USGS
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2006 Minerals Yearbook

SILICA

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

December 2007

SILICA

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Four silica categories are covered in this report—industrial sand and gravel, quartz crystal (a form of crystalline silica), special silica stone products, and tripoli. Most of the stone covered in the special silica stone products section is novaculite. The section on tripoli includes tripoli and other fine-grained, porous silica materials, such as rottenstone, that have similar properties and end uses. Certain silica and silicate materials, such as diatomite and pumice, are covered in other chapters of the U.S. Geological Survey (USGS) Minerals Yearbook, volume I, Metals and Minerals. Trade data in this report are from the U.S. Census Bureau. All percentages in the report were computed using unrounded data.

Industrial Sand and Gravel

Total industrial sand and gravel production increased to 31.7 million metric tons (Mt) in 2006 and was the highest production total in the history of the U.S. industry (table 1). Compared with that of 2005, industrial sand production increased by 3.7%, and gravel production decreased slightly.

Industrial sand and gravel, often called "silica," "silica sand," and "quartz sand," includes sands and gravels with high silicon dioxide (SiO_2) content. Some examples of end uses of these sands and gravels are in glassmaking and for abrasive filtration, foundry, hydraulic fracturing (frac), and silicon metal applications. The specifications for each use vary, but silica resources for most uses are abundant. In almost all cases, silica mining uses open pit or dredging methods with standard mining equipment. Except for temporarily disturbing the immediate area while operations are active, sand and gravel mining usually has limited environmental impact.

The production increase for silica sand followed several years of increasing demand for many uses, which included ceramics, chemicals, fillers (ground and whole-grain), filtration, flat and specialty glass, hydraulic fracturing, recreational, and roofing granules. The demand for silica gravel, which was mostly used for filtration and nonmetallurgical flux, experienced a decrease.

Legislation and Government Programs.—One of the most important issues affecting the industrial minerals industry in recent times has been the potential effect of crystalline silica on human health. Central to the ongoing and often heated debate has been the understanding of the regulations and the implementation of the measurements and actions taken to mitigate exposure to crystalline silica and, most significantly, appreciation of its impact on the future of many industries (Industrial Minerals, 1998). The U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) has created a permissible exposure limit that stipulates the maximum amount of crystalline silica to which workers may be safely exposed during an 8-hour work shift (29 CFR §§1910.1000, 1926.55). The OSHA also presents guidelines and training for the proper handling of crystalline silica (U.S. Department of Labor, Occupational Safety and Health Administration, 2002).

In a decision against the plaintiffs by a Federal judge *in re Silica Products Liability Litigation*, 398 F. Supp. 2d 563 (S.D. Texas June 30, 2005), defendants requested that the court examine the reliability of thousands of silicosis diagnoses under Federal Rule of Civil Procedure 702 and the analytical framework developed by *Daubert* v. *Merrell Dow Pharmaceuticals, Inc.*, 509 U.S. 579 (1993). The court found that the plaintiffs were attempting to generate revenue through silicosis litigation as opposed to creating a procedure for compensating truly injured individuals, and sanctions relating to conduct were imposed on the plaintiffs' counsel.

Production.—Domestic production data for industrial sand and gravel were developed by the USGS from a voluntary survey of U.S. producers. The USGS canvassed 68 producers with 138 operations known to produce industrial sand and gravel. Of the 138 surveyed operations, 120 (87%) were active, and 18 were idle. The USGS received responses from 98 operations, and their combined production represented 94% of the U.S. total. Production for the 40 nonrespondents was estimated, primarily on the basis of previously reported information supplemented with worker-hours reports from the U.S. Department of Labor's Mine Safety and Health Administration and information from State agencies.

The South (South Atlantic, East South Central, and West South Central divisions) led the Nation with 42% of the 31.7 Mt of industrial sand and gravel produced in the United States, followed by the Midwest (East North Central and West North Central divisions) with 41%, and the West (Pacific and Mountain divisions) with 9% (figure 1, table 2).

The leading producing States were, in decreasing order, Illinois, Florida, Wisconsin, California, Oklahoma, Texas, New Jersey, and Michigan (table 3). Their combined production represented 60% of the national total. States for which data have been withheld in table 3 are not included among the leading producers. Of the 34 States that produced silica in 2006, 16 had increased production, 17 had decreased production, and 1 had stable production compared with those of 2005. Florida, Georgia, and Wisconsin reported the largest increases, and California, New Jersey, and Texas reported the largest decreases.

Of the total industrial sand and gravel, 85% was produced by 51 operations, each with production of 200,000 metric tons per year (t/yr) or more (table 4). The 10 leading producers of industrial sand and gravel were, in descending order, Unimin Corp., U.S. Silica Co., SMR Aggregates Inc., Best Sand Corp., Badger Mining Corp., Oglebay Norton Industrial Sands Co., Little Six Corp., Simplot Industries Inc., Nugent Sand Co.

Inc., and Kinder Sand Co. Inc. Their combined production represented 84% of the U.S. total.

Consumption.—Industrial sand and gravel production reported by producers to the USGS was material sold to their customers or used by the producing companies. Stockpiled material is not reported until consumed or sold. Of the 31.7 Mt of industrial sand and gravel sold or used, 33% was consumed as glassmaking sand, and 16%, as foundry sand (table 6). Frac sand and sand for well packing and cementing consumed 15% of industrial sand and gravel production. Other important uses were ground silica and whole grain silica (11%), and building products (10%).

Minable deposits of industrial sand and gravel occur throughout the United States, and successful mining companies are located near markets that have traditionally been in the Eastern United States. In some cases, consuming industries are specifically located near a silica resource. The automotive industry was originally located in the Midwest near clay, coal, iron, and silica resources. Therefore, foundry sands have been widely produced in Illinois, Indiana, Michigan, Ohio, and other Midwestern States. In 2006, at least 79% of foundry sand was produced in the Midwest.

Producers of industrial sand and gravel were asked to provide statistics on the destination of silica produced at their operations. The producers were asked to list only the quantity of shipments (no value data were collected in this section of the questionnaire) and to which State or other location the material was shipped for consumption. The States that received the most industrial sand and gravel were Illinois (6.6%), Pennsylvania (3.9%), Colorado (3.7%), Wisconsin (3.7%), Georgia (3.6%), and Ohio (3.4%). Producers reported sending at least 560,000 t of silica to Canada and 431,000 t to Mexico (table 7). Because some producers did not provide this information, their data were estimated or assigned to the "Destination unknown" category. In 2006, 13% of industrial sand and gravel shipped by producers was assigned to that category.

The share of silica sold for all types of glassmaking as a percentage of all silica sold was 33%, decreasing by 2% compared with that of 2005. In 2006, sales to container glass manufacturers increased slightly compared with those of 2005. On average, in the container glassmaking industry, silica accounts for 60% of raw materials used (Industrial Minerals, 2004). The amount of sand consumed for fiberglass production decreased by 11% compared with that of 2005.

In 2006, sales of sand for flat glass production increased by 8% compared with those of 2005. In the Midwest, consumption for flat glass increased by 35%, and in the South, consumption increased by 2%.

In 2006, 221,000 metric tons (t) of ground silica was used in ceramic production. Silica also is used in plastics as an extender, filler, and reinforcer. Whole-grain and ground silica are used in filler-type applications. In 2006, consumption of whole-grain filler was 3.2 Mt, and ground silica for filler was 761,000 t.

In table 6, industrial sand and gravel that would find its way into specialty silicas is most likely reported by the producers in the categories "Sand, abrasives, chemicals, ground and unground," "Gravel, silicon, ferrosilicon," and possibly "Glassmaking, specialty." In 2006, silica sales for chemical production were 816,000 t, which was a decrease of 2% compared with those of 2005. According to the USGS survey, reported sales of silica gravel for silicon and ferrosilicon production decreased by 80% in 2006 compared with those of 2005. The main uses for silicon metal are in the manufacture of silanes and semiconductor-grade silicon and in the production of aluminum alloys. Consumption may be down owing to new techniques in the field of semiconductors to enable manufacturers to deposit a thin, defect-free layer of single-crystal silicon on wafer-thin microchips in a gas containing silicon. This new technique has superseded the traditional method of creating a massive cylindrical ingot of silicon from a batch of molten silicon, the single large crystal having too many defects for current applications (Hutcheson, 2004). Another new technique involves deforming the crystal structure of silicon, a primary component of all electronic devices. The technique alters the properties of silicon so that the material will transmit an optical or light-based signal, possibly resulting in replacing electronic components with faster optical components. Modern computers may benefit from such improvements (Jacobsen and others, 2006).

Transportation.—Of all industrial sand and gravel produced, 58% was transported by truck from the plant to the site of first sale or use, down from that of 2005; 32% was transported by rail, down slightly from that of 2005; and 10% by unspecified modes of transport.

Prices.—Compared with the average value of 2005, the average value, free on board plant, of U.S. industrial sand and gravel increased by 3.5% to $25.42 per metric ton in 2006 (table 6). The average unit values for industrial sand and industrial gravel were $25.40 per ton and $26.04 per ton, respectively. The average price for sand ranged from $4.65 per ton for metallurgical flux to $119.67 per ton for ground foundry sand. For gravel, prices ranged from $35.33 per ton for filtration to $153.41 per ton for silicon and ferrosilicon. Producer prices reported to the USGS for silica commonly ranged from several dollars per ton to hundreds of dollars per ton, and occasionally prices exceeded the $1,000-per-ton level. Nationally, ground sand for foundry molding and core had the highest value ($119.67 per ton), followed by silica for swimming pool filters ($66.33 per ton), ground sand used as fillers for paint, putty, and rubber ($63.26 per ton), ground sand for ceramics ($46.48 per ton), sand for hydraulic fracturing ($44.31 per ton), abrasive sand for blasting ($42.49 per ton), ground sand for fiberglass ($41.07 per ton), and sand for well packing and cementing ($35.06 per ton).

By geographic region, the average value of industrial sand and gravel was highest in the West ($30.68 per ton), followed by the Northeast ($26.08 per ton), the Midwest ($25.69 per ton), and the South ($23.85 per ton) (table 6). Prices can vary greatly for similar grades of silica at different locations in the United States. For example, the average value of container glass sand varied from $26.63 per ton in the West to $14.40 per ton in the Midwest. Tighter supplies and higher production costs in the West and much greater competition in the Midwest caused the difference in the cost to the consumer of sand and gravel in these two regions.

Foreign Trade.—Exports of industrial sand and gravel in 2006 increased by 32% compared with the amount exported

in 2005, and the associated value increased by 19% (table 8). The large increase in exports can be attributed mainly to increased demand from Asian, European, and North American markets. Canada was the leading recipient of U.S. exports. The distribution of exports was as follows: 40% to Canada, 28% to Japan, 23% to Mexico, and the remainder to Africa and the Middle East, Europe, South America, and Oceania. The average price of exports decreased to $48 per ton in 2006 from $53 per ton in 2005. In 2006, export prices varied widely by region; exports of silica to Oceania averaged $462 per ton, and exports to the rest of the world averaged $47 per ton.

Imports for consumption of industrial sand and gravel rose to 855,000 t, which was an increase of 20% compared with those of 2005 (table 9). Mexico supplied 68% of the silica imports, which averaged $12 per ton; this price included insurance and freight costs to the U.S. port. The total value of imports was $21 million, with an average of $24 per ton. Higher priced imports came from Australia, Chile, China, Germany, and Japan.

World Review.—Based on information provided mainly by foreign governments, world production of industrial sand and gravel was estimated to be 117 Mt (table 11). The United States was the leading producer followed, in descending order, by Slovenia, Germany, Austria, France, Spain, the United Kingdom, and Japan. Most countries in the world had some production and consumption of industrial sand and gravel, which are essential to the glass and foundry industries. Because of the great variation in reporting standards, however, obtaining reliable information was difficult. In addition to the countries listed, many other countries were thought to have had some type of silica production and consumption.

Outlook.—U.S. consumption of industrial sand and gravel in 2007 was expected to be 28 to 29 Mt. All forecasts are based on previous performances for this commodity within various end uses, contingency factors considered relevant to the future of the commodity, and forecasts made by analysts and producers in the various markets.

Sales of glass sand can be expected to vary from market to market. Growth has been noted in some segments, such as flat and specialty glasses, container glass, and frac sand. Total demand for all glass sand end uses is expected to remain static or possibly exhibit slow growth through 2007. Demand for industrial sand and gravel will also be constrained by the producer's rising energy costs for both production and transportation of product.

The demand for foundry sand is dependent mainly on automobile and light truck production. Another important factor for the future consumption of virgin foundry sand is the recycling of used foundry sand. The level of recycling is thought to be increasing. Other materials or minerals compete with silica as foundry sand, but these other "sands" usually suffer from a severe price disadvantage. Based on these factors, consumption of silica foundry sand in 2007 is expected to be 5 Mt, and consumption is expected to range from 4.9 to 5.1 Mt.

Frac sand sales increased in 2006 compared with those of 2005. Based on this trend, demand for frac sand is expected to increase modestly during 2007 to 4 Mt, with a range of 4 to 4.3 Mt.

The United States is the leading producer and a major consumer of silica sand and is self-sufficient in this mined commodity. Most of it is produced at premier deposits in the Midwest and near major markets in the Eastern United States. A significant amount of silica sand is also produced in the West and Southwest, mostly in California and Texas, respectively. Domestic production is expected to continue to meet 97% or 98% of demand well beyond 2007. Imports mostly from Canada and Mexico and higher valued material from China are expected to remain minor.

Because the unit price of silica sand is relatively low, except for a few end uses that require a high degree of processing, the location of a silica sand deposit in relation to the market is an important factor that may work for or against a sand producer. Consequently, a significant number of relatively small operations supply local markets with a limited number of products.

Several factors could affect supply and demand relations for silica sand. Further increases in the development of substitute materials for glass and cast metals could reduce demand for foundry and glass sand. These substitutes, which are mainly ceramics and polymers, would likely increase the demand for ground silica, which is used as a filler in plastics; glass fibers, which are used in reinforced plastics; and silica (chemical, ground, or whole-grain), which is used to manufacture ceramics. Increased efforts to reduce waste and to increase recycling also could lower the demand for mined glass sand. Recycling of glass cullet is increasing in most industrialized nations and recycling accounts for approximately 25% to 70% of the raw material needed for the glass container industry in many countries. It has been estimated that for every 10% of recycled glass cullet used in the melting process for glass container manufacture, energy use will fall approximately 2.5%. During the past 20 years, a 25% to 40% reduction in glass container weight has taken place in many nations, including the United States (Industrial Minerals, 2004). Although developments could cause the demand for silica sand to decrease, the total value of production could increase because of the increased unit value of the more specialized sands.

Health concerns about the use of silica as an abrasive and stricter legislative and regulatory measures concerning crystalline silica exposure could reduce the demand in many silica markets. The use of silica sand in the abrasive blast industry was being evaluated as a health hazard as marketers of competing materials, which include garnet, olivine, and slags, encouraged the use of their "safer" abrasive media. Additionally, abrasive-grade bauxite, which is the feedstock for brown fused alumina, is finding increasing use in abrasives and proppants; in the latter application, bauxite is used to hold fractures open in oil wells, as is silica sand (Industrial Minerals, 2002).

Quartz Crystal

Electronic-grade quartz crystal is single-crystal silica with properties that make it uniquely useful in accurate filters, frequency controls, and timers used in electronic circuits. These devices are used for a variety of electronic applications in aerospace hardware, commercial and military navigational instruments, communications equipment, computers, and consumer goods (for example, clocks, games, television

receivers, and toys). Such uses generate practically all the demand for electronic-grade quartz crystal. A lesser amount of optical-grade quartz crystal is used for lenses and windows in specialized devices, which include some lasers.

Natural quartz crystal was used in most electronic and optical applications until 1971 when it was surpassed by cultured quartz crystal. It has been estimated that approximately 10 billion quartz crystals and oscillators will be manufactured and installed worldwide in all types of electronic devices, from automobiles to cell phones in 2006. Despite this staggering number, quartz technology could face competition in the near future with the advent of more cost-effective microelectromechanical systems (MEMS). MEMS technology was first developed in 1965 and consists of silicon on insulated wafers. MEMS technology is physically compatible with existing quartz oscillator products and have better long-term stability performance characteristics for use in automotive, consumer and computational products, and wireless applications (Partridge, 2006).

The use of natural quartz crystal for carvings and other gemstone applications has continued; more information can be found in the "Gemstones" chapter of the USGS Minerals Yearbook, volume I, Metals and Minerals.

Legislation and Government Programs.—The strategic value of quartz crystal was demonstrated during World War II when it gained widespread use as an essential component of military communication systems. After the war, natural electronic-grade quartz crystal was officially designated as a strategic and critical material for stockpiling by the Federal Government. Cultured quartz crystal, which eventually supplanted natural crystal in nearly all applications, was not commercially available when acquisition of natural quartz crystal for a national stockpile began.

As of December 31, the National Defense Stockpile (NDS) contained 7,134 kilograms (kg) of natural quartz crystal. The stockpile has 11 weight classes for natural quartz crystal that range from 0.2 kg to more than 10 kg. The stockpiled crystals, however, are primarily in the larger weight classes. The larger pieces are suitable as seed crystals, which are very thin crystals cut to exact dimensions, to produce cultured quartz crystal. In addition, many of the stockpiled crystals could be of interest to the specimen and gemstone industry. Little, if any, of the stockpiled material is likely to be used in the same applications as cultured quartz crystal.

No natural quartz crystal was sold from the NDS in 2006, and the Federal Government does not intend to dispose of or sell any of the remaining material. Previously, only individual crystals in the NDS inventory that weighed 10 kg or more and could be used as seed material were sold. Brazil traditionally has been the source of such large natural crystals, but changes in mining operations have reduced output.

Quartz crystal is also affected by the regulation of crystalline silica as discussed in the "Legislation and Government Programs" portion of the "Industrial Sand and Gravel" section of this chapter.

Production.—The USGS collects production data for quartz crystal through a survey of the domestic industry. In 2006, no domestic companies reported the production of cultured quartz crystal. In the past several years, cultured quartz crystal was being predominantly produced overseas, primarily in Asia.

Consumption.—In 2006, the USGS collected domestic consumption data for quartz crystal through a survey of 23 U.S. operations that fabricate quartz crystal devices in 9 States. Of the 23 operations, 9 responded to the survey. Consumption for nonrespondents was estimated based on reports from previous years.

Prices.—The average value of as-grown cultured quartz and lumbered quartz, which is as-grown quartz that has been processed by sawing and grinding, was estimated to be $215 per kilogram in 2006.

Foreign Trade.—The U.S. Department of Commerce (DOC), which is the major Government source of U.S. trade data, does not provide specific import or export statistics on lascas. The DOC also collects export and import statistics on electronic and optical-grade quartz crystal; however, the quartz crystal export and import quantities and values reported in previous years included zirconia and were inadvertently reported to be quartz crystal not including mounted piezoelectric crystals.

World Review.—Cultured quartz crystal production is concentrated in China, Japan, and Russia; several companies produce crystal in each country. Other producing countries are Belgium, Brazil, Bulgaria, France, Germany, South Africa, and the United Kingdom. Details concerning quartz operations in China, the Eastern European countries, and most nations of the Commonwealth of Independent States are unavailable. Operations in Russia, however, have significant capacity to produce synthetic quartz.

Outlook.—Growth of the consumer electronics market (for example, automobiles, cellular telephones, electronic games, and personal computers), particularly in the United States, will continue to provide consumer outlets for domestic production of quartz crystal devices. The expanding global electronics market may require additional production capacity worldwide.

Special Silica Stone Products

Silica stone (another type of crystalline silica) products are materials for abrasive tools, such as deburring media, grinding pebbles, grindstones, hones, oilstones, stone files, tube-mill liners, and whetstones. These products are manufactured from novaculite, quartzite, and other microcrystalline quartz rock. This chapter, however, excludes products that are fabricated from such materials by artificial bonding of the abrasive grains (information on other manufactured and natural abrasives may be found in other USGS Minerals Yearbook, volume I, Metals and Minerals chapters).

Special silica stone is also affected by the regulation of crystalline silica as discussed in the "Legislation and Government Programs" part of the "Industrial Sand and Gravel" section of this chapter.

Production.—In response to a USGS production survey, five of seven domestic firms, representing 95% of crude production, responded during 2006. Data for the remaining producers were estimated. Arkansas accounted for most of the value and quantity of production reported. Plants in Arkansas manufactured files, deburring-tumbling media, oilstones, and whetstones (table 10).

The industry has produced and marketed four main grades of Arkansas whetstone in recent years. The grades range from

the high-quality black hard Arkansas stone down to Washita stone. In general, the black hard Arkansas stone has a porosity of 0.07% and a waxy luster, and Washita stone has a porosity of 16% and resembles unglazed porcelain.

Consumption.—The domestic consumption of special silica stone products is by a combination of craft, household, industrial, and leisure uses. The leading household use is for sharpening of knives and other cutlery, lawn and garden tools, scissors, and shears. Major industrial uses include deburring of metal and plastic castings, polishing of metal surfaces, and sharpening and honing of cutting surfaces. The major recreational use is in sharpening of arrowheads, fishhooks, spear points, and sports knives. The leading craft application is sharpening tools for engraving, jewelry making, and woodcarving. Silica stone files are also used in the manufacture, modification, and repair of firearms.

Prices.—The average value of crude material suitable for cutting into finished products was $4,370 per ton. The average value of stone products made from crude material was $4.45 per kilogram (table 1).

Foreign Trade.—In 2006, silica stone product exports had a value of $9.9 million, down slightly from that of 2005. These exports were categorized as "hand sharpening or polishing stones" by the DOC. This category accounted for most, if not all, of the silica stone products exported in 2006.

In 2006, the value of imported silica stone products was $8.1 million; this was an increase of 5.2% compared with that of 2005. These imports were hand sharpening or polishing stones, which accounted for most or all of the imported silica stone products in 2006. A portion of the finished products that were imported may have been made from crude novaculite produced in the United States and exported for processing.

Outlook.—Consumption patterns for special silica stone are not expected to change significantly during the next several years. Most of the existing markets are well defined, and the probability of new uses is low.

Tripoli

Tripoli, broadly defined, includes extremely fine grained crystalline silica in various stages of aggregation. Grain sizes usually range from 1 to 10 micrometers (μm), but particles as small as 0.1 to 0.2 μm are common. Commercial tripoli contains 98% to 99% silica and minor amounts of alumina (as clay) and iron oxide. Tripoli may be white or some shade of brown, red, or yellow depending upon the percentage of iron oxide.

Tripoli also is affected by the regulation of crystalline silica as discussed in the "Legislation and Government Programs" part of the "Industrial Sand and Gravel" section of this chapter.

Production.—In 2006, five U.S. firms were known to produce and process tripoli. American Tripoli Co. produced crude material in Ottawa County, OK, and finished material in Newton County, MO. Keystone Filler and Manufacturing Co. in Northumberland County, PA, processed rottenstone, which is decomposed fine-grained siliceous shale purchased from local suppliers. Malvern Minerals Co. in Garland County, AR, produced crude and finished material from novaculite. Harbison-Walker Refractories Co. Inc. in Hot Springs County, AR, produced crude and finished tripoli that is consumed in the production of refractory bricks and shapes. Unimin Specialty Minerals Inc. in Alexander County, IL, produced crude and finished material. All these firms except one responded to the USGS survey.

Consumption.—The 2006 USGS annual survey of producers indicated that sales of processed tripoli decreased by 17% in quantity to 76,000 t with a value of $17.5 million (table 1).

Tripoli has unique applications as an abrasive because of its hardness and its grain structure, which lacks distinct edges and corners. It is a mild abrasive, which makes it suitable for use in toothpaste and tooth-polishing compounds, industrial soaps, and metal- and jewelry-polishing compounds. The automobile industry uses it in buffing and polishing compounds for lacquer finishing.

The end-use pattern for tripoli has changed significantly in the past 30 years. In 1970, nearly 70% of the processed tripoli was used as an abrasive. In 2006, 13% of tripoli output was used as an abrasive. The remainder was used in brake friction products, as a filler and extender in enamel, caulking compounds, linings, paint, plastic, refractories, rubber, and other products. The primary use of tripoli (79%) is as a filler and extender in paints. Plastics, resins, and rubbers each account for 8% of the tripoli used as a filler and extender.

Price.—The average reported unit value of all tripoli sold or used in the United States was $231 per ton in 2006. The average reported unit value of abrasive tripoli sold or used in the United States during 2006 was $193 per ton, and the average reported unit value of filler tripoli sold or used domestically was $253 per ton.

Outlook.—Consumption patterns for tripoli are not expected to change significantly during the next several years. Most of the existing markets are well defined, and the probability of new uses is low.

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TABLE 1
SALIENT U.S. SILICA STATISTICS[1]

(Thousand metric tons and thousand dollars unless otherwise specified)

		2002	2003	2004	2005	2006
Industrial sand and gravel:[2]						
Sold or used:						
Quantity:						
Sand		25,900	26,300	28,700	29,700	30,800
Gravel		1,420	1,140	1,070	955	943
Total		27,300	27,500	29,700	30,600	31,700
Value:						
Sand		554,000	594,000	668,000	733,000	782,000
Gravel		19,400	15,300	16,600	19,500	24,600
Total		573,000	609,000	685,000	752,000	807,000
Exports:						
Quantity		1,410	2,620	1,790	2,910	3,830
Value		145,000	155,000	174,000	154,000	183,000
Imports for consumption:						
Quantity		250	440	490	711	855
Value		8,650	9,210	12,400	18,200	21,000
Processed tripoli:[3]						
Quantity	metric tons	66,600	68,800	94,000	91,100	76,000
Value		16,600	17,700	19,400	18,700	17,500
Special silica stone:						
Crude production:						
Quantity	metric tons	748	1,070	227	193	227
Value		240	313	132	191	992
Sold or used:						
Quantity	metric tons	386	513	655	576	328
Value		3,740	3,630	3,660	2,290	1,460

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Excludes Puerto Rico.
[3]Includes amorphous silica and Pennsylvania rottenstone.

TABLE 2

INDUSTRIAL SAND AND GRAVEL SOLD OR USED IN THE UNITED STATES, BY GEOGRAPHIC DIVISION[1]

	2005				2006			
Geographic region	Quantity (thousand metric tons)	Percentage of total	Value (thousands)	Percentage of total	Quantity (thousand metric tons)	Percentage of total	Value (thousands)	Percentage of total
Northeast:								
New England	195	1	$5,250	1	173	1	$6,290	1
Middle Atlantic	2,530	8	49,500	7	2,220	7	56,200	7
Midwest:								
East North Central	10,600	35	223,000	30	10,600	33	244,000	30
West North Central	2,240	7	74,300	10	2,460	8	91,200	11
South:								
South Atlantic	4,080	13	96,800	13	7,120	22	134,000	17
East South Central	1,760	6	38,000	5	1,520	5	48,400	6
West South Central	5,550	18	170,000	23	4,660	15	135,000	17
West:								
Mountain	1,280	4	26,000	3	982	3	24,000	3
Pacific	2,390	8	69,600	9	2,010	6	67,800	8
Total	30,600	100	752,000	100	31,700	100	807,000	100

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 3
INDUSTRIAL SAND AND GRAVEL SOLD OR USED IN THE UNITED STATES, BY STATE[1]

(Thousand metric tons and thousand dollars)

	2005		2006	
State	Quantity	Value	Quantity	Value
Alabama	710	11,200	474	18,700
Arizona	W	W	W	W
Arkansas	W	W	W	W
California	2,030	60,400	1,670	57,800
Colorado	W	W	W	W
Florida	715	9,410	3,340	46,500
Georgia	689	15,000	973	17,400
Idaho	W	W	W	W
Illinois	5,510	104,000	5,410	102,000
Indiana	W	W	W	W
Iowa	W	W	W	W
Kansas	W	W	W	W
Louisiana	509	11,600	663	16,100
Maryland	W	W	--	--
Michigan	1,610	24,500	1,460	30,400
Minnesota	W	W	W	W
Mississippi	W	W	W	W
Missouri	559	14,500	595	16,400
Nevada	W	W	W	W
New Jersey	1,820	34,100	1,520	40,600
New Mexico	113	W	184	W
New York	--	--	W	W
North Carolina	1,150	29,200	1,220	24,700
North Dakota	W	W	W	W
Ohio	1,230	37,900	1,110	33,800
Oklahoma	1,480	33,500	1,640	40,400
Pennsylvania	711	15,400	696	15,500
Rhode Island	W	W	W	W
South Carolina	794	19,400	905	21,800
Tennessee	985	26,500	1,010	29,300
Texas	2,840	114,000	1,530	65,600
Virginia	W	W	W	W
Washington	W	W	W	W
West Virginia	369	17,800	333	17,200
Wisconsin	2,250	55,700	2,450	74,100
Other	4,580	118,000	4,560	138,000
Total	30,600	752,000	31,700	807,000

W Withheld to avoid disclosing company proprietary data; included in "Other." -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 4
INDUSTRIAL SAND AND GRAVEL PRODUCTION IN THE UNITED STATES IN 2006, BY SIZE OF OPERATION[1]

Size range	Number of operations	Percentage of total	Quantity (thousand metric tons)	Percentage of total
Less than 25,000	23	19	243	(2)
25,000 to 49,999	11	9	363	1
50,000 to 99,999	18	15	1,110	3
100,000 to 199,999	17	14	2,250	7
200,000 to 299,999	17	14	3,750	11
300,000 to 399,999	10	8	3,260	10
400,000 to 599,999	3	1	W	4
600,000 to 699,999	6	5	3,670	11
700,000 and more	15	12	15,700	49
Total	120	100	31,700	100

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Less than ½ unit.

TABLE 5
NUMBER OF INDUSTRIAL SAND AND GRAVEL OPERATIONS AND PROCESSING PLANTS IN THE UNITED STATES IN 2006, BY GEOGRAPHIC DIVISION

Geographic region	Mining operations on land		Dredging operations	Total active operations
	Stationary	Portable		
Northeast:				
New England	1	--	--	1
Middle Atlantic	6	1	2	9
Midwest:				
East North Central	25	--	3	28
West North Central	6	--	3	9
South:				
South Atlantic	16	--	6	22
East South Central	8	--	2	10
West South Central	16	--	6	22
West:				
Mountain	7	--	--	7
Pacific	11	--	1	12
Total	96	1	23	120

-- Zero.

TABLE 6
INDUSTRIAL SAND AND GRAVEL SOLD OR USED BY U.S. PRODUCERS IN 2006, BY MAJOR END USE[1]

Major use	Northeast			Midwest			South		
	Quantity (thousand metric tons)	Value (thousands)	Unit value[2] (dollars per ton)	Quantity (thousand metric tons)	Value (thousands)	Unit value[2] (dollars per ton)	Quantity (thousand metric tons)	Value (thousands)	Unit value[2] (dollars per ton)
Sand:									
Glassmaking:									
Containers	702	$16,800	23.90	1,340	$19,400	14.40	1,890	$43,200	22.88
Flat, plate and window	W	W	19.50	1,140	18,100	15.87	1,540	28,500	18.50
Specialty	W	W	29.38	W	W	24.47	223	6,360	28.52
Fiberglass, unground	W	W	20.51	260	3,550	13.63	466	8,350	17.92
Fiberglass, ground	--	--	--	58	2,620	45.14	552	22,400	40.64
Foundry:									
Molding and core, unground	90	6,000	66.66	4,000	53,400	13.35	794	24,000	30.17
Molding and core, ground	--	--	--	(3)	3	--	W	356	118.67
Refractory	(3)	9	--	W	W	104.00	84	2,110	25.13
Metallurgical:									
Silicon carbide	--	--	--	--	--	--	W	10	--
Flux for metal smelting	--	--	--	--	--	--	W	80	2.67
Abrasives:									
Blasting	W	W	39.71	57	3,010	52.84	208	9,370	45.05
Scouring cleansers, ground	--	--	--	(3)	33	--	W	104	26.00
Sawing and sanding	W	W	20.50	--	--	--	W	37	37.00
Chemicals, ground and unground	26	739	28.42	369	8,400	22.76	401	12,200	30.53
Fillers, ground, rubber, paints, putty, etc.	8	506	63.25	231	8,660	37.47	520	38,900	74.79
Whole-grain fillers/building products	353	11,700	33.28	574	18,600	32.34	1,920	35,000	18.22
Ceramic, ground, pottery, brick, tile, etc.	(3)	13	--	55	5,120	93.02	165	5,110	30.95
Filtration:									
Water, municipal, county, local	80	4,950	61.91	132	2,260	17.14	164	4,220	25.74
Swimming pool, other	7	681	97.29	14	1,330	94.71	51	2,840	55.59
Petroleum industry:									
Hydraulic fracturing	(3)	3	--	3,700	166,000	44.71	504	20,900	41.50
Well packing and cementing	--	--	--	4	458	114.50	438	15,000	34.33
Recreational:									
Golf course, greens and traps	W	W	31.22	241	4,910	20.39	406	4,990	12.28
Baseball, volleyball, play sand, beaches	9	597	66.33	106	2,750	25.92	40	857	21.43
Traction, engine	1	36	36.00	36	751	20.86	41	909	22.17
Roofing granules and fillers	W	W	32.04	W	W	40.50	115	2,210	19.17
Other, ground silica	--	--	--	66	1,740	26.35	846	3,030	3.06
Other, whole grain	1,110	20,100	7.03	530	12,700	21.24	1,350	7,270	5.42
Total or average	2,380	62,100	26.07	12,900	333,000	25.79	12,700	298,000	23.41
Gravel:									
Silicon, ferrosilicon	--	--	--	--	--	--	68	10,400	153.41
Filtration	3	175	58.33	W	W	46.50	53	1,680	31.68
Nonmetallurgical flux	--	--	--	--	--	--	--	--	--
Other uses, specified	11	210	--	114	1,430	--	461	7,300	--
Total or average	14	385	27.50	121	1,800	14.86	582	19,400	33.35
Grand total or average	2,400	62,500	26.08	13,000	335,000	25.69	13,300	317,000	23.85

See footnotes at end of table.

TABLE 6—Continued
INDUSTRIAL SAND AND GRAVEL SOLD OR USED BY U.S. PRODUCERS IN 2006, BY MAJOR END USE[1]

Major use	West			U.S. total		
	Quantity (thousand metric tons)	Value (thousands)	Unit value[2] (dollars per ton)	Quantity (thousand metric tons)	Value (thousands)	Unit value[2] (dollars per ton)
Sand:						
Glassmaking:						
Containers	1,040	$27,600	26.63	4,970	$107,000	21.51
Flat, plate and window	469	11,400	24.34	3,370	62,400	18.49
Specialty	W	W	40.67	579	15,800	27.30
Fiberglass, unground	97	2,400	24.78	858	15,000	17.50
Fiberglass, ground	W	W	40.60	615	25,300	41.07
Foundry:						
Molding and core, unground	88	8,340	94.75	4,970	91,700	18.44
Molding and core, ground	--	--	--	W	W	119.67
Refractory	--	--	--	90	2,640	29.33
Metallurgical:						
Silicon carbide	--	--	--	W	W	--
Flux for metal smelting	W	W	7.13	W	W	4.65
Abrasives:						
Blasting	136	4,800	35.29	453	19,200	42.49
Scouring cleansers, ground	--	--	--	W	W	34.25
Sawing and sanding	--	--	--	W	W	26.00
Chemicals, ground and unground	20	578	28.90	816	22,000	26.91
Fillers, ground, rubber, paints, putty, etc.	W	W	42.50	761	48,100	63.26
Whole grain fillers/building products	309	8,370	27.10	3,160	73,700	23.33
Ceramic, ground, pottery, brick, tile, etc.	W	W	37.00	221	10,300	46.48
Filtration:						
Water, municipal, county, local	48	3,080	64.13	424	14,500	34.23
Swimming pool, other	--	--	--	73	4,840	66.33
Petroleum industry:						
Hydraulic fracturing	--	--	--	4,210	187,000	44.31
Well packing and cementing	--	--	--	442	15,500	35.06
Recreational:						
Golf course, greens and traps	W	W	16.78	846	14,800	17.51
Baseball, volleyball, play sand, beaches	W	W	--	155	4,220	27.20
Traction, engine	W	W	72.00	80	1,840	23.01
Roofing granules and fillers	--	--	--	205	5,240	25.57
Other, ground silica	136	11,600	88.01	1,040	16,100	15.06
Other, whole grain	427	10,700	28.07	2,450	25,500	10.52
Total or average	2,770	88,800	32.12	30,800	782,000	25.40
Gravel:						
Silicon, ferrosilicon	--	--	--	68	10,400	153.41
Filtration	--	--	--	63	2,230	35.33
Nonmetallurgical flux	--	--	--	--	--	--
Other uses, specified	226	2,960	--	812	11,900	--
Total or average	226	2,960	13.11	943	24,600	26.04
Grand total or average	2,990	91,800	30.68	31,700	807,000	25.42

W Withheld to avoid disclosing company proprietary data; for sand, included in "Other, ground silica" or "Other, whole grain;" for gravel, included in "Other uses, specified." -- Zero.

[1]Data are rounded to no more than three significant digits except for unit values; may not add to totals shown.

[2]Calculated using unrounded data.

[3]Less than ½ unit.

TABLE 7
INDUSTRIAL SAND AND GRAVEL SOLD OR USED, BY DESTINATION[1]

(Thousand metric tons)

Destination	2005	2006	Destination	2005	2006
States:			States—Continued:		
Alabama	623	598	New Jersey	W	W
Alaska	W	1	New Mexico	169	W
Arizona	55	38	New York	W	W
Arkansas	83	W	North Carolina	W	W
California	2,680	W	North Dakota	W	W
Colorado	848	1,170	Ohio	1,610	1,070
Connecticut	107	71	Oklahoma	952	W
Delaware	W	23	Oregon	82	W
District of Columbia	W	W	Pennsylvania	W	1,250
Florida	789	W	Rhode Island	W	W
Georgia	992	1,140	South Carolina	420	W
Hawaii	--	--	South Dakota	8	W
Idaho	W	W	Tennessee	819	647
Illinois	2,290	2,080	Texas	2,830	W
Indiana	1,190	1,050	Utah	42	41
Iowa	325	W	Vermont	W	W
Kansas	412	W	Virginia	342	262
Kentucky	300	275	Washington	W	W
Louisiana	557	811	West Virginia	W	189
Maine	W	W	Wisconsin	1,250	1,170
Maryland	W	W	Wyoming	W	W
Massachusetts	W	W	Countries:		
Michigan	997	524	Canada	821	560
Minnesota	W	W	Mexico	439	431
Mississippi	129	81	Other	W	W
Missouri	286	287	Other:		
Montana	W	9	Puerto Rico	W	W
Nebraska	W	W	U.S. possessions and territories	W	--
Nevada	109	W	Destination unknown	2,560	4,130
New Hampshire	2	W	Total	30,600	31,700

W Withheld to avoid disclosing company proprietary data; included in "Total." -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 8
U.S. EXPORTS OF INDUSTRIAL SAND AND GRAVEL, BY COUNTRY[1]

(Thousand metric tons and thousand dollars)

	2005		2006	
Country	Quantity	Value[2]	Quantity	Value[2]
Africa and the Middle East:				
Egypt	1	476	1	1,100
Israel	1	49	3	252
Other	6	3,120	3	801
Total	8	3,640	7	2,160
Asia:				
China	17	14,600	48	17,000
Hong Kong	29	988	17	822
Japan	303	34,600	1,080	49,200
Korea, Republic of	4	2,450	4	1,970
Singapore	5	3,150	4	2,630
Taiwan	3	1,930	3	1,420
Other	4	1,120	3	1,730
Total	365	58,800	1,160	74,800
Europe:				
Belgium	4	1,950	6	2,200
Germany	40	19,200	46	20,200
Italy	5	335	(3)	362
Netherlands	11	9,340	61	9,840
Russia	5	4,390	(3)	116
United Kingdom	5	1,930	5	3,180
Other	1	2,380	57	5,970
Total	71	39,600	177	41,900
North America:				
Bahamas, The	(3)	34	(3)	49
Canada	2,130	32,000	1,530	39,000
Mexico	279	7,980	896	10,600
Trinidad and Tobago	2	337	2	560
Other	3	711	10	1,030
Total	2,410	41,000	2,440	51,300
Oceania:				
Australia	3	1,190	2	886
New Zealand	(3)	34	(3)	39
Total	3	1,220	2	924
South America:				
Argentina	35	5,970	35	7,520
Brazil	1	935	1	892
Colombia	2	344	2	420
Peru	6	897	9	2,060
Venezuela	3	1,050	2	846
Other	2	276	1	241
Total	49	9,480	50	12,000
Grand total	2,910	154,000	3,830	183,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Free alongside ship value of material at U.S. port of export. Based on transaction price, includes all charges incurred in placing material alongside ship.

[3]Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 9
U.S. IMPORTS FOR CONSUMPTION OF INDUSTRIAL SAND, BY COUNTRY[1]

(Thousand metric tons and thousand dollars)

	2005		2006	
Country	Quantity	Value[2]	Quantity	Value[2]
Antigua and Barbuda	5	75	--	--
Australia	4	1,790	3	1,280
Canada	295	9,140	264	9,630
Chile	8	1,730	5	1,320
China	(3)	361	1	714
Germany	(3)	202	1	373
Japan	(3)	211	(3)	90
Mexico	382	4,080	580	7,000
Netherlands	(3)	137	(3)	123
Norway	15	63	(3)	31
Other	--	360	--	425
Total	711	18,200	855	21,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Cost, insurance, and freight value of material at U.S. port of entry. Based on purchase price; includes all charges (except U.S. import duties) in bringing material from foreign country to alongside carrier.

[3]Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 10
U.S. PRODUCERS OF SPECIAL SILICA STONE PRODUCTS IN 2006

Company and location	Type of operation	Product
B&C Abrasives, Inc., Hot Springs, AR	Stone cutting and finishing	Whetstones and oilstones.
Blue Mountain Whetstone Co., Hot Springs, AR	do.	Do.
Dan's Whetstone Co., Inc., Hot Springs, AR	do.	Do.
Do.	Quarry	Crude novaculite.
Hall's Arkansas Oilstones, Inc., Pearcy, AR	Stone cutting and finishing	Whetstones and oilstones.
Kraemer Co., The, Baraboo, WI	Crushing and sizing	Deburring media.
Do.	Quarry	Crude silica stone.
Norton Company Oilstones:		
Hot Springs, AR	do.	Do.
Littleton, NH	Stone cutting and finishing	Whetstones and oilstones.
Smith Abrasives, Inc., Hot Springs, AR	do.	Do.
Do.	Quarry	Crude novaculite.

TABLE 11
INDUSTRIAL SAND AND GRAVEL (SILICA): WORLD PRODUCTION, BY COUNTRY[1, 2]

(Thousand metric tons)

Country[3]	2002	2003	2004	2005	2006[e]
Argentina	280	301	848	461 [r]	500
Australia	4,046 [r]	4,181 [r]	3,670 [r]	3,600 [r, e]	3,700
Austria[e]	6,800	6,800	6,800	6,800	6,800
Belgium[e]	1,800	1,800	1,800	1,800	1,800
Belize	46 [e]	37	33	33 [r, e]	33
Bosnia and Herzegovina[e]	50	50	50	50	50
Brazil, silex[e]	1,600	1,600	1,600	1,600	1,600
Bulgaria[e]	900	900	900	900	900
Canada, quartz	1,540	1,581	1,690	1,600 [e]	1,600
Chile	879 [r]	916 [r]	1,085 [r]	1,151 [r]	1,150
Croatia[e]	95	95	95	95	95
Cuba[e]	21 [r]	31 [r]	33 [r]	14 [r]	14
Czech Republic[e]	900	900	900	900	1,000
Denmark, sales[e]	55	60	60	60	60
Ecuador	41	39	32 [r]	38 [r]	38
Egypt[e, 4]	600	640	640	650	650
Eritrea[e]	(5) [6]	(5)	(5)	(5)	(5)
Estonia[e]	24	34	35	37	38
Ethiopia[e]	6 [e]	5	5	5 [e]	5
Finland[e]	148	112	100	100	100
France[e]	6,500	6,500	6,500	6,500	6,500
Gambia, The	1,508	1,534	1,389 [r]	1,390 [r, e]	1,390
Germany	7,839	7,953	8,162	7,681 [r]	7,700
Greece[e]	90	100	100	100	100
Guatemala	38	30 [r]	1 [r]	(5) [r]	1
Hungary[e]	500	500	520	520	520
Iceland[e]	4	4	4	4	4
India[e]	1,400	1,500	1,500	1,600	1,600
Indonesia[e, 7]	128	132	132	132	135
Iran[8]	1,879	1,965	1,880	1,900 [e]	1,900
Ireland[e]	5	5	5	5	5
Israel	209	211	196	196 [r]	200
Italy[e]	3,000	3,000	3,000	3,000	3,000
Jamaica	9	13	11	14 [r]	14
Japan	4,893	4,700	4,705	4,549 [r]	3,900
Jordan[e]	60	33 [6]	46 [6]	46	46
Kenya[e]	12	13	13	13	13
Korea, Republic of	891	480	554	461 [r]	550
Latvia[e]	50	50	50	50	50
Lithuania	63 [r]	50 [r]	58 [r]	47 [r]	50
Malaysia	447	534	631	532 [r]	550
Mexico	1,779	1,689	2,056	2,121 [r]	2,630 [6]
Netherlands[e]	5	5	5	5	5
New Caledonia[e]	40	40	40	40	40
New Zealand	60 [r]	48 [r]	60 [r]	65 [r]	66
Norway[e]	1,400	1,500	1,500	1,600	1,500
Pakistan	172 [r, e]	75 [r, e]	-- [r]	-- [r]	--
Paraguay[e]	25	26	25	25	25
Peru	300	196	871	900	900
Philippines	170 [r]	170 [r]	237 [r]	224 [r]	225
Poland	1,486	1,500	1,500 [e]	1,500 [e]	1,500
Portugal[e]	5	5	5	5	5
Romania	1,569	3,061	3,900 [r]	1,394 [r]	1,500
Serbia and Montenegro[e]	75	75	75	100	100
Slovakia	2,200	2,200	2,200 [e]	2,000 [e]	2,000
Slovenia[e]	11,000 [6]	11,000	11,000	11,000	10,000
South Africa	2,239	2,448	2,388	2,754	3,216 [6]
Spain[e]	6,500	6,500	5,063 [r, 6]	5,100 [r]	5,100
Sweden[e]	600	600	700	700	700

See footnotes at end of table.

TABLE 11—Continued
INDUSTRIAL SAND AND GRAVEL (SILICA): WORLD PRODUCTION, BY COUNTRY[1, 2]

(Thousand metric tons)

Country[3]	2002	2003	2004	2005	2006[e]
Thailand	781	1,294	588	750 [r, e]	580
Turkey	1,274	1,283	1,188	1,200 [e]	1,200
United Kingdom	3,833 [r]	4,073 [r]	5,011 [r]	5,000 [r, e]	5,000
United States, sold or used by producers	27,300	27,500	29,700	30,600	31,700 [6]
Venezuela	878 [r]	625 [r]	943 [r]	207 [r]	500
Zimbabwe[9]	25	23	(5)	1	1
Total	113,000	115,000	119,000 [r]	116,000 [r]	117,000

[e]Estimated. [r]Revised. -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through June 20, 2007.

[3]In addition to the countries listed, Angola, Antigua and Barbuda, The Bahamas, China, countries of the Commonwealth of Independent States, Iraq, and Saudi Arabia produce industrial sand, but current available information is inadequate to formulate reliable estimates of output levels.

[4]Fiscal years beginning July 1 of that stated.

[5]Less than ½ unit.

[6]Reported figure.

[7]The quantities for quartz sand and silica stone, in cubic meters, were as follows: 2002—145,000 (estimated); 2003-05—150,000 (estimated); and 2006—153,000 (estimated).

[8]Fiscal years beginning March 21 of that stated.

[9]Includes rough and ground quartz as well as silica sand.

FIGURE 1
PRODUCTION OF INDUSTRIAL SAND AND GRAVEL IN THE UNITED STATES IN 2006, BY GEOGRAPHIC DIVISION