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 29.7 million metric tons (Mt) in 2004 compared with that of 2003 and was the highest production total since 1979 (table 1). Compared with 2003, industrial sand production increased by about 9%, and gravel production decreased by about 6%.

Industrial sand and gravel, often called “silica,” “silica sand,” and “quartz sand,” includes sands and gravels with high silicon dioxide (SiO_2) content. These sands and gravels are used, for example, 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 2004.

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]).

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 69 producers with 153 operations known to produce industrial sand and gravel. Of the 153 surveyed operations, 138 (90%) were active, and 15 were idle. The USGS received responses from 108 operations, and their combined production represented about 86% of the U.S. total. Production for the 45 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 about 41% of the 29.7 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 39%, and the West (Pacific and Mountain divisions) with 12% (figure 1, table 2).

The leading producing States were, in decreasing order, Illinois, Texas, Wisconsin, New Jersey, California, Michigan, North Carolina, and Oklahoma (table 3). Their combined production represented about 63% of the national total. States that have data withheld in table 3 are not included among the leading producers. Of the 36 States that produced silica in 2004, 20 had increased production, 12 had decreased production, and 4 stayed about even compared with 2003. Texas, Illinois, New Jersey, and Wisconsin reported the largest increases, and Michigan, Alabama, and Louisiana reported the largest decreases.

About 85% of the total industrial sand and gravel was produced by 49 operations, each with production of more than 200,000 metric tons per year (t/yr) (tables 4-5). The 10 leading producers of industrial sand and gravel were, in descending order, Unimin Corp., U.S. Silica Co., Oglebay Norton Industrial Sands Co., Fairmount Minerals Ltd., Badger Mining Corp., Simplot Industries Inc., Nugent Sand Co. Inc., Little Six Corp., Hedrick Industries (B.V. Hedrick Gravel and Sand Co. and Grove Stone Co.), and Manley Brothers, Inc. Their combined production from 75 operations represented 82% 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 29.7 Mt of industrial sand and

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

gravel sold or used, about 35% was consumed as glassmaking sand, and about 19%, as foundry sand (table 6). Frac sand and sand for well packing and cementing consumed about 12% of industrial sand and gravel production. Other important uses were building products (10%) and abrasive sand (3%).

Minable resources 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. Because of the abundance of silica deposits, locating near a silica resource has not always been a priority, although it certainly has been a consideration. 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 2004, more than 77% 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, flat). Hence, glass plants were more evenly distributed. In 2004, 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.

Improvements in data collection affected the reported distribution by market segment for glass sand. Some sand consumption formerly attributed to container and fiberglass production has been reclassified as flat and specialty segments. Although the increasing or decreasing trends in each market accurately reflect the growth in the various glass segments, the actual increase or decrease is likely not as large as the data portray.

The share of silica sold for all types of glassmaking as a percentage of all silica sold was about 37%. This percentage decreased slightly compared with that of 2003. In 2004, sales to container glass manufacturers decreased by 8% compared with those of 2003. On average, in the container glassmaking industry, silica accounts for about 60% of raw materials used (Industrial Minerals, 2004b). The amount of sand consumed for fiberglass production increased by about 15% compared with that of 2003.

In 2004, sales of sand for flat glass production increased by about 4% compared with those of 2003. In the Midwest, consumption for flat glass increased by about 6%, but in the South, consumption decreased slightly.

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 of 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 passed through platinum bushings at 1,300° C. Various mineral wools are fabricated by 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 about 25% quartz or silica. In 2004, about 192,000 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-based 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 2004, consumption of whole-grain filler was about 2.5 Mt, and ground silica for filler was 462,000 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 2004, silica sales for chemical production were 771,000 t, which was a decrease of about 11% compared with those of 2003. According to the USGS survey, reported sales of silica gravel for silicon and ferrosilicon production decreased by about 4% in 2004 compared with those of 2003. 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 due 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).

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 all 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 the total industrial sand and gravel produced, 63% was transported by truck from the plant to the site of first sale or use, down slightly from 2003; 35% was transported by rail, unchanged from 2003; and 1.2%, by waterway.

Prices.—Compared with the average value of 2003, the average value, free on board plant, of U.S. industrial sand and gravel increased by about 4% to $23.03 per metric ton in 2004 (table 6). The average unit values for industrial sand and industrial gravel were $23.31 per ton and $15.47 per ton, respectively. The average price for sand ranged from $7.10 per ton for metallurgical flux to $77.61 per ton for ground foundry sand. For gravel, prices ranged from $9.20 per ton for nonmetallurgical flux to $42.22 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 ($77.61 per ton), followed by ground sand used as fillers for paint, putty, and rubber ($67.28 per ton), silica for swimming pool filters ($66.96 per ton), ground sand for ceramics ($55.16 per ton), ground sand for well packing and cementing ($47.72 per ton), ground sand for scouring cleansers ($46.78 per ton), silica for municipal water filtration ($42.73 per ton), and sand for hydraulic fracturing ($41.26 per ton).

By geographic region, the average value of industrial sand and gravel was highest in the South ($25.73 per ton) followed by the West ($24.56 per ton), the Midwest ($20.86 per ton), and the Northeast ($19.31 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 $22.52 per ton in the West to $12.14 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.

Destination of Shipments.—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 (9.5%), California (9.2%), Illinois (6.7%), Ohio (5.1%), New Jersey (5%), and Wisconsin (4.1%). Producers reported sending at least 848,000 t of silica to Canada and 413,000 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 2004, 9.3% of industrial sand and gravel shipped by producers was assigned to that category.

Foreign Trade.—On the basis of U.S. Census Bureau data, exports of industrial sand and gravel in 2004 decreased by about 32% compared with the amount exported in 2003, and the associated value increased by about 12% (table 8). The large decrease in exports can be attributed to several factors including the widening trade imbalance (particularly with Asia), currency imbalance, increased fuel and transportation costs, and reliability of trade data. Canada was the leading recipient of U.S. exports. Export distribution was as follows: 69% to Canada, 16% to Mexico, 4.2% to China and Hong Kong, 1.7% to Argentina, and the remainder to Europe, South America, the Middle East and Africa, and Oceania. The average price of exports increased from $59 per ton in 2003 to $97 per ton in 2004. In 2004, export prices varied widely by region; exports of higher grade silica to Europe averaged about $927 per ton, and exports to the rest of the world averaged $65 per ton.

The U.S. Census Bureau also reported that imports for consumption of industrial sand and gravel rose to 490,000 t, which was an increase of 11% compared with those of 2003 (table 9). Mexico supplied 61% of the silica imports, which averaged $9.43 per ton; this price included insurance and freight costs to the U.S. port. The total value of imports was about $12.4 million, with an average of about $25 per ton. Higher priced imports came from Australia, Germany, and Japan.

World Review.—New data supplied by foreign governments have resulted in revisions to the world production of industrial sand and gravel. On the basis of information provided mainly by foreign governments, world production of industrial sand and gravel was estimated to be 115 Mt (table 11). The United States was the leading producer followed, in descending order, by Slovenia, Germany, Belgium, France, Spain, Australia, 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.—The forecast range of total U.S. consumption for industrial sand and gravel in 2005 is 26 to 28 Mt. Consumption is expected to be about 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. The market share for container glass in the United States is expected to remain the same. Total demand for all glass sand end uses is expected to grow slowly, probably to the range of 10 to 12 Mt through 2005. 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. On the basis of these factors, consumption of silica foundry sand in 2005 is expected to be 5.5 Mt, and the consumption range is expected to be 5 to 6 Mt.

Frac sand sales increased in 2004, compared with those of 2003. On the basis of this trend, demand for frac sand is expected to increase modestly during 2005. Demand for frac sand in 2005 is expected to be 3.2 Mt, with a range of 3.1 to 3.3 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 the Southwest, mostly in California and Texas, respectively. Domestic production is expected to continue to meet 97% or 98% of demand well beyond 2005. 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. 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 about 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 2004. 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 2004, 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 can 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 about 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 2004, the USGS collected domestic consumption data for quartz crystal through a survey of 24 U.S. operations that fabricate quartz crystal devices in 10 States. Of the 24 operations, 11 responded to the survey. Consumption for nonrespondents was estimated on the basis of 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 about $186 per kilogram in 2004.

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 towards 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 62% of crude production, responded during 2004. 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 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 about $581 per ton. The average value of stone products made from crude material was $5.58 per kilogram (table 1).

Foreign Trade.—In 2004, silica stone product exports had a value of about $8.9 million, up from that of 2003. 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 2004.

In 2004, the value of imported silica stone products was $6.8 million; this was an increase of 8.5% compared with that of 2003. These imports were hand sharpening or polishing stones, which accounted for most of or all the imported silica stone products in 2004. 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 2004, 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 of these firms except one responded to the USGS survey.

Consumption.—The 2004 USGS annual survey of producers indicates that sales of processed tripoli increased by about 37% in quantity to 94,000 t with a value of about $19.4 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 2004, about 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 (about 85%) 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 about 3% 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 2004. The average reported unit value of abrasive tripoli sold or used in the United States during 2004 was $188 per ton, and the average reported unit value of filler tripoli sold or used domestically was $214 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)

		2000	2001	2002	2003	2004
Industrial sand and gravel:[2]						
Sold or used:						
Quantity:						
Sand		26,800	26,900	25,900	26,300 [3]	28,700
Gravel		1,660	1,060	1,420	1,140	1,070
Total		28,400	27,900	27,300	27,500	29,700
Value:						
Sand		532,000	559,000	554,000	594,000 [3]	668,000
Gravel		24,400	17,600	19,400	15,300	16,600
Total		556,000	576,000	573,000	609,000	685,000
Exports:						
Quantity		1,660	1,540	1,410	2,620	1,790
Value		179,000	163,000	145,000	155,000	174,000
Imports for consumption:						
Quantity		247	172	250	440	490
Value		11,800	11,000	8,650	9,210	12,400
Processed tripoli:[4]						
Quantity	metric tons	72,000	60,500	66,600	68,800	94,000
Value		15,900 [e]	15,000	16,600	17,700	19,400
Special silica stone:						
Crude production:						
Quantity	metric tons	553	705	748	1,070	227
Value		158	234	240	313	132
Sold or used:						
Quantity	metric tons	312	393	386	513	655
Value		4,610	4,040	3,740	3,630	3,660

[e]Estimated.

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

[2]Excludes Puerto Rico.

[3]Includes gravel data withheld on table 6.

[4]Includes amorphous silica and Pennsylvania rottenstone.

TABLE 2

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

Geographic region	2003 Quantity (thousand metric tons)	2003 Percentage of total	2003 Value (thousands)	2003 Percentage of total	2004 Quantity (thousand metric tons)	2004 Percentage of total	2004 Value (thousands)	2004 Percentage of total
Northeast:								
New England	145	1	$2,880	(2)	W	W	W	W
Middle Atlantic	2,170	8	44,500	8	2,760	9	53,300	8
Midwest:								
East North Central	9,650	35	177,000	29	9,990	34	193,000	28
West North Central	1,820	7	44,400	7	2,030	7	57,300	8
South:								
South Atlantic	4,380	16	93,600	15	4,460	15	92,700	14
East South Central	1,760	6	31,300	5	1,680	6	36,200	5
West South Central	4,230	15	135,000	22	5,290	18	165,000	24
West:								
Mountain	1,200	4	21,900	4	1,210	4	22,700	3
Pacific	2,140	8	58,600	10	2,310	8	63,800	9
Total	27,500	100	609,000	100	29,700	100	685,000	100

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

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

[2]Less than ½ unit.

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

(Thousand metric tons and thousand dollars)

	2003		2004	
State	Quantity	Value	Quantity	Value
Alabama	723	9,180	643	9,800
Arizona	W	W	W	792
Arkansas	W	W	W	W
California	1,790	50,100	1,990	55,700
Colorado	70	3,000	W	3,300
Florida	624	7,270	679	8,520
Georgia	590	11,900	665	13,400
Idaho	W	W	W	W
Illinois	4,440	72,600	4,950	86,200
Indiana	W	W	W	W
Iowa	W	W	W	W
Kansas	W	W	W	W
Louisiana	499	17,200	476	14,800
Maryland	W	W	W	W
Michigan	2,130	31,400	1,690	25,200
Minnesota	W	W	W	W
Mississippi	W	W	W	W
Missouri	586	12,800	589	14,200
Nebraska	W	W	W	W
Nevada	W	W	W	W
New Jersey	1,570	32,700	2,020	35,800
New York	W	W	W	W
North Carolina	1,530	26,700	1,630	29,000
North Dakota	W	W	W	W
Ohio	1,120	32,100	1,180	34,200
Oklahoma	1,360	29,700	1,390	31,600
Pennsylvania	W	W	570	11,800
Rhode Island	W	W	W	W
South Carolina	655	16,700	719	17,600
Tennessee	961	21,800	975	26,100
Texas	1,930	81,700	2,790	109,000
Virginia	W	W	W	W
Washington	W	W	W	W
West Virginia	W	W	343	17,300
Wisconsin	1,930	40,200	2,140	47,000
Other	4,370	101,000	4,300	93,300
Total	27,500	609,000	29,700	685,000

W Withheld to avoid disclosing company proprietary data; included with "Other."

[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 2004, 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	304	1
25,000 to 49,999	11	9	365	1
50,000 to 99,999	22	18	1,460	5
100,000 to 199,999	19	15	2,500	8
200,000 to 299,999	10	8	2,130	7
300,000 to 399,999	8	6	2,460	8
400,000 to 499,999	4	3	1,650	6
500,000 to 599,999	5	4	2,420	8
600,000 to 699,999	9	7	4,700	16
700,000 and more	13	10	11,800	40
Total	124	100	29,700	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 2004, 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	7	--	--	--	4	11
Midwest:						
East North Central	25	--	--	--	4	29
West North Central	6	1	--	--	3	10
South:						
South Atlantic	20	--	--	--	6	26
East South Central	8	--	--	--	3	11
West South Central	12	--	--	--	9	21
West:						
Mountain	5	--	--	--	--	5
Pacific	10	--	--	--	--	10
Total	94	1	--	--	30	124

-- Zero.

TABLE 6

INDUSTRIAL SAND AND GRAVEL SOLD OR USED BY U.S. PRODUCERS IN 2004, BY MAJOR END USE[1]

	Northeast			Midwest			South		
Major use	Quantity (thousand metric tons)	Value (thousands)	Value[2] (dollars per ton)	Quantity (thousand metric tons)	Value (thousands)	Value[2] (dollars per ton)	Quantity (thousand metric tons)	Value (thousands)	Value[2] (dollars per ton)
Sand:									
Glassmaking:									
Containers	W	W	$19.93	1,380	$16,800	12.14	1,640	$27,900	$17.02
Flat, plate and window	W	W	18.73	1,080	14,700	13.64	1,560	27,400	17.52
Specialty	W	W	27.41	297	5,690	19.20	277	7,140	25.76
Fiberglass, unground	W	W	19.57	346	4,460	12.87	452	7,790	17.22
Fiberglass, ground	--	--	--	W	W	34.60	506	21,700	42.87
Foundry:									
Molding and core, unground	238	4,860	20.43	4,220	62,600	14.83	827	14,400	17.48
Molding and core, ground	--	--	--	W	W	91.76	W	W	63.56
Refractory	(3)	1	15.84	57	2,650	46.35	129	1,420	10.97
Metallurgical:									
Silicon carbide	--	--	--	W	W	29.70	--	--	--
Flux for metal smelting	--	--	--	W	W	56.49	(3)	(3)	3.32
Abrasives:									
Blasting	43	2,070	47.85	126	4,120	32.77	498	15,000	30.17
Scouring cleansers, ground	(3)	(3)	66.20	W	W	75.05	W	W	44.22
Sawing and sanding	W	W	23.10	--	--	--	--	--	--
Chemicals, ground and unground	W	W	26.01	331	4,690	14.18	383	11,000	28.61
Fillers, ground, rubber, paints, putty, etc.	W	W	32.70	309	10,600	34.33	136	19,900	146.54
Whole grain fillers/building products	254	8,310	32.69	568	17,400	30.58	1,070	26,500	24.74
Ceramic, ground, pottery, brick, tile, etc.	(3)	6	60.30	W	W	82.07	129	7,960	61.61
Filtration:									
Water, municipal, county, local	58	1,700	29.28	68	3,390	49.99	175	6,120	34.89
Swimming pool, other	10	619	59.39	W	W	85.25	35	2,490	71.99
Petroleum industry:									
Hydraulic fracturing	(3)	4	49.73	2,090	75,300	36.10	1,180	59,600	50.31
Well packing and cementing	--	--	--	7	470	70.94	128	5,160	40.40
Recreational:									
Golf course, greens and traps	120	2,930	24.40	241	5,590	23.19	302	3,430	11.37
Baseball, volleyball, play sand, beaches	W	W	53.05	120	3,470	28.84	95	1,400	14.65
Traction, engine	10	327	34.04	62	1,010	16.26	52	974	18.55
Roofing granules and fillers	W	W	27.49	W	W	21.93	157	3,270	20.77
Other, ground silica	87	2,760	31.58	224	9,490	42.37	60	2780.00	46.16
Other, whole grain	1,920	28,800	15.03	420	7,440	17.73	1,020	9,790	9.62
Total or average	2,740	52,400	19.14	11,900	250,000	20.92	10,800	283,000	26.17
Gravel:									
Silicon, ferrosilicon	--	--	--	25	118	4.70	545	9,730	17.85
Filtration	W	W	47.24	W	W	48.62	17	842	49.11
Nonmetallurgical flux	--	--	--	W	W	17.64	--	--	--
Other uses, specified	22	900	40.99	62	895	14.49	50	405	8.13
Total or average	22	900	40.99	87	1,010	11.67	612	11,000	17.94
Grand total or average	2,760	53,300	19.31	12,000	251,000	20.86	11,400	294,000	25.73

See footnotes at end of table.

TABLE 6—Continued

INDUSTRIAL SAND AND GRAVEL SOLD OR USED BY U.S. PRODUCERS IN 2004, BY MAJOR END USE[1]

Major use	West			U.S. total		
	Quantity (thousand metric tons)	Value (thousands)	Value[2] (dollars per ton)	Quantity (thousand metric tons)	Value (thousands)	Value[2] (dollars per ton)
Sand:						
Glassmaking:						
Containers	W	W	$22.52	4,560	$77,900	$17.08
Flat, plate and window	W	W	20.41	3,410	57,400	16.84
Specialty	W	W	34.56	817	19,600	23.95
Fiberglass, unground	W	W	22.10	1,040	17,300	16.64
Fiberglass, ground	W	W	35.57	696	28,300	40.62
Foundry:						
Molding and core, unground	72	1,750	24.48	5,360	83,600	15.61
Molding and core, ground	--	--	--	(4)	(4)	77.61
Refractory	--	--	--	186	4,070	21.84
Metallurgical:						
Silicon carbide	--	--	--	(4)	(4)	29.70
Flux for metal smelting	W	W	7.01	19	134	7.10
Abrasives:						
Blasting	117	6,160	52.62	784	27,400	34.91
Scouring cleansers, ground	--	--	--	(4)	(4)	46.78
Sawing and sanding	W	W	39.93	(4)	(4)	37.32
Chemicals, ground and unground	W	W	23.41	771	17,100	22.17
Fillers, ground, rubber, paints, putty, etc.	W	W	34.38	462	31,100	67.28
Whole grain fillers/building products	564	18,800	33.33	2,460	70,900	28.89
Ceramic, ground, pottery, brick, tile, etc.	W	W	21.65	192	10,600	55.16
Filtration:						
Water, municipal, county, local	109	6,310	58.05	410	17,500	42.73
Swimming pool, other	W	W	41.87	64	4,310	66.96
Petroleum industry:						
Hydraulic fracturing	W	W	44.09	3,280	135,000	41.26
Well packing and cementing	31	2,260	72.96	165	7,890	47.72
Recreational:						
Golf course, greens and traps	224	4,970	22.14	887	16,900	19.07
Baseball, volleyball, play sand, beaches	W	W	17.60	240	5,770	24.08
Traction, engine	12	365	29.76	137	2,680	19.60
Roofing granules and fillers	W	W	28.51	266	6,230	23.41
Other, ground silica	82	1,910	23.16	XX	XX	XX
Other, whole grain	1,960	40,200	20.57	XX	XX	XX
Total or average	3,170	82,800	26.12	28,700	668,000	23.31
Gravel:						
Silicon, ferrosilicon	--	--	--	570	9,840	17.27
Filtration	W	W	32.42	55	2,320	42.22
Nonmetallurgical flux	W	W	9.06	W	W	9.20
Other uses, specified	351	3,690	10.50	447	4,410	9.87
Total or average	351	3,690	10.50	1,070	16,600	15.47
Grand total or average	3,520	86,400	24.56	29,700	685,000	23.03

W Withheld to avoid disclosing company proprietary data; for sand, included with "Other, ground silica" or "Other, whole grain;" for gravel, included with "Other uses, specified." XX Not applicable. -- Zero.

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

[2]Calculated by using unrounded data.

[3]Less then ½ unit.

[4]Included with "Total or average."

TABLE 7

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

(Thousand metric tons)

Destination	2003	2004	Destination	2003	2004
States:			States—Continued:		
Alabama	594	657	New Jersey	1,010	1,460
Alaska	2	(2)	New Mexico	106	179
Arizona	63	68	New York	392	397
Arkansas	54	75	North Carolina	968	956
California	2,460	2,720	North Dakota	27	35
Colorado	276	651	Ohio	1,400	1,510
Connecticut	60	94	Oklahoma	619	815
Delaware	11	14	Oregon	76	63
District of Columbia	--	(2)	Pennsylvania	1,380	1,160
Florida	734	581	Rhode Island	49	50
Georgia	756	905	South Carolina	299	480
Hawaii	(2)	--	South Dakota	14	10
Idaho	430	399	Tennessee	838	881
Illinois	1,790	1,990	Texas	2,350	2,810
Indiana	1,190	940	Utah	32	46
Iowa	283	333	Vermont	4	3
Kansas	443	438	Virginia	294	330
Kentucky	265	295	Washington	239	206
Louisiana	552	540	West Virginia	153	137
Maine	1	2	Wisconsin	1,070	1,220
Maryland	102	93	Wyoming	161	154
Massachusetts	60	141	Countries:		
Michigan	1,240	980	Canada	718	848
Minnesota	381	296	Mexico	318	413
Mississippi	141	125	Other foreign countries	25	44
Missouri	298	284	Other:		
Montana	24	48	Puerto Rico	--	(2)
Nebraska	50	38	U.S. possessions and territories	(2)	--
Nevada	65	42	Destination unknown	2,630	2,760
New Hampshire	4	3	Total	27,500	29,700

-- 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)

Country	2003 Quantity	2003 F.a.s. value[2]	2004 Quantity	2004 F.a.s. value[2]
North America:				
Bahamas, The	1	127	7	249
Canada	820	33,500	1,240	33,900
Mexico	496	17,300	287	9,210
Other	15 r	1,560 r	9	2,190
Total	1,330	52,400	1,540	45,600
South America:				
Argentina	25	4,080	30	4,490
Brazil	2	1,240	6	580
Peru	3	429	2	227
Venezuela	(3)	36	2	464
Other	4 r	506 r	2	400
Total	34	6,290 r	42	6,160
Europe:				
Belgium	3	2,730	4	4,000
Denmark	10	6,280	12	8,110
Germany	36	14,000	10	15,000
Netherlands	18	10,500	14	11,600
Russia	3	1,950	19	11,700
Other	6 r	10,700 r	8	11,700
Total	76	46,200	67	62,100
Asia:				
China	902	3,630	18	8,730
Hong Kong	(3)	199	57	1,510
Indonesia	2	620	2	553
Japan	226	19,900	22	29,700
Singapore	4	3,280	5	3,620
Taiwan	12	5,290	11	5,560
Other	11 r	4,160 r	5	3,200
Total	1,160	37,100 r	120	52,800
Middle East and Africa:				
Egypt	--	--	2	1,290
Oman	15	9,590	5	3,180
Other	4 r	1,900 r	2	2,050
Total	19	11,500	9	6,510
Oceania:				
Australia	5	1,680	5	1,100
New Zealand	(3)	146	(3)	193
Total	5	1,820	5	1,290
Grand total	2,620	155,000	1,790	174,000

[r]Revised. -- Zero.

[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, including 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)

	2003		2004	
Country	Quantity	C.i.f. value[2]	Quantity	C.i.f. value[2]
Australia	2	779	3	1,240
Canada	109	2,820	152	4,610
Chile	8	1,370	9	1,680
Germany	(3)	99	(3)	475
Japan	(3)	60	1	525
Mexico	319	2,650	300	2,830
New Zealand	(3)	38	2	232
Norway	--	--	21	84
Other	2 r	1,400 r	3	711
Total	440	9,210	490	12,400

[r]Revised. -- 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 and 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 2004

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	Stone cutting and finishing	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 (SILICA) SAND AND GRAVEL: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Thousand metric tons)

Country[3]	2000	2001	2002	2003	2004[e]
Argentina	496	891	280	300	300
Australia[e]	4,266 [4, 5]	4,500 [5]	4,500	4,500	4,500
Austria[e]	6,800	6,800	6,800	6,800	6,800
Belgium[e]	1,800	1,800	1,800	1,800	1,800
Bosnia and Herzegovina[e]	50	50	50	50 [r]	50
Brazil, silex[e]	1,600	1,600	1,600	1,600	1,600
Bulgaria[e]	900	900	900	900	900
Canada, quartz	1,514	1,613	1,540 [r]	1,586 [r]	1,590
Chile[e]	300	300	300	300	300
Croatia[e]	96 [4]	95	95	95	95
Cuba[e]	52 [4]	50	50	50	50
Czech Republic[e]	985 [4]	950	900	900	900
Denmark, sales[e]	43	50	55 [r]	60	60
Ecuador	28	35	41 [r]	45 [r, e]	45
Egypt[e, 5]	600	600	600	640 [r]	640
Eritrea	--	--	(6)	(6) [e]	(6)
Estonia[e]	34 [4]	25	24	34	35
Ethiopia[e]	6 [4]	6	6	6	6
Finland[e]	73	148	148	155	156
France[e]	6,500	6,500	6,500	6,500	6,500
Gambia	170	170 [e]	1,508 [r]	1,534 [r]	1,530
Germany[e]	8,500	8,500	7,500 [r]	7,500 [r]	7,500
Greece[e]	90	90	90	100	100
Guatemala[e]	173 [4]	161 [r]	38 [r]	30 [r]	30
Hungary[e]	500 [4]	500	500	500	520
Iceland[e]	4	4	4	4	4
India[e]	1,350	1,400	1,400	1,500	1,500
Indonesia[e, 7]	124	124	124	124	120
Iran[e, 8]	1,000	1,700	1,700	1,700	1,700
Ireland[e]	5	5	5	5	5
Israel[e]	300 [4]	306	330	320	320
Italy[e]	3,000	3,000	3,000	3,000	3,000
Jamaica	7	8	9	13 [r]	13
Japan	6,121	5,768	4,893	4,700	4,500
Jordan[e]	118 [4]	122	132	129	129
Kenya[e]	9	7	7	7	7
Korea, Republic of	879	900	891	480 [r]	480
Latvia[e]	50	50	50	50	50
Lithuania[e]	30	30	30	30	30
Malaysia	447	575	447	534 [r]	550
Mexico	1,803	1,720	1,779	1,689	2,003 [p]
Netherlands[e]	5	5	5	5	5
New Caledonia[e]	40	40	40	40	40
New Zealand[e]	47 [4]	48	45	45	45
Norway[e]	1,300	1,500	1,400	1,500	1,500
Pakistan[e]	162 [4]	165	165	165	165
Paraguay[e]	25	28	25	26	25
Peru	74	120	300	196 [r]	196 [p]
Philippines[e]	70 [4]	70	70	70	70
Poland	1,675	1,564	1,486	1,500	1,500
Portugal[e]	5	5	5	5	5
Romania	814	733	1,569	1,013	1,100
Serbia and Montenegro[e]	100	75	75	75	100
Slovakia	2,000	2,000	2,200	2,200	2,200

See footnotes at end of table.

TABLE 11—Continued

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

(Thousand metric tons)

Country[3]	2000	2001	2002	2003	2004[e]
Slovenia	12,526	11,510	11,000 r	11,000 r, e	11,000
South Africa	2,137 r	2,127 r	2,248 r	2,457	2,388 4
Spain[e]	6,600	6,500	6,500	6,500	6,500
Sweden[e]	500	600	600	600	600
Thailand	472	514	781	1,294 r	1,300
Turkey	1,485	1,207	1,274	1,283 r	1,300
United Kingdom[e]	4,500	4,500	4,500	4,500	4,500
United States, sold or used by producers	28,400	27,900	27,300	27,500	29,700 4
Venezuela	422	627	690	700 e	700
Zimbabwe[9]	121 e	43 r	25 r	23 r	(6) 4
Total	114,000 r	114,000 r	113,000 r	113,000 r	115,000

[e]Estimated. [p]Preliminary. [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, 2005.

[3]In addition to the countries listed, Angola, Antigua and Barbuda, The Bahamas, China, countries of the Commonwealth of Independent States (CIS), 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: 2000-02—145,000 (estimated) and 2003-04—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 2004, BY GEOGRAPHIC DIVISION