing for local consumption. Although greater volumes of block and uncut dimension stone are exported, slabs and polished dimension stone are of much higher value. USAID and OTF Group noted that recent investments for cutting equipment have been made, and dimension stone processors seem eager to capture more value and cooperate with the dimension stone project.

Roughly 80 percent of dimension stone quarried in Afghanistan is exported as raw block. Most processed dimension stone is sourced and sold locally. USAID and OTF Group identified six cities where dimension stone is processed. Kabul and Herat each process about 300 metric tons/month (t/m). Herat, which has nine factories, produces a white stone of very good quality. Kabul, with 13 factories, produces white, black, and green colored stone. Kandahar and Jalalabad produce 150 t/m, each. Kandahar has one factory which produces a low quality white stone among other colors. Jalalabad with three factories produces a medium-quality white stone. Lashkar Gah has one factory and produces about 10 t/m of white stone and onyx. The production of Mazar is not known.

USAID and OTF Group estimate that Afghanistan has an estimated 60 deposits of dimension stone. Some deposit can support multiple quarries. They too suspect there are undiscovered deposits. Chesht quarry has a projected production of 22,000 m^3 and Khogiani quarry 10,000 m^3 /yr. A conservative goal for Afghanistan is an average production of 2,500 m^3/yr per quarry.

Dimension Stone Processing

Besides meeting the desired physical and esthetic properties, the rock must be relatively free of fractures so that it can be split or cut from a quarry face in large multi-tonne blocks and transported to the processing plant. Prospecting for, and mining and production of dimension stone are more sophisticated and require more care than the same processes or the methods used for natural stone aggregate or sand and gravel.

The dimension-stone market for all rock types is increasingly shifting away from imports of unprocessed rock blocks towards slabs and finished goods (*www.ccca.org.af*). This is a natural economic adjustment to high transportation costs and high levels of product lost in further processing. Trimming an uncut rock to form a uniform block can easily reduce the weight by 20 percent or more. Cutting a block into slabs can remove 40 percent of the block depending on the thickness of the slabs. With transportation costs being on the order of twice as much as processing costs, it makes economic sense to do as much processing as close to the quarry as possible and not pay to transport material that will be lost in processing (*www.ccca.org.af*).

An important recent study of Afghanistan's market competitiveness focused on Afghanistan's marble industry voiced the opinion that Afghanistan has the natural resources to profit from marble and granite, but is not doing enough to capture local and foreign markets and that investment into better processing is key to improving industry competitiveness (USAID and others, 2006). Economic factors for marble discussed in USAID and others (2006) pertain to other dimension stone rock types as well.

The size of the Afghan dimension stone industry is largely unknown (McReady, 2006). Afghanistan has considerable potential as a source of high quality dimension stone, particularly marble. A range of polished products are manufactured in Kabul from green, white, and black varieties of marble are quarried in Kabul, Nangahar, and Wardak Provinces. Active marble quarries are also located in Badakhshan, Balgh, Helmand, Herat, Kandahar, Mayden Provinces (McReady, 2006). There are major potential markets for these products in the Persian Gulf (*http://www.bgs.ac.uk/afghanminerals/indmin.htm*).

According to World Bank estimates, the gross annual market value of solid minerals production from Afghanistan (including coal, marble and dimension stone, quarries, sand, salt, gemstones, and copper) can be increased from estimated $60 million to $253 million per year by 2008, with immediate investment opportunities for the private sector totaling $360 million (*http://www.aisa.org.af/Business-Guide.htm#cons*).

Rock types such as granite and marble commonly used as dimension stone are abundant in Afghanistan. The igneous and metamorphic rocks in Afghanistan have been exposed to the heat and pressures of burial; they have been folded ductilely, in some cases partly melted and withstood weathering at the surface. While they may vary in brittleness, durability, porosity, permeability, resistance to wear, and other properties on both a regional and local scale, the genetic stresses and strain may have produced rocks that have a natural attractiveness and durability that makes them suited for use as dimension stone. Additionally, dimension stone has a high value added factor. Special preparation (such as polishing, making shingles, or preparing building facings) greatly adds to the value of the rock per tonne. Therefore, location of a dimension stone quarry and distance to market are not as critical as with natural aggregate.

11.1 Description of dimension stone deposit models

The only descriptive deposit model for dimension stone deposits is for travertine, a type of limestone (Hora, 1996). In Canada, the British Columbia Geological Survey (BCGS) plans to complete at least four profiles for different types of dimension stone—granite, marble, andesite, and sandstone (*http://www.em.gov.bc.ca/ Mining/Geolsurv/MetallicMinerals/Mineral-DepositProfiles/*). The many varied criteria for making a good dimension stone, some of which such as visual attractiveness are subjective, may make modeling of dimension stone deposits difficult.

Rather than building deposit models with which to estimate the nation’s dimension stone resources, the Geological Survey of India recognizes the importance of dimension-stone granite (DSG) production to that nation’s economy and promotes production by carrying out regional evaluations and resource inventories with the following objectives that may be applicable to Afghanistan:

(1) to identify potential belts of dimension stone using satellite imagery, aerial photographs, and geological maps;
(2) to identify favorable target areas for resource evaluation through reconnaissance; surveys, and delineating extensions of known deposits, besides locating new varieties;
(3) to study petrological, geochemical, physical, and mechanical properties of the DSG to assess their market suitability and thereby delineate promising and productive zones; to delineate the limits of different varieties of DSG and categorize them based on specifications for use in domestic and foreign market;

(4) to assess the quarriable reserves of DSG;
(5) to render advice on quarry planning so as to increase recovery and contain failures;
(6) to study the environmental problems arising out of quarrying and suggest remedial measures for eco-friendly and sustainable development; and
(7) to create databases on geology, resource potential, leases, production etc., state wise belt-wise, district-wise, for each variety of DSG (*http://www.worldstonex.com/en/InfoItem.asp?ICat=16&ArticleID=60*).

Similar governmental/private-sector cooperation, for example USAID and others (2006), may give Afghanistan's dimension-stone industry the support it needs to grow into a viable economic resource.

11.2 Description of dimension stone tracts

Delineation of tracts permissive, favorable, or prospective for the presence of undiscovered dimensions stone deposits should take into account all available information to make the best possible, geologically sound tracts. Unfortunately, there is almost no information on the physical and esthetic properties of the rocks in Afghanistan that point to their suitability for use in dimension stone applications. The fact that dimension stone known to be mined, processed, and marketed from Afghanistan is evidence that despite the hardships, work continues and products are shipped.

In general, the permissive tracts drawn for assessing dimension stone resources are based on the first designation of the rock unit on the Russian 1:500,000-scale geologic map be it granite or other rock types marketed as granite, limestone, marble, or sandstone (Doebrich and Wahl, 2006). Any rock unit described as containing travertine was included in the travertine permissive tract. Delineation of favorable tracts or areas within the permissive tracts was determined by the distance from the nearest reported village. A distance of 25 km was chosen, because that is an average distance that a high-volume, low-value product such as dimension stone can be transported before the cost of transportation becomes higher that the value of the product. Obviously, this distance varies with the quality of the product, the quality and security of the roads, and other economic factors.

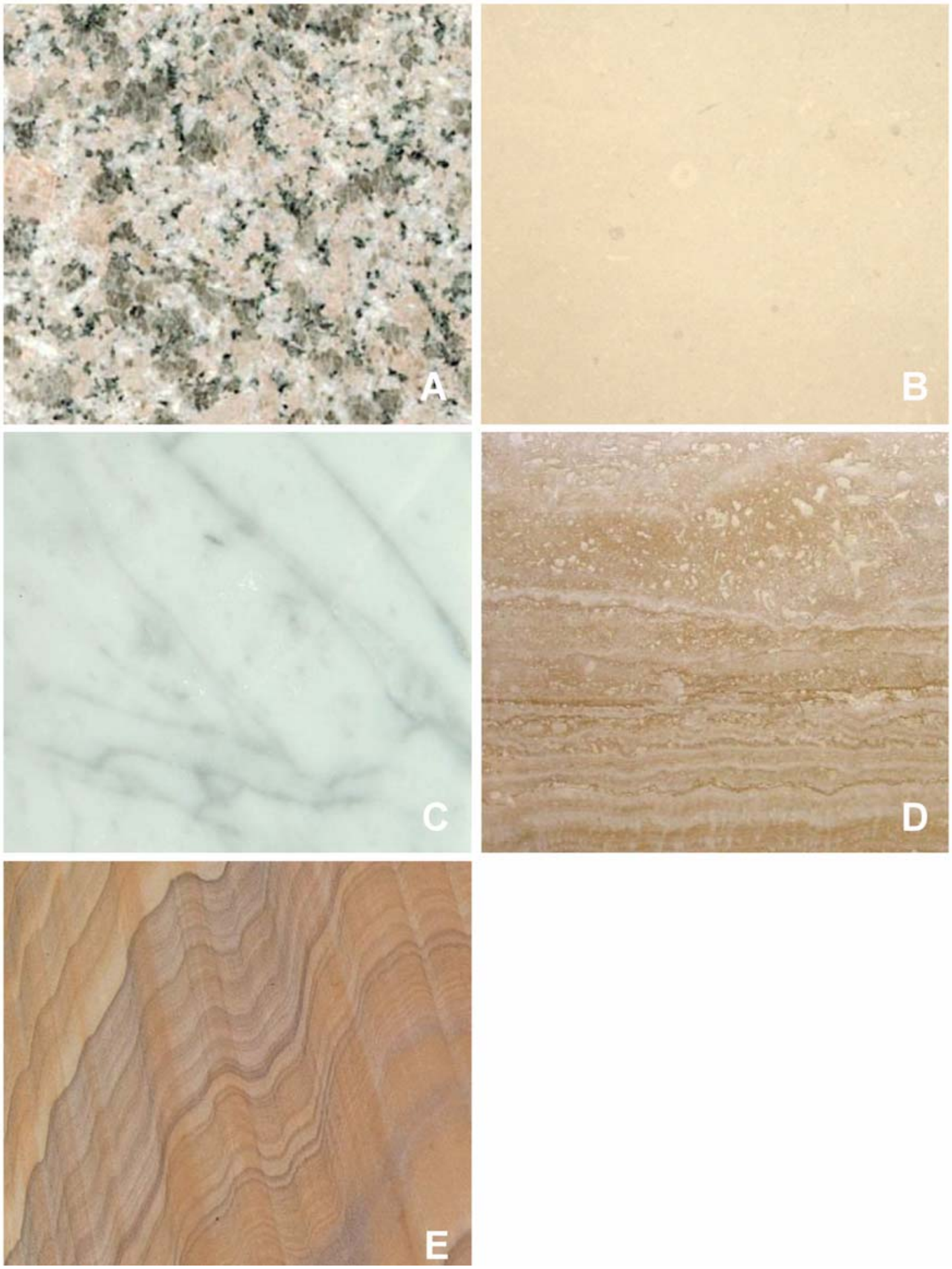

Figure 11.1–1. Photograph typical building stones. A) Photograph of typical polished granite. (B) Polished fossiliferous limestone tile (*www.farrarnaturalstone.co.uk/site/page8-.html*). (C) Polished white marble (*www.ced.ltd.uk/Gallery.php*). (D) Roman vein-cut polished travertine (*www.stonecontact.com*). (E) Honed Rainbow sandstone (*www.ced.ltd.uk/Gallery.php*).

11.2.1 Granite

Dimension stone sold as granite includes all feldspathic crystalline rocks of mainly interlocking texture and with individual grains that are visible to the naked eye. Granite includes such rock types as anorthosite, gneiss, granite granodiorite, monzonite, syenite, and all other intermediate igneous and coarse-grained metamorphic rock types. Colors of commercial granite are primarily white, gray, pink, and red. Colors such as green and brown are secondary. Black granites are also included in this rock type but are not true granites. Mineralogically, black granites are generally mafic rock types, such as diabase, diorite, and gabbro. Slabs of Afghanistan granite dimension stone are marketed under the trade names of Black Absolute, Black Galaxy, Colombo Juprana, and Raw

Silk, and Tan Brown, range in price from $3.10 to $7.75 or more per square foot FOB Dubai (*http://www.stonecontact.com/c-Granite/pricelist1328.html*).

There are more than 300 varieties of dimension stone sold as “granite” (*http://www.worldstonex.com/en/InfoItemasp?ICat=16&ArticleID=60*), many of which are not granite, but some other rock type, including gabbro. Migmatites are permissive "granites" because they often have aesthetically pleasing flow patterns. Syenite, commercially classified as granite, makes excellent polished building facing. Gneisses, marketed as granite, and marbles are popular for ornamental dimension-stone applications. Granulites and charnockites may be good sources of dimension stone (Figure 4.4-13). Much of eastern Afghanistan is permissive for the occurrence of dimension stone deposits because of the presence of high-grade metamorphic and igneous rocks at or near the surface. Further work is required to find the most desirable rocks, determine their physical and esthetic properties, decide how they can best be used, and find customers for them. The following tracts are permissive and favorable for the occurrence of undiscovered granite dimension stone deposits.

Tract ID: dms01 granite permissive tract

***Deposit type*—**Granite dimension stone

***Age of mineralization*—**Archean, Proterozoic, Mississippian, Early Triassic, Late Triassic, Late Jurassic-Early Cretaceous, Late Cretaceous-Paleocene, Miocene, and Oligocene.

***Examples of deposit type*—**There are no reported granite dimension stone occurrences, prospects or workings in Afghanistan.

***Exploration history*—**Unknown

***Tract boundary criteria*—**The permissive tract where granite dimension stone resources are expected to be found includes rock units mapped as containing any of the rock types sold commercially as granite. These include amphibolite, granite, granodiorite, granophyre, gneisses, diorite, gabbro, gabbrodiabase, migmatite, monzonite, plagiogranite, syenite, and associated rock types. Permissive areas where the polygons are outlined in black are areas where mafic rocks such as dunite and gabbro have been mapped and where rocks that can be produced as black granite may be located.

***Important data sources*—**Doebrich and Wahl (2006), Orris and Bliss (2002), Abdullah and others (1977).

***Needs to improve assessment*—**Detailed geologic mapping with special attention given to the rock physical and esthetic properties that would make them suitable for dimension stone applications.

Optimistic factors—At present (2006), some Afghan dimension stone is reportedly being mined and processed in cities in that country. Other material is shipped to Pakistan, where it is processed, which adds value, and is sold as either a product of Afghanistan or of Pakistan. Such production shows a willingness of Afghan workers to mine and transport the stone under adverse conditions and it shows continuing demand for their product.

Pessimistic factors—Countries such as India, Pakistan, and others in central Asia have sufficient resources and have spent much time and money developing dimension stone mines, production facilities, and markets. For Afghanistan to gain a foothold in the world dimension stone market would take a like investment by both indigenous and foreign investors.

Quantitative assessment—No estimate of the numbers of undiscovered granite dimension stone deposits was attempted, but the areas outlined have a more than negligible probability of yielding such deposits.

Tract ID: dms01-f1 Granite favorable tract

Tract criteria—Tract dms01-f1 was delineated to include rocks permissive for undiscovered granite dimension stone deposits being within 25 km of a town or village. Twenty-five km is approximately the maximum distance average quality dimension stone can be transported before the cost of moving the material outweighs the value of the rock. There are several areas, mostly in the northern part of the country, where granitic rocks are within 25 km of the nearest town. If these rocks are of sufficient physical and aesthetic, they would likely be the first rocks made available for mining when conditions are favorable for the mining of granite dimension stone.

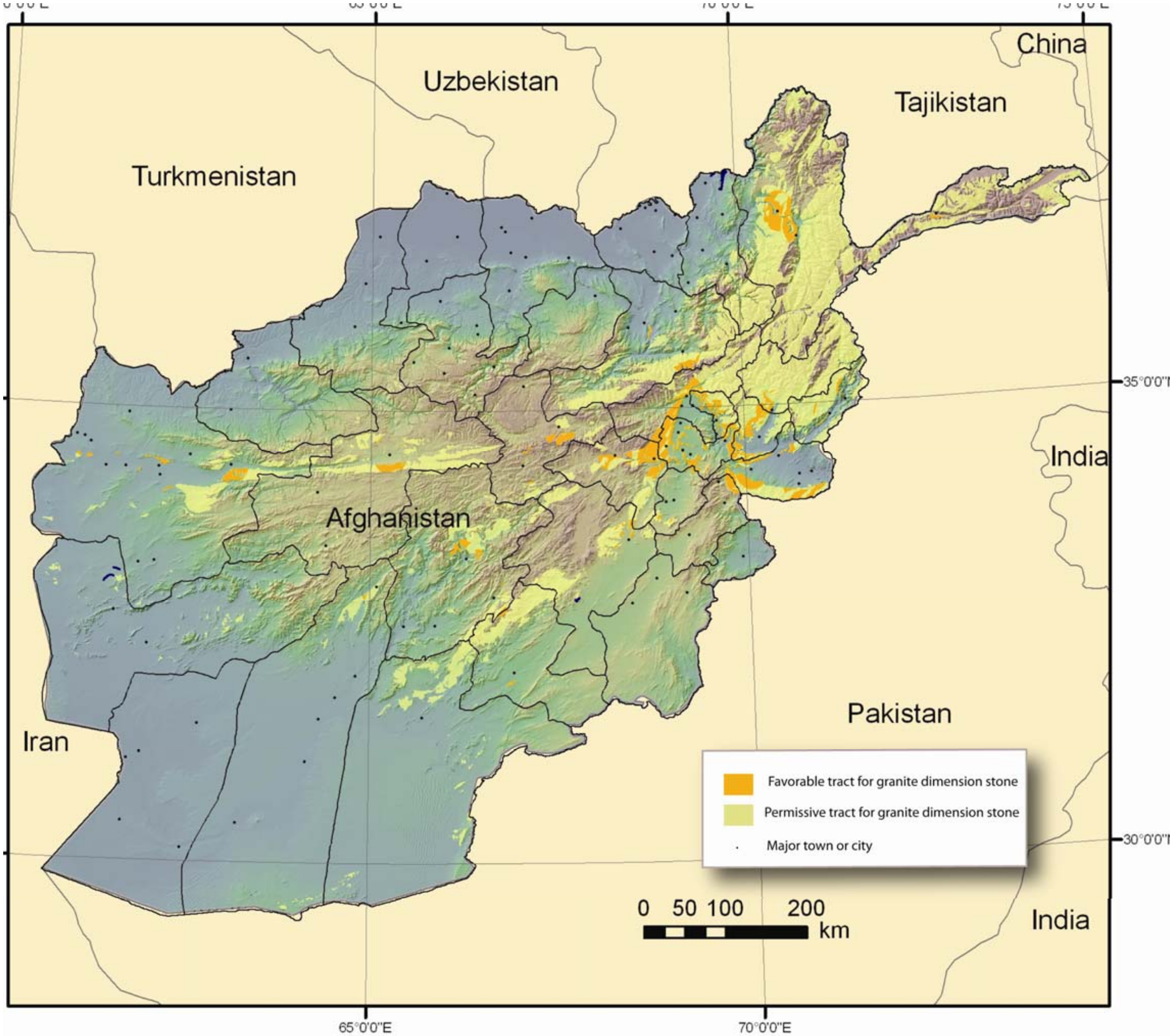

Figure 11.2.1-1. Tracts permissive (yellow) and favorable (orange) for the occurrence of undiscovered granite dimension stone deposits in Afghanistan.

11.2.2 Limestone

Carbonate material commercially sold as limestone is sedimentary rock that is primarily composed of calcium carbonate with or without magnesium. This includes limestone, dolomite, dolomitic limestone, and travertine. In this report, travertine is assessed separately from limestone. This is because the geologic map identifies rock units containing travertine, and the mineral occurrence database contains several aragonite ornamental stone (travertine). Limestone is also quarried in Afghanistan for dimension stone (McReady, 2006). The largest deposits are in Badakhshan Province at Jamarchi-Bolo, Sabz, and Bakunvi quarries. Limestone suitable for use as dimension stone occurs elsewhere in Afghanistan.

Tract ID: dms02 limestone permissive tract

Deposit type—Limestone dimension stone

Age of mineralization—Various stages of deposition within several geologic periods including: Cambrian (Vendian complex), Silurian, Devonian, Mississippian, Pennsylvanian, Late Permian, Triassic, Middle-Late Jurassic, and Late Cretaceous-Paleocene.

Examples of deposit type—Jamarch-Bolo, had active quarrying of a 6 km^2 dense massive, thick-plated, slightly jointed, fine- and medium-grained Silurian limestone and marl. The host rock is suitable for cement and as a building stone (Moraliov and others, 1967). At Ghumay in Badakhshan Province, Permian limestone and dolomite occurs over an area of several km^2 on the hillsides as large talus blocks up to 1.5 m across. These rocks were being quarried in 1967 (Moraliov and others, 1967). Sabz, Badakhshan Province, is the site of a dense, massive, fine- and medium-grained Lower Carboniferous limestone. The deposit covers an area of about 3 km^2 and is found in talus on hillsides. Resources may be as much as 500 million m^3 (Moraliov and others, 1967). Permian dolomite and limestone have been quarried at Bakunvij, Badakhshan Province, where the rocks are exposed over an area of several tenths of a km (Moraliov and others, 1967). At Shenivaghur in Baghlan Province, a deposit consisting of black, dense, massive Upper Cretaceous-Paleocene dolomite is 80 m thick and about 1,000 m long (Mikahilov and others, 1967).

Tract boundary criteria—The limestone permissive tract was drawn to include all rock units that were mapped as limestone as the first designation of the rock unit on the Russian 1:500,000-scale geologic map (Doebrich and Wahl, 2006).

Important data sources—Doebrich and Wahl (2006), Orris and Bliss (2002), Abdullah and others (1977).

Needs to improve assessment—Detailed geologic mapping with special attention given to the rock physical and esthetic properties that would make them suitable for dimension stone applications.

Optimistic factors—The presence of significant identified resources and past (and possibly current) production at places such as Jamarch-Bolo, Ghumay, Sabz, Bakunvij, and Shenivaghur are very positive. That it is also used as an ingredient in cement, allows another market for limestone not suitable for dimension stone.

Pessimistic factors—Lack of security, poor infrastructure, and lack of a dimension stone industry with established customers are some of the problems facing the Afghan dimension stone industry.

Quantitative assessment—No estimate of the numbers of undiscovered limestone dimension stone deposits was attempted, but the areas outlined above are thought to have a more than reliable probability on hosting such deposits.

Favorable Tracts

Tract ID: dms01-f1 limestone favorable tract

***Tract criteria*—**For the tract dms01-f2, a distance of 25 km from the nearest village was chosen, because that is an average distance that a high-volume, low-value product such as limestone dimension stone can be transported before the cost of transportation becomes higher that the value of the product.

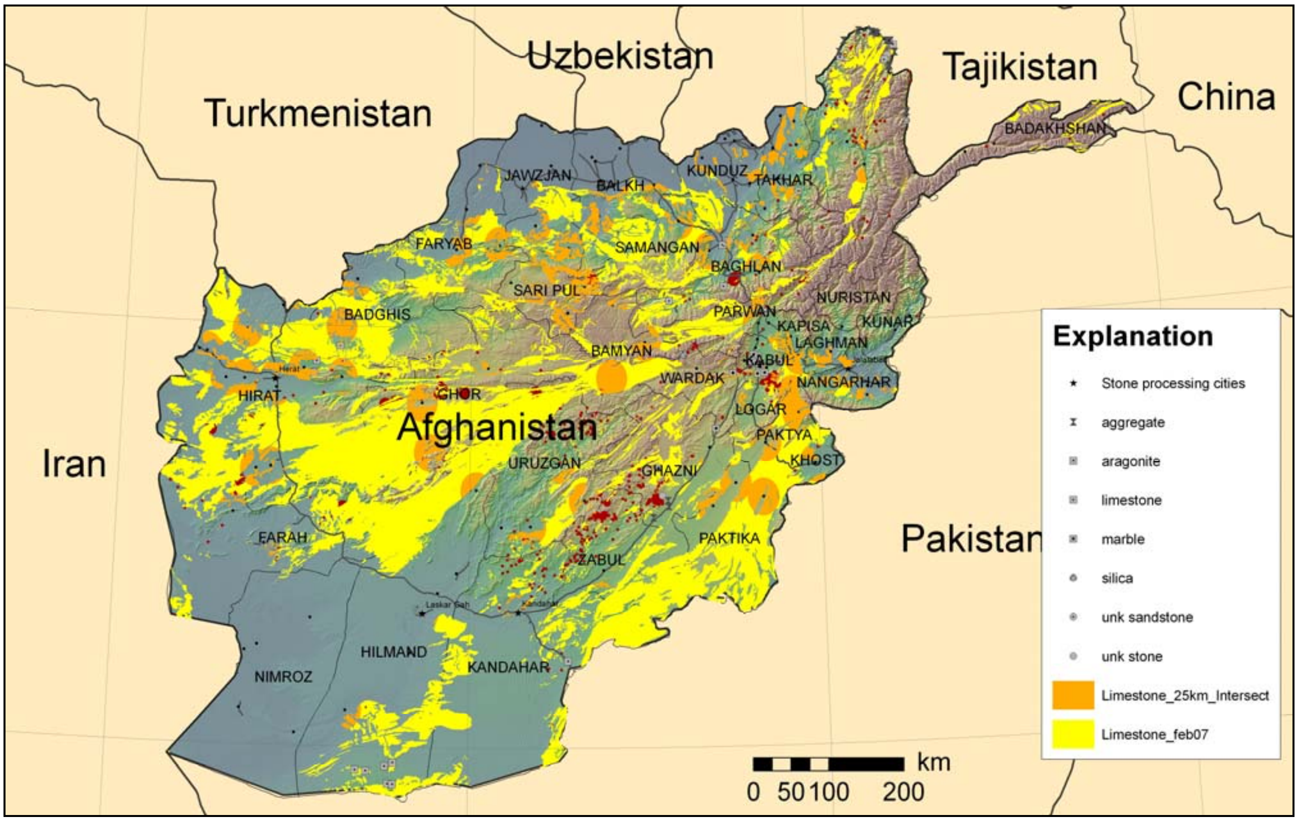

Figure 11.2-1. Areas permissive and favorable for the occurrence of limestone deposits in Afghanistan. Areas in red are zones of high sulfide minerals (adapted from the data base of Doebrich and Wahl, 2006). These areas would be generally non permissive.

11.2.3 Marble

Marble is crystalline metamorphosed limestone, composed of relatively pure calcite ($CaCO_3$). The name marble dates back to the ancient Romans and may be the oldest term used for dimension stone. Commercially, it is defined as any crystalline rock composed predominantly of calcite, dolomite, or serpentine that is capable of taking a polish (Power, 1994). The most common variety of marble is white, but it can also be yellow, red, or green. It is extensively used for sculpture, as a building material, and in many other applications (*en.wikipedia.org/wiki/Marble*). Serpentine marble, also known as verde antique, is an important member of this rock type. In Afghanistan, Proterozoic marble is considered to be the highest quality for use in dimension stone applications. At least 21 dimension stone factories are known in Afghanistan mostly producing marble (McReady, 2006).

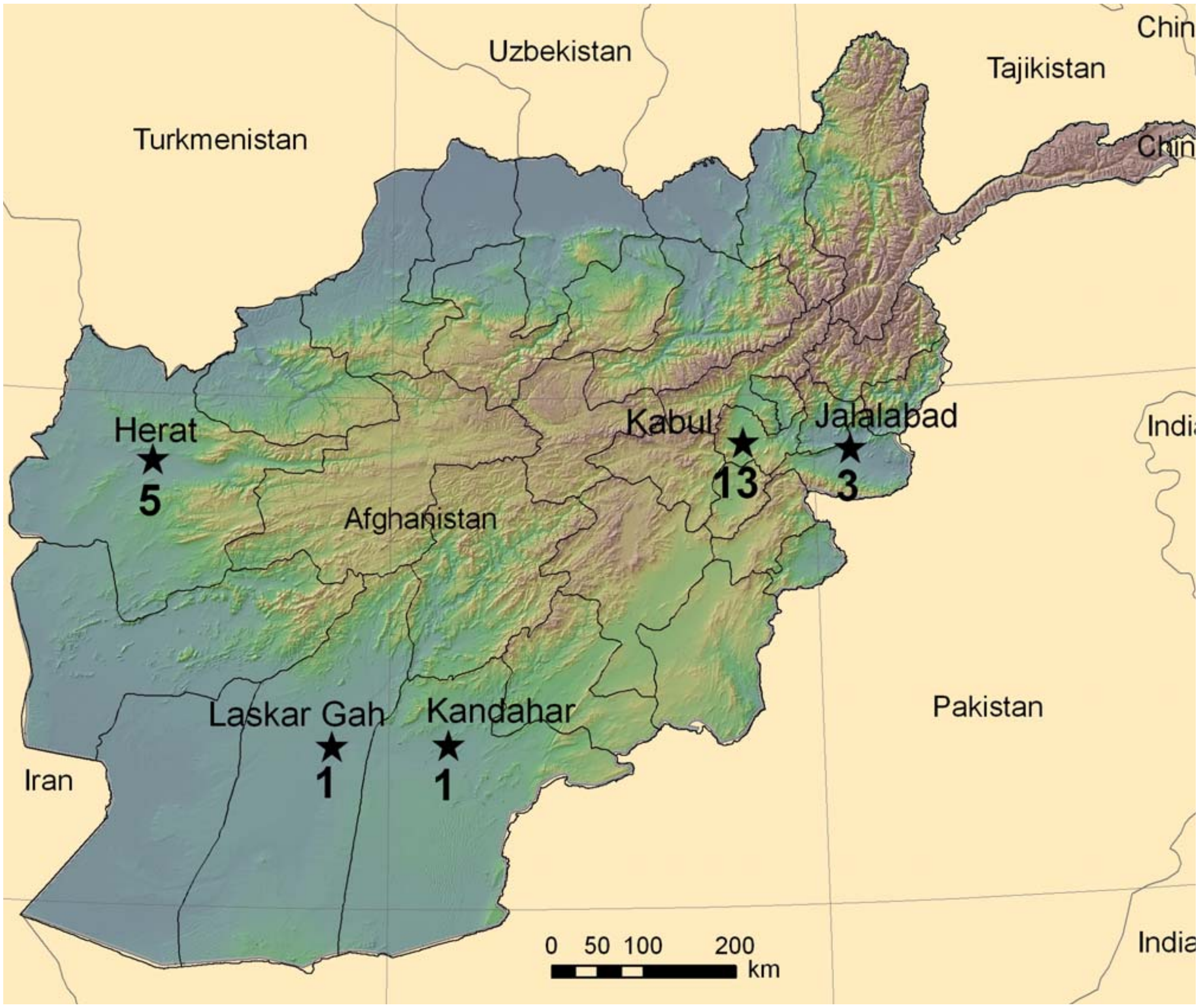

Figure 11.3-1. Afghanistan cities with known marble processing factories and the numbers of those factories in the cities (after USAID and others, 2006). Mazar in north Afghanistan is not shown because of uncertainty about its processing facilities.

Pakistan and Iran are strong competitors in the marble market within Afghanistan due to more efficient quarrying and processing and possible government subsidies (USAID and others, 2006). Imported marble, for example sells for about \$6 to \$7/m^2 in Afghanistan, while indigenous marble sells for \$15 to \$17/m^2 (USAID and others, 2006). Upgrading Afghanistan's production and processing would eliminate their competitive advantage within that country.

The Afghanistan mineral occurrence database contains twelve marble occurrences; another marble occurrence is known to occur in Parwan Province in the Darye-Koglami River Valley where a newly constructed road is expected to provide transportation access to a new marble quarry. That mining operation could be a whole new industry in the region and in turn provide jobs for greater than 200 local workers (Shane, 2006). Two additional quarries Chest and Khogiani in Nangahar Province contain Carrara-quality marble comparable to that imported from Italy (*www.cca.org.af*). Roughly 80 percent Afghan marble quarried is exported, mostly to Pakistan, as rough hewn blocks and re-exported or re-imported as higher value polished marble products (McReady, 2006). Afghanistan's marble processing capacity is in the cities of Herat, Jalalabad, Kabul, Kandahar, Lashkar Gah, and possibly Mazar (figure 4) (USAID and others, 2006).

Tract ID: dms03 marble permissive tract

Deposit Type—Marble dimension stone

Age of mineralization—Proterozoic to Cambrian

Examples of deposit type—Reported marble quarries occur in several provinces as reported in Abdullah (1977).

Badakshan Province

At Bini-Kama, a dense massive, medium- and coarse-grained slightly jointed Silurian-Devonian age marble outcrops over an area of about 2 km^2. The marble is 0.20 percent SiO_2, 0.63 percent hematite, 53.57 wt. percent lime, 1.71 wt. percent magnesia, and 0.13 wt. percent sulfite. The marble may be used as raw material for cement production and as building facing stone (Moraliov and others, 1967). The deposit has a resource of an estimated 1.3 billion metric tons of coarsely crystalline marble (McReady, 2006).

Maydan Province

Maydan quarry is located in Proterozoic age grey and dark-grey marble 300– to 450–m-thick interbedded with crystalline schists, each as much as 40 m thick. The marble was exploited as early as the 1930 and are referred to in the literature as the Maydan marble mines (Hunger, 1961). At Wardak, a Proterozoic age white fine-grained marble with some grey interbedded marble is 8,000 m long and 50 m thick. Volume weight is 2.8 g/cm^3 and specific magnetic permeability is 0.989 (Hunger, 1961; Hanukaev and others, 1971).

Nangahar Province

At the Khogiani quarry very fine-grained white marble similar in color and quality to Carrara marble is mined. Buyers in Dubai and Lebanon indicate that the marble is of exceptional quality and is likely to command strong prices (*www.ccca.org.af*)

Kabul Province

At Kariz-Amir, a 25–m-high hill has granular white (rarely grey-yellowish) Proterozoic age marble that was being exploited in 1961 (Hunger, 1961). Yellow and grey coarse-grained Proterozoic marble 20 m thick occurs at Alghoi. The marble appears suitable for mining (Hunger, 1961). At Dex Kenak, granular, white (occasionally grey and yellow) Proterozoic age marble is suitable for exploitation (Hunger, 1961). The rocks at Gezak are attributed to the Proterozoic and are strongly marbled in limestone and marble exposures. Volume weight is 2.79 g/cm^3 (Hunger, 1961; Hanukaev and others, 1971). Khojarawas, which occurs in Proterozoic marble, has been exploited periodically (Hunger, 1961). At Sharar, a white (with grey and grey-yellow inclusions) homogeneous marble bed 20 m thick in Proterozoic amphibolite and gneiss had been exploited periodically (Hunger, 1961). At the Shanhi-Baranty quarry, a fine- and coarse-grained, white Proterozoic marble has been exploited periodically using hand methods (Hunger, 1961). Proterozoic age grey, white, granular, fine-grained partly dolomitized marble occurs at Sultan Padshah. The marble may be suitable for industrial exploitation (Hunger, 1961).

Ghazni Province

In 1961, Upper Permian marble was being exploited by hand at Anghuri. The marble is a white, grayish-white, massive, fine-grained, and slightly jointed (Dovgal and others, 1971). At Alaghzar, grey, occasionally multicolored Proterozoic age marble was being exploited for ornamental stone in 1971 (Dovgal and others, 1971).

Exploration history—The amount and quality of exploration is unknown, but having locations of several deposits, estimates of their resources, and exploitation of several deposits is indicative of successful exploration at some level.

Tract boundary criteria—All rocks containing marble in Doebrich and Wahl (2006)

Important data sources—Doebrich and Wahl (2006), Orris and Bliss (2002), Abdullah and others (1977).

Needs to improve assessment—Detailed geologic mapping with special attention given to locating marble deposits and the rock physical and esthetic properties that would make them suitable for dimension stone applications.

Optimistic factors—The presence of several known marble deposits over a widespread area and several provinces is optimistic for the occurrence of additional marble resources in undiscovered deposits.

Pessimistic factors—Many areas very remote. Not all units have marble.

Quantitative assessment—No estimate of the numbers of undiscovered marble dimension stone deposits was attempted, but the areas outlined above are the most probable in Afghanistan to yield such deposits.

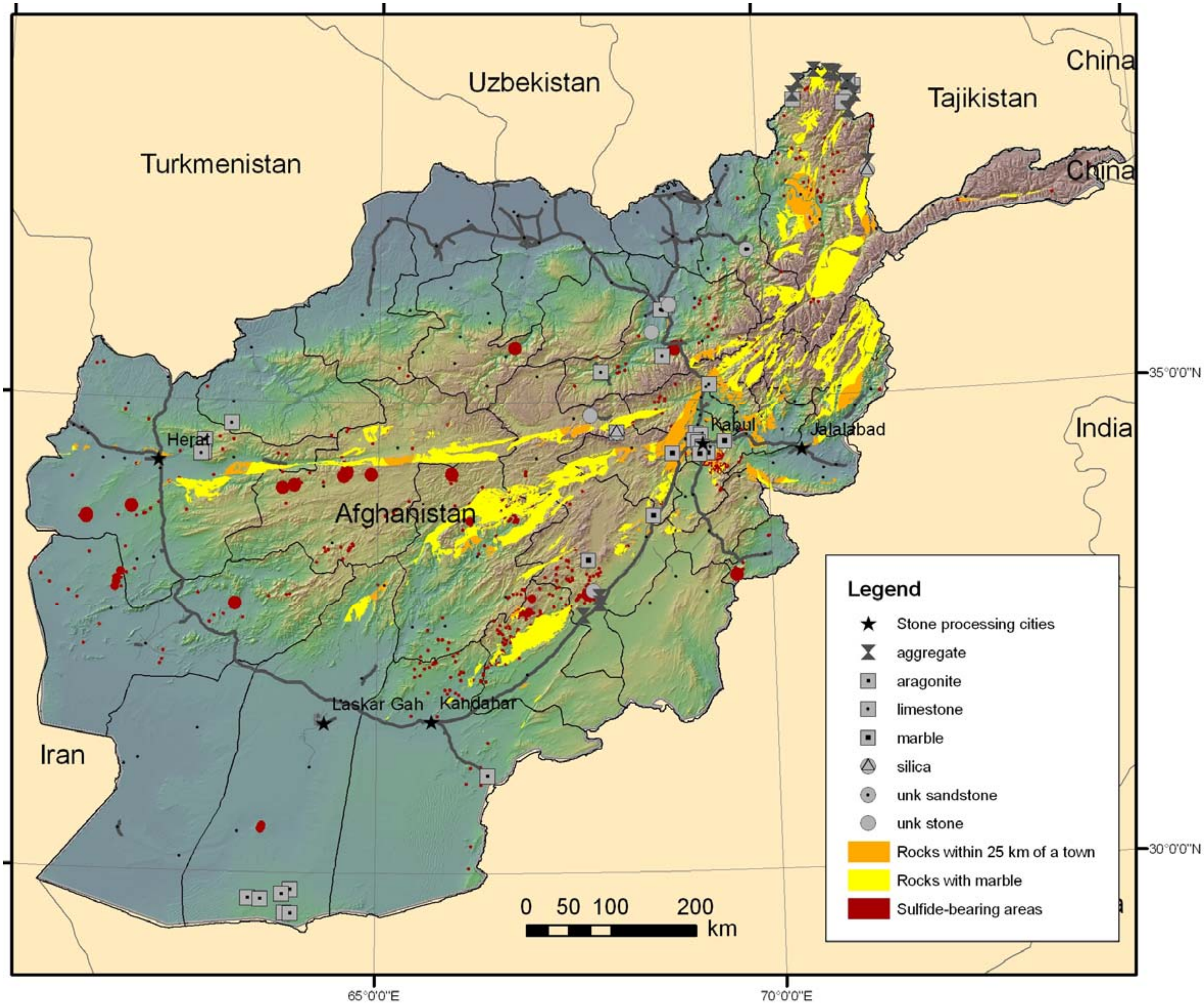

Figure 11.3-2. Tracts permissive and favorable for the occurrence of undiscovered marble dimension stone deposits in Afghanistan. Areas in red are zones of high sulfide minerals (adapted from the data base of Doebrich and Wahl, 2006). These areas would be generally non permissive.

Favorable Tracts

Tract ID: dms01-f1 marble favorable tract

***Tract criteria*—**Favorable tracts are delineated by selecting rock units that are known to contain marble and are within 25 km of a known city or village. Twenty-five km distance is a reasonable distance that a volume of dimension stone can be shipped before transportation costs become so high as to make mining uncompetitive as compared to more proximal resources. The distance can be adjusted as economic or security conditions warrant. The favorable tracts include the nine reported marble occurrences in the Kabul Basin and nearby surrounding towns. Wardak occurrence is a few km outside of the favorable tract, but its location between Kabul and Kandahar may give it a competitive advantage. The Anghuri Stone occurrence occurs in rocks reported as unmetamorphosed units such as limestone, marl, conglomerate, and sandstone, and the Bini Kama occurrence in Badakhshan Province, along the Tajikistan border in northern-most Afghanistan, is likewise located in rocks said to be limestone, dolomite, schist, and sandstone. While the favorable tract is based upon the proximity of permissive rocks to Afghan population centers, it may be that permissive rocks along the borders with other countries may be within 25 km of foreign populations centers that would make exporting the marble economic and independent of the Afghan market.

11.2.4 Travertine

Travertine is a dense, banded rock composed of aragonite (calcium carbonate, $CaCO_3$). It is a variety of limestone that has a light color and takes a good polish; it is often used for walls and interior decorations in public buildings. Travertine may also be marketed as tufa, calcareous sinter, onyx marble, or Mexican onyx, and takes the form of tile, ashlar, custom shapes such as steps and sills, lapidary work, and precious stone applications (Hora, 1996). Dusty turquoise onyx tile (believed to be a variety of travertine) from Afghanistan is striking when used as decorative stone tile in a bathroom setting (Rhodes, 2006).

Travertine deposit descriptive models

Travertine is found in young orogenic belts with carbonate sediments in the subsurface (Hora, 1996). There are often thrust and faults with deep-water circulation. Travertine deposits are also found in intercontinental rift zones having strike-slip faulting, with or without associated volcanic activity (Hora, 1996). Travertine precipitates subaerially after water has been enriched by atmospheric carbon dioxide seeps into carbonate rocks and dissolves them. The dissolution is further enhanced by carbon dioxide of juvenile post-volcanic origin. The water then rises to the surface pushed by the pressure of the CO_2. The influence of temperature and pressure decreases in combination with the presence of algae resulting in the precipitation of $CaCO_3$ around a mineral or thermal spring. New $CaCO_3$ layers build up around the spring, giving rise to travertine piles of considerable dimensions, sometimes with a small crater on their tops (*http://www.poznajachran.sk/pages/-sk_travert_kopy_besenova_en.html*). Hot spring waters which produce travertine deposits usually do not originate at temperatures above 100 °C (Hora, 1996). Ore mineralogy in a travertine deposit is calcite and aragonite with subordinate silica, fluorite, barite, and native sulfur. Travertine deposits may form as conical mounds, or sheets, are sometimes terraced, may be shallow lake in-fills, or valley in-fills (Hora, 1996). Their texture may be banded, porous, or brecciated; some deposits are pisolitic (Hora, 1996). Deposits range in age from Tertiary to Recent. Geophysical resistivity surveys can reliably locate travertine deposits, because travertine has a higher apparent resistivity than the bedrock, which is usually weathered (Kuzvart, 1984). Figure 11.0.4-1 shows the locations of tracts permissive and favorable for the occurrence of undiscovered travertine dimension stone deposits.

Hora (1996) reports that large travertine deposits reach 1 to 2 million metric tons in size, but deposits as small as tens of thousands to 100 thousand metric tons may be important locally or for custom-type work. Thus, even small occurrences can be exploited to the benefit of owners and workers.

Permissive Tract

Tract ID: dms04 Travertine permissive tract

Deposit type—Travertine dimension stone

Age of mineralization—Cretaceous, Eocene-Oligocene, Early Quaternary

Examples of deposit type—There are six reported travertine deposits in Afghanistan, five in Helmand (figure 11.0.4-2) and one in Kandahar Provinces (figure 11.0.4-3).

Helmand Province

At Arbu, numerous tabular predominantly high-grade aragonite veins 100 to 250 m long and 0.5 to 4.0 m thick occur in a Lower Quaternary andesite-dacite vent surrounding Lower Quaternary clastic rocks. Speculative reserves are 170,000 metric tons aragonite. The deposit was being exploited in the 1970s (Slavin and others, 1972; Eriomenko and others, 1974). At Zoldag, bed-like aragonite bodies occur in Lower Quaternary subvolcanic rocks and Pliocene sedimentary rocks. The largest of these bodies is 250 m long and 50 m thick. Speculative reserves are 580,000 metric tons aragonite (Slavin and others, 1972; Eriomenko and others, 1974). Small aragonite bodies at Sukalog deposit are conformable with Eocene to Oligocene volcanic tuffs. The bodies are 50 m by 50 m and 15 by 20 m across, respectively and 0.5 to 0.8 m thick. Reserves are speculated to be 6,350 metric tons aragonite (Sborshchikov and others, 1974). Malik Dukan deposit occurs in Eocene to Oligocene volcanic rocks close to the Lower Quaternary dacite-andesite volcanic neck. The deposit consists of aragonite veins as much as 500 m long and 1.2 to 5 m thick over an area of 128,300 m^2. The aragonite occurs as a high-grade green and yellow facing and ornamental stone. The reserves are 42,200 metric tons of aragonite (Slavin and others, 1972; Chinze, 1960). At Panawuk, a dense, fine-grained, light-green, yellowish-green, white, and brownish aragonite occurs in Eocene to Oligocene volcanic rocks. The aragonite forms a tabular body 12 m in diameter and 3 m thick. Reserves are speculated to be 1,000 metric tons of aragonite (Sborshchikov and others, 1974). The aragonite at Muzdan occurs in Eocene to Oligocene volcanic rocks as three aragonite bodies 200 m long and 1 to 2 m thick. The bodies consist of large, blocky, green and yellow aragonite. Reserves are speculated to be 11,800 metric tons of aragonite (Sborshchikov and others, 1974).

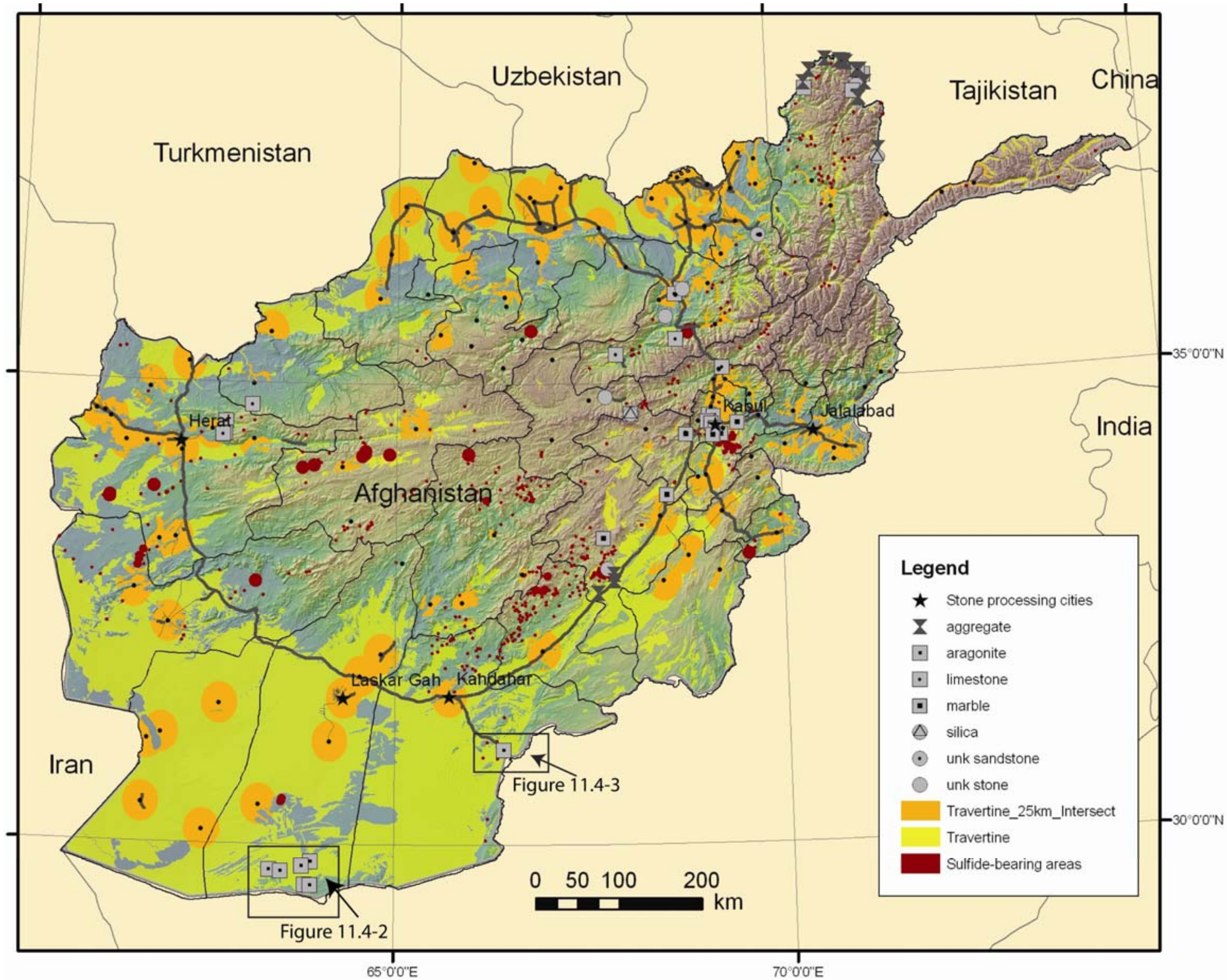

Figure 11.4–1. Tracts permissive and favorable for the occurrence of undiscovered travertine dimension stone deposits in Afghanistan. Insets show locations of areas of interest in Helmand province and Spin Boldak. Areas in red are zones of high sulfide minerals (adapted from the data base of Doebrich and Wahl, 2006). These areas would be generally non permissive.

Kandahar Province

At Spin-Boldak, several aragonite veins occur in Lower Cretaceous calcareous sedimentary inliers in Quaternary rocks. The veins are 0.1 to 0.5 m thick. The coarse, medium- and fine-grained cryptocrystalline aragonite is yellow, dark-yellow, grey, and white. The deposit is worked by hand to produce small items (Chmyriov, 1973)

Exploration history—Identification of six small aragonite deposits small-scale mining of some of those deposits in a remote part of the desert in southern Afghanistan shows that some exploration has been undertaken. The scope and extent, however, of the exploration are unknown.

Tract boundary criteria—The permissive tract for travertine includes all rock units where travertine was noted during geologic mapping. Additionally, rock units that contained any of the seven reported aragonite occurrences were added to the permissive tract in such cases where travertine was not in the rock unit description.

Important data sources—Doebrich and Wahl (2006), Orris and Bliss (2002), Abdullah and others (1977).

Needs to improve assessment—Detailed geologic mapping paying special attention to Tertiary and Quaternary volcanic and geothermal activity, noting the presence of travertine, and reporting rock physical and esthetic properties of the travertine.

Optimistic factors —Travertine is identified in many of the rocks units in Afghanistan and several small deposits have been reported. The reported deposits are mostly in within the valley fill alluvium. There may be additional deposits or extensions of the known deposits beneath the valley sediments.

Pessimistic factors—The known deposits are small.

Quantitative assessment—No estimate of the numbers of undiscovered travertine dimension stone deposits was attempted, but the areas outlined above are the most probable in Afghanistan to yield such deposits.

Favorable Tracts

Tract ID: dms04-f1 Travertine favorable tract

Tract criteria—Favorable tracts are delineated by selecting rock units that are known to contain marble and are within 25 km of a known city or village. Twenty-five km distance is a reasonable distance that a volume of dimension stone can be shipped before transportation costs become so high as to make mining uncompetitive as compared to more proximal resources. The distance can be adjusted as economic or security conditions warrant.

Areas of interest within tract dms04

Two parts of pemissive tract dms04 have known travertine deposits and are areas of interest for undiscovered travertine occurrences (figures 11.0.4-2 and 11.0.4-3). It should be noted that the travertine occurrences on these maps are in the basins usually a km or more from the nearest hills. This is because the hills act as recharge areas where meteoric water is introduced to the system. From the hills, the water migrates into the subsurface becoming enriched in CO_2. After acquiring sufficient CO_2, it rises to the surface where calcium carbonate is precipitated as aragonite for use as travertine. This process seems to require a km or more of migration away from the nearest hills to form a travertine deposit.

In tract dms04 in south Helmand Province (figure 11.0.4-2), the rocks consist of three units mapped as Cretaceous acid and mafic volcanic rocks, flint, and fine- and coarse-grained terrigenous rocks, marl, and limestone; Early Pliocene variegated sandstone, conglomerate, clay, and siltstone; and Early Quaternary conglomerate, shingly sediments, gravel, siltstone, limestone, gypsum andesite, dacite and their tuffs. There are six small reported aragonite deposits in tract dms04 all of which have recognized ornamental stone potential. These are Arbu, Zoldag, Sukalog, Malik Dukan, Panawuk, and Muzdan. The latter two deposits are of Eocene-Oligocene age and are found in the tract's volcanic rocks. Geographically, the deposits are mostly located near the bases of the nearby hills out in the basin a kilometer or two into the valley fill sediments.

Another area of interest in tract dms04 is located in south Kandahar Province and includes the Spin-Boldak ornamental stone deposit and the rock unit that hosts it (figure 11.0.4-3). The rocks are mostly valley fill mapped shingly detrital sediments, gravel, sand, clay, clayey sand, loam, loess, and travertine. The Spin-Boldak deposit is located away from the small mountains and in the Late Quaternary sedimentary deposits near the southern boundary of the tract about 10 km north of the Pakistan border.

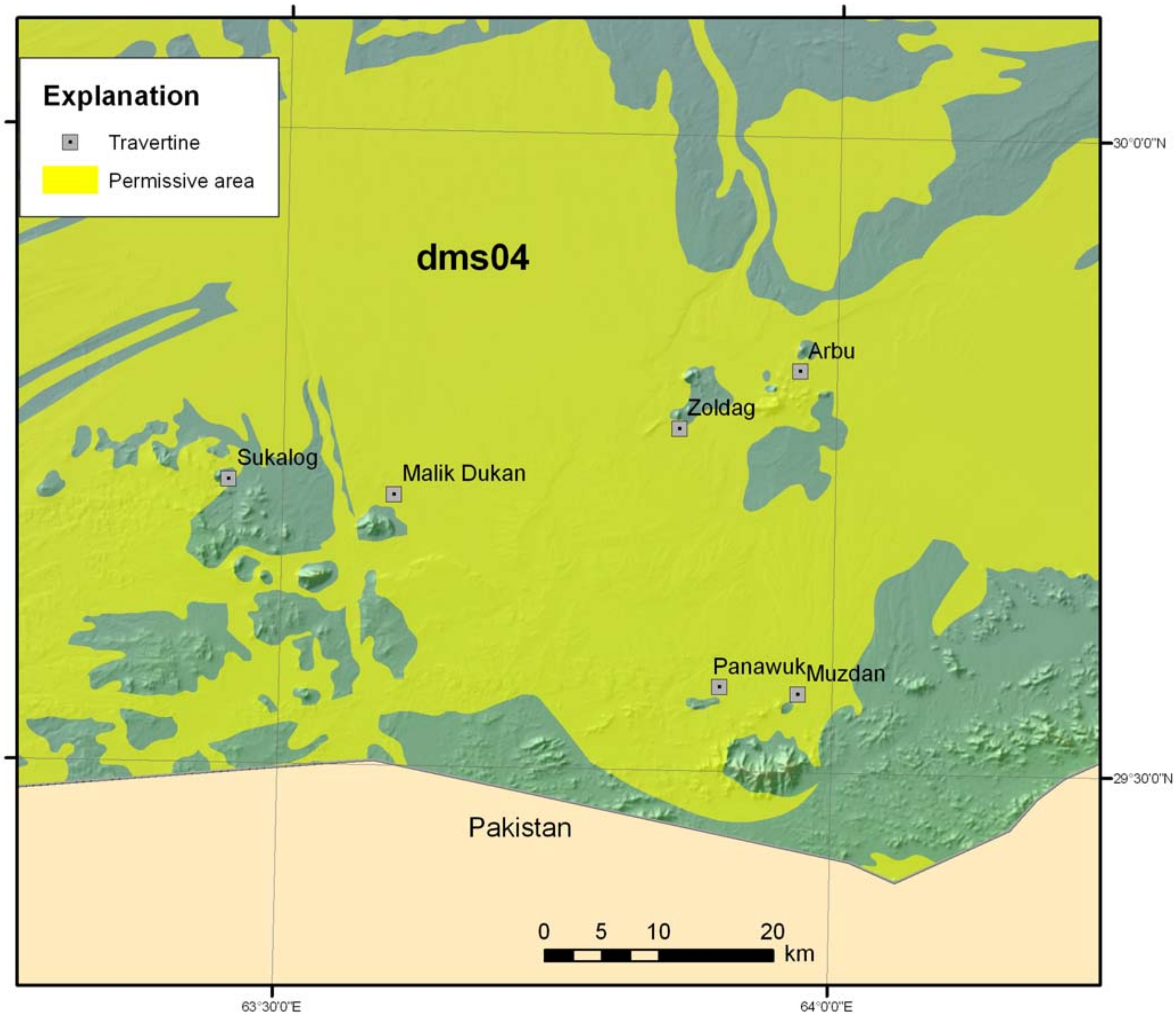

Figure 11.4–2. An area of interest within tract dms04 is in Helmand Province along the Pakistan border. In this area, travertine is mined and carved into small figurines and made into other objects.

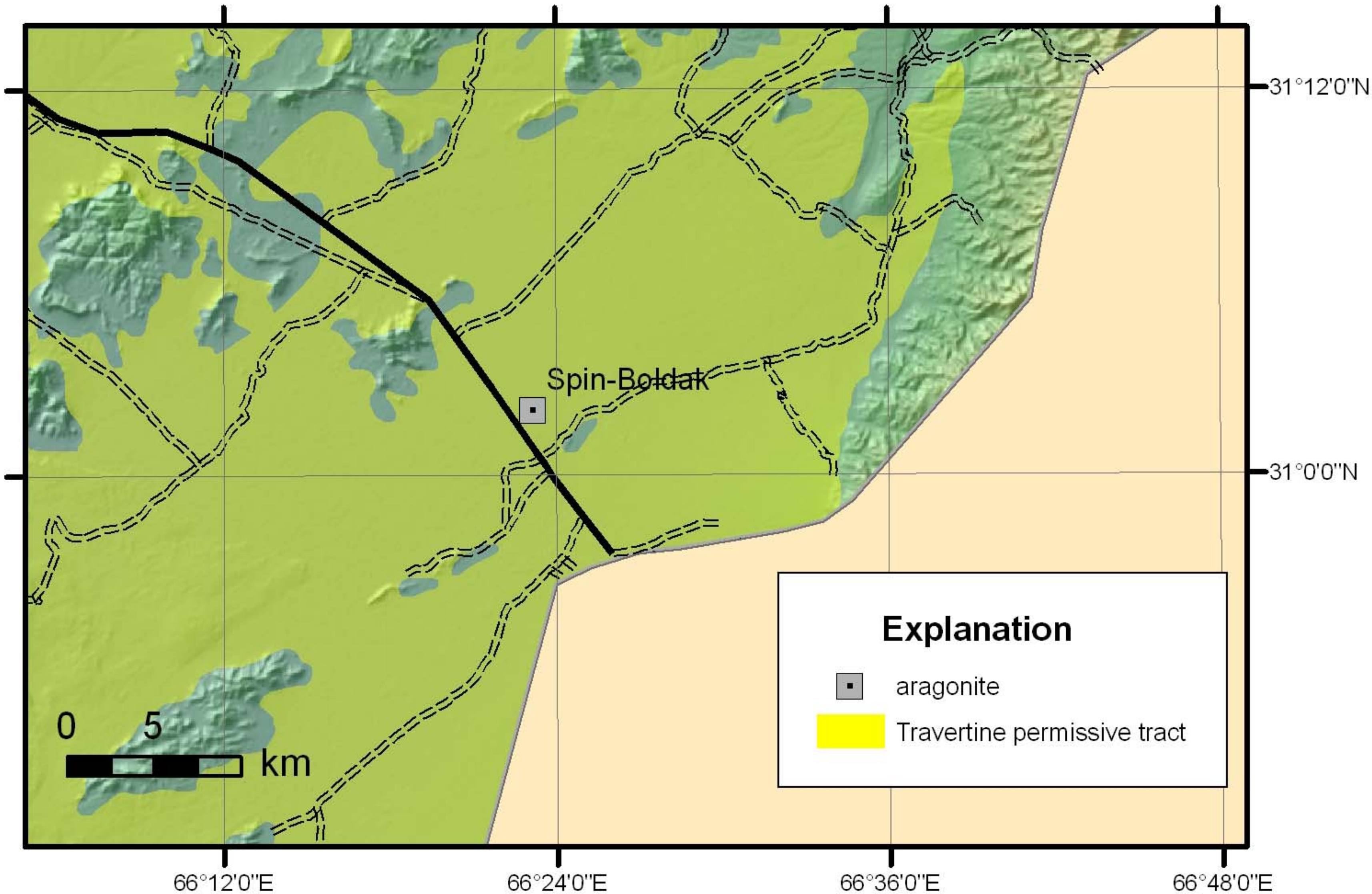

Figure 11.4-3. Part of tract dms04 in Kandahar Province along the border with Pakistan where there is a known travertine deposit and travertine has been produced. Note that sulfide areas are not shown

11.2.5 Sandstone

Sandstone sold commercially is lithified sand that comprises chiefly quartz or quartz and feldspar with a clastic texture. Sandstones may all bedded rocks of sedimentary origin consisting of grains weathered quartz, feldspar, or other non-carbonate material more or less strongly bound together by some type of cement (Wybergh, 1932). Sandstone contains interstitial cement, such as calcite, clay, iron oxides, or silica. Arkose, greywacke, breccia, and conglomerate are included in this rock type. Other members of this type are bluestone, brownstone, and flagstone. Quartzite is included, because it may be described as any metamorphosed siliceous-cemented sandstone that fractures conchoidally through the grains (Antonides, 1997). The Afghan mineral occurrence database contains the locations and brief descriptions of two sandstone mining operations.

Sandstones vary widely in color, texture, and composition of the material in the grains and the cement. The variation produces great difference in strength, durability, and other characteristics affecting suitability for different applications. Sandstone can be easy to work. Tan and gray are the most desired colors. But oxidized, weathered sandstone is marketed, because of its aesthetically pleasing spotted or streaked patterns (figure 11.1.0-1E). Sandstone dimension stone is sold primarily as dressed flagstones, and dressed stone for ashlars and partially squared pieces (Antonides, 1997). It is used as building stone in residential construction, for exterior trim and facing on large buildings, as curbstones and flagstones, and in retaining walls and bridge abutments (*www.answers.com/topic/dimension-stone*).

Tract ID: dms05 sandstone permissive tract

Deposit type—Sandstone dimension stone

Age of mineralization—Rocks in the permissive tract are of the following ages: Cambrian, Ordovician, Late Devonian, Carboniferous-Permian, Middle-Late Triassic, Early-Middle Jurassic, Early-Late Cretaceous, and Oligocene.

Examples of deposit type—There are two reported sandstone deposits in Afghanistan one each in Bamian and Takhar Provinces.

Bamian Province

The Haji Gak siliceous sandstone deposit consists of a 50 m thick Upper Devonian age sandstone bed assaying 93.66 to 97.31 percent silica, which can be used to make refractory materials. Speculative reserves are 650,000 metric tons siliceous sandstone (Meshkovskiy and others, 1965).

Takhar Province

At the Frakhar siliceous sandstone deposit, which occurs in Lower Carboniferous siltstone, sandstone, and slate, are two siliceous sandstone beds 1.2 to 8.0 km long and 50 to 120 m thick. The beds assay 95.0 to 97.3 percent silica. The silica may be use to make dinas brick, for facing electric furnaces, and to make dinas coke (Kolchanov, 1967).

Exploration history—No information is available on sandstone exploration in Afghanistan.

Tract boundary criteria—Tract dms05 was delineated to include all rocks in Afghanistan that were described on the 1:500,000-scale map as containing sandstone (Doebrich and Wahl, 2006). This leads to a relatively large permissive area, which is to be expected with such a common commodity as sandstone. Geographical distribution of the sandstones is uneven. Large areas of the country are without surficial sandstone deposits. Also, the distribution of sandstone within the rock formations is quite uneven. Some formations may be predominantly sandstone, while in others sandstone may be a very subordinate constituent.

Tract ID dms05-f1 sandstone favorable tract

Tracts dms05 includes all rocks favorable for the occurrence of undiscovered sandstone dimension stone deposits (figure 11.5-2). The rocks in the tract were selected on the basis of being permissive for sandstone deposits and being no farther than 25 km from the nearest town. Twenty-five km is approximately the maximum distance an average quality sandstone can be transported before the cost of moving the material outweighs the value of the sandstone itself. There are several individual areas where sandstones are within 25 km of the nearest town. If parts of these rocks are of sufficient physical and esthetic properties, they would most likely be the first rocks available for mining when conditions are favorable for the mining of sandstone dimension stone.

Important data sources—Doebrich and Wahl (2006), Orris and Bliss (2002), Abdullah and others (1977).

Needs to improve assessment—Detailed geologic mapping with special attention given to locating sandstone deposits and the rock physical and esthetic properties that would make them suitable for dimension stone applications.

Optimistic factors—The absence of reported sandstone dimension stone deposits is probably indicative of a lack of reporting or lack of exploration and not from a lack of permissive and favorable host rocks.

Pessimistic factors—That there are so few identified sandstone quarries reported may be indicative of a resource problem.

Quantitative assessment—No quantitative assessment of tract dms05 was attempted. Although the rocks in the tract are permissive and favorable for the occurrence of sandstone dimension stone deposits, there is no deposit model on which to do a quantitative assessment.

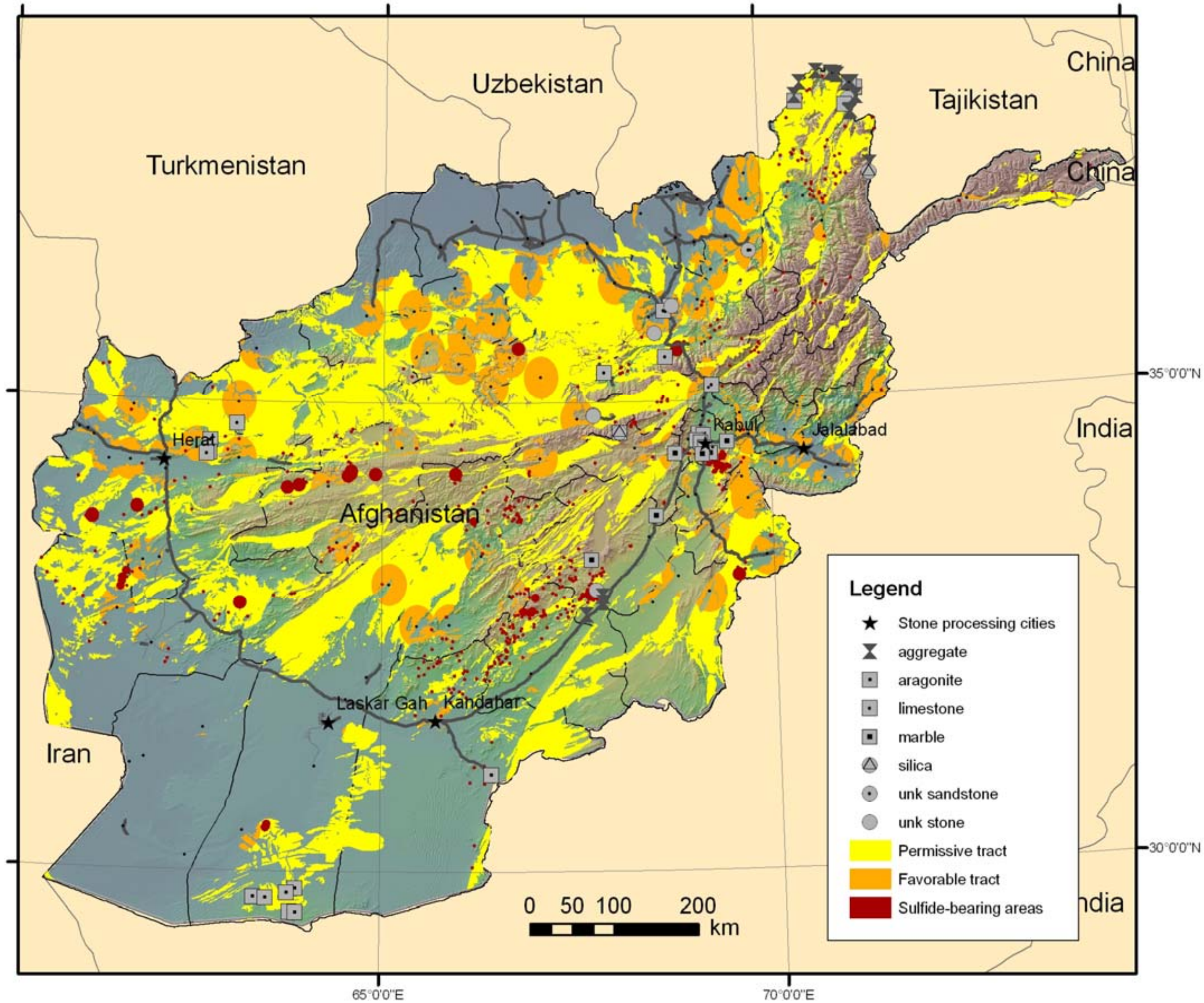

Figure 11.5-1 Tracts permissive and favorable for the occurrence of undiscovered sandstone dimension stone deposits in Afghanistan. Areas in red are zones of high sulfide minerals (adapted from the data base of Doebrich and Wahl, 2006). These areas would be generally non permissive.

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