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SILICA

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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 30.6 million metric tons (Mt) in 2005 and was the highest production total in the history of the U.S. industry (table 1). Compared with 2004, industrial sand production increased by 3.5%, and gravel production decreased by 11%.

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 significant decrease. Increases in the total production and value of silica can be attributed in part to an overall increase in demand and to growth in the economy, particularly the construction sectors, petroleum sector, and increased energy costs to the silica producers in 2005.

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, 1998a). 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 §§1926.55, 1910.1000). 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§[1]).

Important news during 2005 centered on a silicosis litigation decision that continues to affect the industrial sand and gravel industry. 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. The OSHA recently found that deaths attributed to silicosis in the United States have declined steadily each year since the late 1960s to 187 in 1999 from 1,157 in 1968.

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 73 producers with 151 operations known to produce industrial sand and gravel. Of the 151 surveyed operations, 136 (90%) were active, and 15 were idle. The USGS received responses from 108 operations, and their combined production represented 85% of the U.S. total. Production for the 43 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 Midwest (East North Central and West North Central divisions) continued to lead the Nation with 42% of the 30.6 Mt of industrial sand and gravel produced in the United States, followed by the South (South Atlantic, East South Central, and West South Central divisions) with 37%, and the West (Pacific and Mountain divisions) with 12% (fig. 1, table 2).

The leading producing States were, in decreasing order, Illinois, Texas, Wisconsin, California, New Jersey, Michigan, Oklahoma, and Ohio (table 3). Their combined production represented 61% 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 2005, 22 had increased production, 10 had decreased production, and 2 had

[1]A reference that includes a section mark (§) is found in the Internet Reference Cited section.

stable production compared with 2004. Illinois, Minnesota, and Pennsylvania reported the largest increases, and North Carolina, New Jersey, and Michigan reported the largest decreases.

Of the total industrial sand and gravel, 84% was produced by 48 operations, each with production of 200,000 metric tons per year (t/yr) or more (tables 4-5). The 10 leading producers of industrial sand and gravel were, in descending order, Unimin Corp., U.S. Silica Co., Fairmount Minerals Ltd., Oglebay Norton Industrial Sands Co., Badger Mining Corp., Simplot Industries Inc., Little Six Corp., Nugent Sand Co. Inc., Manley Brothers, Inc., and Sand Products Corp. Their combined production from 64 operations represented 83% 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 30.6 Mt of industrial sand and gravel sold or used, 35% was consumed as glassmaking sand, and 18%, as foundry sand (table 6). Frac sand and sand for well packing and cementing consumed 14% of industrial sand and gravel production. Other important uses were building products (8%) and abrasive sand (3%).

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 2005, more than 80% of foundry sand was produced in the Midwest.

Conversely, the glass industry located plants where it could minimize the shipping distance of finished glass products (for example, container or flat). Hence, glass plants were more evenly distributed. In 2005, 42% of glass sand was produced in the South; 31%, in the Midwest; 16%, in the West; and 11%, in the Northeast. To varying degrees, all silica production and sales are similarly influenced by the location of the consuming industries.

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 Texas (9.2%), California (8.7%), Illinois (7.5%), Ohio (5.2%), New Jersey (5%), and Wisconsin (4%). Producers reported sending at least 821,000 t of silica to Canada and 439,000 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 2005, 8.4% 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 35%, the same compared with that of 2004. In 2005, sales to container glass manufacturers increased by 9% compared with those of 2004. On average, in the container glassmaking industry, silica accounts for 60% of raw materials used (Industrial Minerals, 2004b). The amount of sand consumed for fiberglass production decreased by 4% compared with that of 2004.

In 2005, sales of sand for flat glass production decreased by 8% compared with those of 2004. In the Midwest, consumption for flat glass decreased by 22%, and in the South, consumption decreased by 4%.

Specialty glass consists of many segments, but the largest portion comprises laboratory and lighting glass (for example, incandescent and fluorescent light bulbs). Specialty laboratory glass also makes up part of the components used in many segments of the electronics industry, including the production of optical fiber and semiconductors.

The U.S. fiberglass industry comprises four major insulation manufacturers and six major textile producers. Continuous glass fiber specifications are very strict. Batch grain-size control is very important, so ground silica (ultrafine powder) is used. Iron, potassium, and sodium oxide content is tightly controlled. The raw mix is fused at 1,600° C and then drawn through platinum bushings at 1,300° C. Various mineral wools are fabricated using basalt and diabase (rock wool), blast furnace slag (slag wool), or glass (glass wool) (Industrial Minerals, 1998c).

Silica is used in ceramics in ground and whole-grain forms. Generally, 22% to 32% of the ceramic body of sanitaryware (for example, sinks, toilets, urinals) consists of whole-grain silica. Ground silica is used to decrease viscosity and the expansion coefficient of ceramic glazes and ceramic materials in applications. A typical glaze composition consists of 25% quartz or silica. In 2005, 208,000 metric tons (t) of ground silica was used in ceramic production.

Advanced ceramics, such as silicon nitride and silicon carbide, represent a growing market for silica and silica-base chemicals. Silicon carbide is manufactured by cooking silica sand or crushed quartz and oil coke at 2,400° C in an electric furnace for several days; sawdust or rice husks are added to increase porosity. Because of the anthropomorphic thermal conductivity and expansion coefficient of silicon carbide, it is especially useful in the refractory industry (Industrial Minerals, 1998b). Applications for silicon carbide include composite bearings used in a variety of pumps or wear parts, such as dynamic pressure, seal rings, shafts, and slide bearings. The global market for silicon nitride, based on powder use, has been estimated to be 300,000 t/yr. Primary markets for hybrid bearings, which are based on silicon nitride and silicon carbide, have been aerospace components, dental drills, gyroscopes, machine tool spindles, and vacuum systems. Other markets for silicon nitride included cutting tools and engine components (Ceramic Industry, 1998).

Silica also is used in plastics as an extender, filler, and reinforcer. Whole-grain and ground silica are used in filler-type applications. Ground silica is used to thicken liquid systems, to avoid plateout in polyvinyl chloride, as a thixotropic and flatting agent, and in many other filler applications. Silica also is used in paint because it offers acid, scrubbing, and wear resistance. In 2005, consumption of whole-grain filler was 2.5 Mt, and ground silica for filler was 465,000 t.

Specialty silicas are produced primarily by means of chemical and thermal processing of natural silica or silicon metal or as a byproduct of other mineral or chemical processing. Although the USGS does not specifically collect information on specialty silicas, consumption does affect natural silica sales. Specialty silicas and silanes (silica chemicals) include colloidal silicas, fused silica, organofunctional silanes, precipitated silica, pyrogenic (fumed) silica, quartz, silica gels, silicones, and ultra-high-purity silica. These silicas are used in a variety of industries and products, which include abrasives, adhesives, beverages, catalysts, coatings, electronics, encapsulants, food, health care, optics, paper and packaging, plastics, refractories, rubber, sealants, specialty coatings, textiles, thermoplastics, wafer polishing, and water treatment. Additionally, surface modification with silanes can improve the performance of several types of mineral fillers used in plastics. For example, when treated with silanes, the performance of iron oxide mineral filler is greatly enhanced (Industrial Minerals, 2004a).

Fumed silica forms tridimensional polymers used as thixotropic agents in silicons and silanes and is widely used as a coating agent for filler-grade calcium carbonate (Industrial Minerals, 1998c). In table 6, industrial sand and gravel that would find its way into these 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 2005, silica sales for chemical production were 830,000 t, which was an increase of 8% compared with those of 2004. According to the USGS survey, reported sales of silica gravel for silicon and ferrosilicon production decreased by 11% in 2005 compared with those of 2004. 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).

Optical fiber production involves a series of highly sophisticated manufacturing methods. For the optical fiber, a glass core with a high refractive index surrounded by glass with a lower refractive index is required. This problem has been solved by using several manufacturing methods, such as producing the fiber with fused silica but doping its core with an element that increases the refractive index (Industrial Minerals, 1998b).

The high-purity fused silica used by the electronics industry is typically at least 99.95% SiO_2 and has a high electromagnetic radiation transparency, a very low expansion coefficient, and good insulation properties. Silica grain and powder products are mainly produced from fused silica, which is made from silica sands. Fused silica has characteristics similar to zircon and is often mixed with zircon to form casting shells (Industrial Minerals, 2002b).

Synthetic precipitated silica and silica gel are produced by reacting sodium silicate with hydrochloric acid. Precipitated silica has been used increasingly in tires, more so in Europe than in the United States. Through replacement of a portion of carbon black with precipitated silica in the tread, the reinforcing action of the silica particles extends tire life (Industrial Minerals, 2000b). European consumers prefer the “green” tires made with precipitated silica, which is used in 70% to 80% of tires for passenger cars in Europe (Industrial Minerals, 2000a).

Transportation.—Of all industrial sand and gravel produced, 64% was transported by truck from the plant to the site of first sale or use, up slightly from 2004; 34% was transported by rail, down slightly from 2004; and less than 1% by waterway.

Prices.—Compared with the average value of 2004, the average value, free on board plant, of U.S. industrial sand and gravel increased by 7% to $24.56 per metric ton in 2005 (table 6). The average unit values for industrial sand and industrial gravel were $24.69 per ton and $20.42 per ton, respectively. The average price for sand ranged from $6.75 per ton for metallurgical flux to $103.85 per ton for ground foundry sand. For gravel, prices ranged from $9.29 per ton for nonmetallurgical flux to $49.79 per ton for filtration. 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 ($103.85 per ton), followed by silica for swimming pool filters ($81.81 per ton), ground sand used as fillers for paint, putty, and rubber ($59.32 per ton), ground sand for ceramics ($50.30 per ton), ground sand for scouring cleansers ($47.96 per ton), silica for municipal water filtration ($46.02 per ton), sand for hydraulic fracturing ($43.45 per ton), and ground sand for fiberglass ($40.81 per ton).

By geographic region, the average value of industrial sand and gravel was highest in the South ($26.72 per ton), followed by the West ($26.05 per ton), the Midwest ($23.16 per ton), and the Northeast ($20.13 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 $22.37 per ton in the West to $12.02 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 2005 increased by 63% compared with the amount exported in 2004, and the associated value decreased by 12% (table 8). The large increase in exports can be attributed mainly to increased demand from Asian and North American markets. Canada was the leading recipient of U.S. exports. The distribution of exports was as follows: 73% to Canada, 10% to Japan, 9.6% to Mexico, 1.4% to Germany, and the remainder to Africa and the Middle East, Europe, South America, and Oceania. The average price of exports decreased to $53 per ton in 2005 from $97 per ton in 2004. In 2005, export prices varied widely by region; exports of higher grade silica to Europe averaged $557 per ton, and exports to the rest of the world averaged $40 per ton.

Imports for consumption of industrial sand and gravel rose to 711,000 t, which was an increase of 45% compared with those of 2004 (table 9). Mexico supplied 54% of the silica imports, which averaged $10.66 per ton; this price included insurance and freight costs to the U.S. port. The total value of imports was $18.2 million, with an average of $24 per ton. Higher priced imports came from Australia, China, Germany, and Japan.

World Industry Structure.—Based on information provided mainly by foreign governments, world production of industrial sand and gravel was estimated to be 118 Mt (table 11). The United States was the leading producer followed, in descending order, by Slovenia, Germany, Austria, France, Spain, Japan, and the United Kingdom. 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 2006 was expected to be 26 to 28 Mt. Consumption is expected to be 27 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, fiberglass, and frac sand. Total demand for all glass sand end uses is expected remain static or possibly exhibit slow growth, probably to the range of 10 to 11 Mt through 2006. 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 believed 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 2006 is expected to be 5 Mt, and consumption is expected to range from 5 to 5.3 Mt.

Frac sand sales increased in 2005 compared with those of 2004. Based on this trend, demand for frac sand is expected to increase modestly during 2006 to 4 Mt, with a range of 4 to 4.2 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 2006. 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, 2004b). 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, 2002a).

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 consumer and computational products, automotive, 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 7,236 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 2005. The Federal Government continues to assess its stockpile goals for 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 2005, 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.

Companies produce cultured quartz crystal by using a hydrothermal process in large pressure vessels called autoclaves. Seed crystals are mounted on racks and suspended in the upper growth region of the vessel. Lascas, which is a high-purity natural quartz feedstock, is loaded in an open-mesh wire basket that is placed in the bottom of the autoclave. A solution of sodium hydroxide or sodium carbonate (the mineralizer) with such additives as lithium salts and deionized or distilled water is used to fill the vessel to 75% to 85% of its volume. The bottom half of the growing vessel is heated to temperatures averaging between 350° and 400° C; the temperature of the top portion is maintained at 5° to 50° C lower than that in the bottom half of the vessel, depending upon the mineralizer used. At these temperatures, the solution expands and creates internal pressure between 700 and 2,100 kilograms per square centimeter. Under these conditions, the lascas dissolves to create a solution saturated with silica. Through convection, the saturated solution transports dissolved silica to the cooler upper half of the vessel where it becomes supersaturated, and the excess dissolved quartz deposits on the seed crystals in the top half of the autoclave. The process continues until the growing crystals reach their desired size. The process normally takes from 30 to 60 days for a 1-inch-thick bar and longer for larger crystals; at least one producer has made runs of 180 days. The cultured crystals can be custom grown with specific properties.

Processing quartz crystal for various end uses is the same whether natural or cultured seed crystal is used. Producers, however, must avoid seed crystals with defects that could be passed on to new generations of cultured crystal. Natural quartz crystal is preferred as seed material to ensure that genetic defects will not be repeated in the succeeding generations.

Once produced, cultured crystals are examined for physical defects before cutting. They are then cut, usually with diamond or slurry saws, along a predetermined crystallographic plane to a thickness slightly larger than that desired. Each wafer is inspected and diced into blanks of the desired dimensions. The blanks then progress through a series of lapping stages until they reach the final thickness, electrodes are attached, and the crystals are mounted in suitable holders. The final assembly, which is called a quartz crystal unit, is ready for insertion into an electronic circuit.

Consumption.—In 2005, 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.

Quartz crystal is used in piezoelectric and optical applications. The piezoelectric effect is achieved when a suitable electrical signal applied to a quartz wafer makes the wafer vibrate mechanically throughout the bulk of the material at a characteristic natural resonance frequency. Quartz resonators are uniquely suitable for aerospace, commercial, and military bandpass filter applications that require very high selectivity or for oscillator applications that require very high stability. In addition, for many applications that require only moderate stability, a quartz resonator offers a unique combination of high performance, small size, and low cost. Quartz resonators also are used for many less demanding applications, such as providing timing signals for electronic circuits in automotive, consumer, and industrial products.

Cultured quartz is used almost exclusively by the crystal device industry because of the cost advantages. For resonator applications, raw cultured quartz must be cut into thin wafers oriented precisely in line with raw material crystal axes. The uniformity and convenience of cultured quartz have made its use almost universal. Unlike cultured quartz, natural electronic-grade quartz requires special orientation, cutting, grading, and sizing to produce a quartz wafer. As a result, most device manufacturers that cut natural quartz in the past have discontinued its use. One of the remaining applications of the natural electronic-grade material is in pressure transducers used in deep wells.

Quartz wafers must be cut thin for practical use at very high frequencies (above 100 megahertz). Quartz crystal structures that use surface vibrations, in which the frequency is determined by electrode dimensions rather than by wafer thickness, have become more prevalent at these higher frequencies. These structures are called surface acoustic wave devices.

Most optical applications use quartz in the fused form as silica glass. Small quantities of cultured quartz crystal are used directly in optical applications. Quartz crystal also has uses that involve birefringent filters, Brewster windows and prisms, normally polarized laser beams, quartz retardation plates (especially quartz wave plates), and tuning elements in laser optics.

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 $156 per kilogram in 2005.

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, Russia, and the United States; 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.—The trend toward importing quartz could have a negative effect on domestic quartz growers. 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. The growing 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, four of seven domestic firms, representing 88% of crude production, responded during 2005. 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 $989 per ton. The average value of stone products made from crude material was $3.97 per kilogram (table 1).

Foreign Trade.—In 2005, silica stone product exports had a value of $10 million, up from that of 2004. 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 2005.

In 2005, the value of imported silica stone products was $7.7 million; this was an increase of 12.9% compared with that of 2004. These imports were hand sharpening or polishing stones, which accounted for most of or all the imported silica stone products in 2005. 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 2005, 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 2005 USGS annual survey of producers indicated that sales of processed tripoli decreased by 3% in quantity to 91,000 t with a value of $18.7 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 2005, 12% 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 (84%) is as a filler and extender in paints. In exterior latex paints, tripoli also aids in durability, flowability, leveling, and tint retention. In enamels, it makes application easier and improves sheen. The controlled grain and particle size of tripoli in paints improves dispersal and promotes a more uniform coating. Additionally, paints with tripoli resist chemical agents and wear better than those in which water-ground whitings and other softer or more reactive fillers are used.

Plastics, resins, and rubbers each account for 5% of the tripoli used as a filler and extender. Tripoli is used in plastics for electrical uses because of its dielectric characteristics and its effects on compression and flexibility properties. Its chemical resistance, resistance to salt spray, and weatherability also are important to its use in plastics. The physical properties of tripoli allow high frictional loading in most compounds, but its abrasiveness results in high wear in extruding nozzles and molds. The same properties that make tripoli useful as a filler and extender in plastic make it valuable to the rubber and resin industries.

Price.—The average reported unit value of all tripoli sold or used in the United States was $206 per ton in 2005. The average reported unit value of abrasive tripoli sold or used in the United States during 2005 was $197 per ton, and the average reported unit value of filler tripoli sold or used domestically was $209 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)

		2001	2002	2003	2004	2005
Industrial sand and gravel:[2]						
Sold or used:						
Quantity:						
Sand		26,900	25,900	26,300	28,700	29,700
Gravel		1,060	1,420	1,140	1,070	955
Total		27,900	27,300	27,500	29,700	30,600
Value:						
Sand		559,000	554,000	594,000	668,000	733,000
Gravel		17,600	19,400	15,300	16,600	19,500
Total		576,000	573,000	609,000	685,000	752,000
Exports:						
Quantity		1,540	1,410	2,620	1,790	2,910
Value		163,000	145,000	155,000	174,000	154,000
Imports for consumption:						
Quantity		172	250	440	490	711
Value		11,000	8,650	9,210	12,400	18,200
Processed tripoli:[3]						
Quantity	metric tons	60,500	66,600	68,800	94,000	91,100
Value		15,000	16,600	17,700	19,400	18,700
Special silica stone:						
Crude production:						
Quantity	metric tons	705	748	1,070	227	193
Value		234	240	313	132	191
Sold or used:						
Quantity	metric tons	393	386	513	655	576
Value		4,040	3,740	3,630	3,660	2,290

[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]

	2004				2005			
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	W	W	W	W	W	W	W	W
Middle Atlantic	2,760	9	$53,300	8	2,720	9	$54,800	7
Midwest:								
East North Central	9,990	34	193,000	28	10,600	35	223,000	30
West North Central	2,030	7	57,300	8	2,240	7	74,300	10
South:								
South Atlantic	4,460	15	92,700	14	4,080	13	96,800	13
East South Central	1,680	6	36,200	5	1,760	6	38,000	5
West South Central	5,290	18	165,000	24	5,550	18	170,000	23
West:								
Mountain	1,210	4	22,700	3	1,280	4	26,000	3
Pacific	2,310	8	63,800	9	2,390	8	69,600	9
Total	29,700	100	685,000	100	30,600	100	752,000	100

W Withheld to avoid disclosing company proprietary data; included in "Middle Atlantic."

[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)

	2004		2005	
State	Quantity	Value	Quantity	Value
Alabama	643	9,800	710	11,200
Arizona	W	792	W	W
Arkansas	W	W	W	W
California	1,990	55,700	2,030	60,400
Colorado	W	3,300	W	W
Florida	679	8,520	715	9,410
Georgia	665	13,400	689	15,000
Idaho	W	W	W	W
Illinois	4,950	86,200	5,510	104,000
Indiana	W	W	W	W
Iowa	W	W	W	W
Kansas	W	W	W	W
Louisiana	476	14,800	509	11,600
Maryland	W	W	W	W
Michigan	1,690	25,200	1,610	24,500
Minnesota	W	W	W	W
Mississippi	W	W	W	W
Missouri	589	14,200	559	14,500
Nebraska	W	W	--	--
Nevada	W	W	W	W
New Jersey	2,020	35,800	1,820	34,100
New Mexico	--	--	W	W
New York	W	W	--	--
North Carolina	1,630	29,000	1,150	29,200
North Dakota	W	W	W	W
Ohio	1,180	34,200	1,230	37,900
Oklahoma	1,390	31,600	1,480	33,500
Pennsylvania	570	11,800	711	15,400
Rhode Island	W	W	195	5,250
South Carolina	719	17,600	794	19,400
Tennessee	975	26,100	985	26,500
Texas	2,790	109,000	2,840	114,000
Virginia	W	W	W	W
Washington	W	W	W	W
West Virginia	343	17,300	369	17,800
Wisconsin	2,140	47,000	2,250	55,700
Other	4,300	93,300	4,380	112,000
Total	29,700	685,000	30,600	752,000

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 2005, BY SIZE OF OPERATION[1]

Size range	Number of operations	Percentage of total	Quantity (thousand metric tons)	Percentage of total
Less than 25,000	20	16	259	1
25,000 to 49,999	9	7	303	1
50,000 to 99,999	21	17	1,390	5
100,000 to 199,999	25	20	3,140	10
200,000 to 299,999	10	8	2,210	7
300,000 to 399,999	9	7	2,860	9
400,000 to 499,999	3	2	1,200	4
500,000 to 599,999	6	4	2,970	10
600,000 to 699,999	4	3	2,330	8
700,000 and more	16	13	14,000	46
Total	123	100	30,600	100

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

TABLE 5
NUMBER OF INDUSTRIAL SAND AND GRAVEL OPERATIONS AND PROCESSING PLANTS IN THE UNITED STATES IN 2005, BY GEOGRAPHIC DIVISION

	Mining operations on land					
Geographic region	Stationary	Portable	Stationary and portable	No plants or unspecified	Dredging operations	Total active operations
Northeast:						
New England	1	--	--	--	--	1
Middle Atlantic	5	--	--	--	3	8
Midwest:						
East North Central	25	--	--	--	3	28
West North Central	6	--	--	--	3	9
South:						
South Atlantic	18	1	--	--	6	25
East South Central	9	--	--	--	2	11
West South Central	17	--	--	--	5	22
West:						
Mountain	5	1	1	--	--	7
Pacific	12	--	--	--	--	12
Total	98	2	1	--	22	123

-- Zero.

TABLE 6

INDUSTRIAL SAND AND GRAVEL SOLD OR USED BY U.S. PRODUCERS IN 2005, 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	W	W	20.39	1,640	$19,700	12.02	1,680	$28,600	17.08
Flat, plate and window	W	W	19.07	844	12,500	14.85	1,510	27,100	18.01
Specialty	W	W	26.24	284	7,630	26.87	331	8,270	24.98
Fiberglass, unground	W	W	19.88	332	4,710	14.20	520	8,870	17.07
Fiberglass, ground	--	--	--	155	4,540	29.26	453	20,500	45.16
Foundry:									
Molding and core, unground	149	$4,620	30.98	4,400	70,200	15.93	737	13,200	17.92
Molding and core, ground	--	--	--	9	872	96.89	4	478	119.50
Refractory	(3)	9	30.95	8	711	88.88	96	2,210	23.03
Metallurgical:									
Silicon carbide	--	--	--	--	--	--	--	--	--
Flux for metal smelting	--	--	--	--	--	--	W	W	19.05
Abrasives:									
Blasting	55	1,910	34.73	78	3,210	41.18	655	17,200	26.25
Scouring cleansers, ground	(3)	1	70.82	W	W	97.50	W	W	44.62
Sawing and sanding	W	W	21.00	--	--	--	W	W	41.33
Chemicals, ground and unground	W	W	26.86	391	7,130	18.22	404	11,500	28.35
Fillers, ground, rubber, paints, putty, etc.	W	W	40.40	339	11,700	34.65	119	15,500	130.46
Whole grain fillers/building products	255	9,630	37.75	522	17,000	32.63	991	26,300	26.53
Ceramic, ground, pottery, brick, tile, etc.	W	W	82.80	33	2,120	64.30	120	6,800	56.68
Filtration:									
Water, municipal, county, local	53	1,790	33.81	57	2,690	47.23	154	6,300	40.91
Swimming pool, other	8	752	94.00	W	W	89.69	26	2,470	94.85
Petroleum industry:									
Hydraulic fracturing	(3)	2	41.45	2,740	110,000	40.19	1,250	63,100	50.53
Well packing and cementing	11	646	58.73	2	162	81.00	228	7,820	34.30
Recreational:									
Golf course, greens and traps	134	3,200	23.87	337	7,650	22.71	344	4,240	12.31
Baseball, volleyball, play sand, beaches	10	611	61.10	101	3,310	32.72	122	1,530	12.51
Traction, engine	20	469	23.45	60	1,160	19.35	69	1,270	18.42
Roofing granules and fillers	W	W	26.75	33	867	26.27	145	2,660	18.31
Other, ground silica	5	213	42.80	37	1,540	41.19	46	2,060	44.74
Other, whole grain	2,020	30,600	15.15	344	6,590	19.14	934	12,700	13.64
Total or average	2,720	54,400	20.02	12,800	296,000	23.23	10,900	291,000	26.60
Gravel:									
Silicon, ferrosilicon	--	--	--	W	W	7.08	W	W	15.31
Filtration	W	W	W	11	645	58.64	W	W	57.00
Nonmetallurgical flux	--	--	--	W	W	18.74	--	--	--
Other uses, specified	W	W	W	W	W	7.82	466	13,800	29.56
Total or average	4	374	93.50	99	1,330	13.45	466	13,800	29.56
Grand total or average	2,720	54,800	20.13	12,900	298,000	23.16	11,400	304,000	26.72

See footnotes at end of table.

TABLE 6—Continued

INDUSTRIAL SAND AND GRAVEL SOLD OR USED BY U.S. PRODUCERS IN 2005, 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	W	W	22.37	4,950	$83,700	16.90
Flat, plate and window	W	W	22.19	3,130	56,200	17.97
Specialty	W	W	39.38	826	21,500	26.08
Fiberglass, unground	W	W	22.72	1,020	17,100	16.79
Fiberglass, ground	W	W	36.44	641	26,200	40.81
Foundry:						
Molding and core, unground	68	$1,760	25.91	5,360	89,700	16.75
Molding and core, ground	--	--	--	13	1,350	103.85
Refractory	--	--	--	104	2,930	28.18
Metallurgical:						
Silicon carbide	--	--	--	--	--	--
Flux for metal smelting	W	W	6.63	W	W	6.75
Abrasives:						
Blasting	119	6,180	51.96	908	28,500	31.38
Scouring cleansers, ground	--	--	--	W	W	47.96
Sawing and sanding	W	W	42.10	18	711	39.50
Chemicals, ground and unground	W	W	28.71	830	19,500	23.53
Fillers, ground, rubber, paints, putty, etc.	W	W	36.67	465	27,600	59.32
Whole grain fillers/building products	749	25,800	34.38	2,520	78,700	31.28
Ceramic, ground, pottery, brick, tile, etc.	W	W	27.76	208	10,500	50.30
Filtration:						
Water, municipal, county, local	112	6,470	57.79	375	17,300	46.02
Swimming pool, other	W	W	44.20	59	4,830	81.81
Petroleum industry:						
Hydraulic fracturing	W	W	47.47	4,010	174,000	43.45
Well packing and cementing	32	913	28.53	273	9,540	34.96
Recreational:						
Golf course, greens and traps	260	6,420	24.68	1,070	21,500	20.02
Baseball, volleyball, play sand, beaches	14	266	19.00	247	5,710	23.11
Traction, engine	12	361	30.08	161	3,260	20.26
Roofing granules and fillers	W	W	16.80	255	5,530	21.69
Other, ground silica	107	3,170	29.44	XX	XX	XX
Other, whole grain	1,810	40,200	22.23	XX	XX	XX
Total or average	3,280	91,500	27.90	29,700	733,000	24.69
Gravel:						
Silicon, ferrosilicon	--	--	--	343	5,150	15.02
Filtration	22	715	32.50	52	2,590	49.79
Nonmetallurgical flux	263	2,400	9.12	W	W	9.29
Other uses, specified	101	905	8.97	XX	XX	31.65
Total or average	386	4,020	10.41	955	19,500	20.42
Grand total or average	3,670	95,500	26.05	30,600	752,000	24.56

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." XX Not applicable. -- 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 then ½ unit.

TABLE 7

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

(Thousand metric tons)

Destination	2004	2005	Destination	2004	2005
States:			States—Continued:		
Alabama	657	623	New Jersey	1,460	1,490
Alaska	(2)	1	New Mexico	179	169
Arizona	68	55	New York	397	381
Arkansas	75	83	North Carolina	956	947
California	2,720	2,680	North Dakota	35	52
Colorado	651	848	Ohio	1,510	1,610
Connecticut	94	107	Oklahoma	815	952
Delaware	14	25	Oregon	63	82
District of Columbia	(2)	1	Pennsylvania	1,160	1,010
Florida	581	789	Rhode Island	50	60
Georgia	905	992	South Carolina	480	420
Hawaii	--	--	South Dakota	10	8
Idaho	399	320	Tennessee	881	819
Illinois	1,990	2,290	Texas	2,810	2,830
Indiana	940	1,190	Utah	46	42
Iowa	333	325	Vermont	3	3
Kansas	438	412	Virginia	330	342
Kentucky	295	300	Washington	206	212
Louisiana	540	557	West Virginia	137	156
Maine	2	(2)	Wisconsin	1,220	1,250
Maryland	93	101	Wyoming	154	170
Massachusetts	141	161	Countries:		
Michigan	980	997	Canada	848	821
Minnesota	296	338	Mexico	413	439
Mississippi	125	129	Other	44	51
Missouri	284	286	Other:		
Montana	48	23	Puerto Rico	(2)	(2)
Nebraska	38	21	U.S. possessions and territories	--	1
Nevada	42	109	Destination unknown	2,760	2,560
New Hampshire	3	2	Total	29,700	30,600

-- Zero.

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

[2]Less than ½ unit.

TABLE 8

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

(Thousand metric tons and thousand dollars)

	2004		2005	
Country	Quantity	Value[2]	Quantity	Value[2]
Africa and the Middle East:				
Oman	5	3,180	3	2,130
United Arab Emirates	1	995	2	548
Other	3	2,330	3	967
Total	9	6,500 r	8	3,640
Asia:				
China	18	8,730	17	14,600
Hong Kong	57	1,510	29	988
Japan	22	29,700	303	34,600
Korea, Republic of	3	1,820	4	2,450
Singapore	5	3,620	5	3,150
Taiwan	11	5,560	3	1,930
Other	4	1,540	2	1,120
Total	119 r	52,400 r	365	58,800
Europe:				
Belgium	4	4,000	4	1,950
Germany	10	15,000	40	19,200
Italy	(3)	81	5	335
Netherlands	14	11,600	11	9,340
Russia	19	11,700	5	4,390
United Kingdom	4	2,230	5	1,930
Other	17 r	17,500 r	2	2,380
Total	67	62,100	71	39,600
North America:				
Bahamas, The	7	249	(3)	34
Canada	1,240	33,900	2,130	32,000
Mexico	287	9,210	279	7,980
Trinidad and Tobago	1	191	2	337
Other	9 r	2,000 r	3	712
Total	1,540	45,600	2,410	41,000
Oceania:				
Australia	5	1,100	3	1,190
New Zealand	(3)	193	(3)	34
Total	5	1,290	3	1,220
South America:				
Argentina	30	4,490	35	5,970
Brazil	6	580	1	935
Colombia	2	286	2	344
Peru	2	227	6	897
Venezuela	2	464	3	1,050
Other	1 r	503 r	1	277
Total	43 r	6,550 r	49	9,480
Grand total	1,790	174,000	2,910	154,000

[r]Revised.

[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)

Country	2004 Quantity	2004 Value[2]	2005 Quantity	2005 Value[2]
Antigua and Barbuda	--	--	5	75
Australia	3	1,240	4	1,790
Canada	152	4,610	295	9,140
Chile	9	1,680	8	1,730
China	(3)	281	(3)	361
Germany	(3)	475	(3)	202
Japan	1	525	(3)	211
Mexico	300	2,830	382	4,080
New Zealand	2	232	--	--
Norway	21	84	15	63
Other	1 r	431 r	1	497
Total	490	12,400	711	18,200

rRevised. -- 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 2005

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.
Taylor Made Crafts Inc.:		
Hot Springs, AR	Stone cutting and finishing	Whetstones and oilstones.
Pearcy, AR	Quarry	Crude novaculite.

TABLE 11

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

(Thousand metric tons)

Country[3]	2001	2002	2003	2004	2005[e]
Argentina	891	280	301 [r]	848 [r]	850
Australia[e]	4,500 [4]	4,500	4,500	4,500	4,000
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	28	46	37	33	34
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	1,613	1,540	1,581 [r]	1,690 [r]	1,600
Chile[e]	300	300	300	300	300
Croatia[e]	95	95	95	95	95
Cuba[e]	50	50	50	50	50
Czech Republic[e]	950	900	900	900	900
Denmark, sales[e]	50	55	60	60	60
Ecuador	35	41	39 [r]	43 [r]	43
Egypt[e, 5]	600	600	640	640	650
Eritrea	--	(6)	(6) [e]	(6) [e]	(6)
Estonia[e]	25	24	34	35	37
Ethiopia[e]	6 [e]	6 [e]	5 [r]	5 [r]	5
Finland[e]	148	148	112 [r]	100 [r]	100
France[e]	6,500	6,500	6,500	6,500	6,500
Gambia	170 [e]	1,508	1,534	1,530 [e]	1,530
Germany	7,835 [r]	7,839 [r]	7,953 [r]	8,162 [r]	8,160
Greece[e]	90	90	100	100	100
Guatemala	161	38	30	-- [r]	--
Hungary[e]	500	500	500	520	520
Iceland[e]	4	4	4	4	4
India[e]	1,400	1,400	1,500	1,500	1,600
Indonesia[e, 7]	128 [r]	128 [r]	132 [r]	132 [r]	132
Iran[8]	1,782 [r]	1,879 [r]	1,965 [r]	1,880 [r]	1,900
Ireland[e]	5	5	5	5	5
Israel	250 [r, e]	209 [r]	211 [r]	196 [r]	200
Italy[e]	3,000	3,000	3,000	3,000	3,000
Jamaica	8	9	13	11 [r]	11
Japan	5,768	4,893	4,700	4,705 [r]	4,750
Jordan[e]	90 [r]	60 [r]	33 [r, 4]	46 [r, 4]	46
Kenya[e]	12 [r]	12 [r]	13 [r]	13 [r]	13
Korea, Republic of	900	891	480	554 [r]	554
Latvia[e]	50	50	50	50	50
Lithuania[e]	30	30	30	30	30
Malaysia	575	447	534	631 [r]	620
Mexico	1,720	1,779	1,689	2,056 [r]	2,078 [4]
Netherlands[e]	5	5	5	5	5
New Caledonia[e]	40	40	40	40	40
New Zealand[e]	48	45	45	45	45
Norway[e]	1,500	1,400	1,500	1,500	1,600
Pakistan[e]	165	165	165	165	165
Paraguay[e]	28	25	26	25	25
Peru	120	300	196	871 [r]	900
Philippines[e]	70	70	70	70	70
Poland	1,564	1,486	1,500	1,500 [e]	1,500
Portugal[e]	5	5	5	5	5
Romania	733	1,569	3,061 [r]	1,458 [r]	1,500
Serbia and Montenegro[e]	75	75	75	75 [r]	100

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]	2001	2002	2003	2004	2005[e]
Slovakia	2,000	2,200	2,200	2,200 [e]	2,000
Slovenia	11,510	11,000	11,000 [e]	11,000 [e]	11,000
South Africa	2,127	2,239 [r]	2,448 [r]	2,388	2,754 [4]
Spain[e]	6,500	6,500	6,500	6,500	6,500
Sweden[e]	600	600	600	700 [r]	700
Thailand	514	781	1,294	588 [r]	590
Turkey	1,207	1,274	1,283	1,188 [r]	1,200
United Kingdom[e]	4,500	4,500	4,500	4,500	4,500
United States, sold or used by producers	27,900	27,300	27,500	29,700	30,600 [4]
Venezuela	627	690	700 [e]	700 [e]	750
Zimbabwe[9]	43	25	23	(6)	(6) [4]
Total	113,000 [r]	113,000	115,000 [r]	117,000 [r]	118,000

[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, 2006.

[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]Reported figure.

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

[6]Less than ½ unit.

[7]The quantities for quartz sand and silica stone, in cubic meters, were as follows: 2001-02—145,000 (estimated) and 2003-05—150,000 (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 2005, BY GEOGRAPHIC DIVISION