SILICA

By Thomas P. Dolley

Domestic survey data and tables were prepared by Nicholas A. Muniz, statistical assistant, and the world production table was prepared by Glenn J. Wallace, international data coordinator.

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 Minerals Yearbook, Metals and Minerals, volume I.

Industrial Sand and Gravel

Total industrial sand and gravel production increased slightly to 27.5 million metric tons (Mt) in 2003 compared with that of 2002 (table 1). Compared with 2002, industrial sand production increased by 1.5%, and gravel production decreased by about 20%.

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, foundry, and hydraulic fracturing (frac) 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 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, in 2003.

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 implementations of the measurements and actions taken with regard to 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's 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 exposed during an 8-hour work shift (29 CFR §§1926.55 and 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 U.S. Geological Survey (USGS) from a voluntary survey of U.S. producers. The USGS canvassed 65 producers with 153 operations known to produce industrial sand and gravel. Of the 153 surveyed operations, 137 (90%) were active, and 16 were idle. The USGS received responses from 105 operations, and their combined production represented about 84% of the U.S. total. Production for the 48 nonrespondents was estimated, primarily on the basis of previously reported information supplemented with man-hour 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 42% of the 27.5 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 38%, and the West (Pacific and Mountain divisions) with 12% (figure 1, table 2).

The leading producing States were, in descending order, Illinois, Michigan, Texas, Wisconsin, California, New Jersey, North Carolina, and Oklahoma (table 3). Their combined production represented about 61% of the national total. Of the 36 States that produced silica in 2003, 15 had increased production, 19 had decreased production, and 2 stayed about even compared with 2002. North Carolina, New Jersey, Ohio, Texas, and Wisconsin reported the largest increases, and South Carolina, Louisiana, Tennessee, and Michigan reported the largest decreases.

About 82% 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., Fairmount Minerals Ltd., Oglebay Norton Industrial Sands Co., Badger Mining Corp., Nugent Sand Co. Inc., Simplot Industries Inc., Little Six Corp., Owens-Illinois, Inc., and Manley Brothers, Inc. Their combined production from 64 operations represented 78% 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 companies. Stockpiled material is not reported until consumed or sold. Of the 27.5 Mt of industrial sand and gravel sold or used, about 39% was consumed as glassmaking sand and 19% as foundry sand (table 6). Building products, which is a broad category that includes nonskid flooring, paints, putty, and stucco, consumed about 10% of

---

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

industrial sand and gravel production. Other important uses were frac sand (7.8%) and abrasive sand (3%).

Minable resources of industrial sand and gravel occur throughout the United States, and successful mining companies are located near markets, which 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 2003, more than 83% 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 2003, 43% of glass sand was produced in the South; 31%, in the Midwest; 16%, in the West; and 10%, in the Northeast. To varying degrees, all silica production and sales are similarly influenced by the location of the consuming industries.

Some 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 therefore, is likely not as large as the statistics portray.

The share of silica sold for all types of glassmaking as a percentage of all silica sold was about 39%. This percentage increased slightly compared with that of 2002. In 2003, sales to container glass manufacturers increased 8% compared with those of 2002. The amount of sand consumed for fiberglass production increased by about 6% compared with that of 2002.

In 2003, sales of sand for flat glass production decreased by about 7% compared with those of 2002. In the Midwest, consumption for flat glass increased by about 6%, but in the South, consumption decreased by about 9%.

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 in the production of optical fiber and semiconductors.

The U.S. fiberglass industry consists 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, from 22% to 32% of the ceramic body of sanitaryware (for example, sinks, toilets, urinals) is comprised 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 2003, about 221,000 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 2003, consumption of whole-grain filler was about 2.0 Mt, and ground silica for filler was 519,000 t.

Synthetic cristobalite, a high-temperature silica mineral, is made by heating quartz to above 1,470° C. It consists of small octahedral crystals, which aggregate into rounded particles. The crystal structure is more open than quartz, resulting in lower specific gravity. The major market for cristobalite is in the solid mold industry, but it is also used in ceramics, grinding products, reflective coatings, refractories, and paint used on road surfaces (Paint and Coatings Industry, 1997).

Sodium silicate, produced primarily by reacting sand and soda ash in a furnace, is one of the traditional chemicals made with silica sand. One of the forces that drives the increased demand for sodium silicate is the zeolite industry, which uses sodium silicate in synthetic zeolite production.

Potassium silicate is produced in a process similar to that for sodium silicate but uses potassium carbonate or potassium hydroxide. Potassium silicate is more expensive than sodium silicate and is used primarily in welding rods as a flux.

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.

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 2003, silica sales for chemical production were 867,000 t, which was a decrease of about 1% compared with those of 2002. According to the USGS survey, reported sales of silica gravel for silicon and ferrosilicon production decreased by about 2% in 2003 compared with those of 2002. The main uses for silicon metal are in the manufacture of silanes and semiconductor-grade silicon and in the production of aluminum alloys. Additionally, new techniques in the field of semiconductors 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 superceded 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 proportion 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). Although these tires reportedly produce greater gas mileage, higher costs to consumers and manufacturers account for their lack of popularity in the United States. Some new silicas, which aim to alleviate these problems, are being produced. If these problems are solved, then the "green" tire will probably become more popular in the United States. Precipitated silica is also used in battery separators and as a flatting agent in coatings, mainly high-solid, low-volatility organic compound coatings.

Transportation.—Of the total industrial sand and gravel produced, 64% was transported by truck from the plant to the site of first sale or use, unchanged from 2002; 35% was transported by rail, up from 34% in 2002; and 1.4%, by waterway.

Prices.—Compared with the average value of 2002, the average value, free on board plant, of U.S. industrial sand and gravel increased by about 6% to $22.17 per metric ton in 2003 (table 6). The average unit values for industrial sand and industrial gravel were $22.54 per ton and $13.47 per ton, respectively. The average price for sand ranged from $7.00 per ton for metallurgical flux to $85.29 per ton for ground foundry sand. For gravel, prices ranged from $9.07 per ton for other uses to $40.08 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 ($85.29 per ton), followed by silica for swimming pool filters ($73.76 per ton), ground sand used as fillers for paint, putty, and rubber ($73.30 per ton), ground sand for scouring cleansers ($54.26 per ton), ground sand for ceramics ($51.90 per ton), silica for municipal water filtration ($49.75 per ton), ground sand for well packing and cementing ($42.04 per ton), and sand for hydraulic fracturing ($40.72 per ton).

Industrial sand and gravel price changes were mixed; some markets remained level, others had small increases or decreases, and still others had large increases or decreases. Although the silica was essentially the same, this situation was possible because most markets were independent of each other, and price competition was influenced by availability, competition from other materials, health concerns, and regulations.

By geographic region, the average value of industrial sand and gravel was highest in the South ($25.09 per ton) followed by the West ($24.17 per ton), the Northeast ($20.52 per ton), and the Midwest ($19.28 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 glass sand varied from $24.93 per ton in the West to $16.69 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 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 California (8.9%), Texas (8.5%), Illinois (6.5%), Ohio (5.1%), Pennsylvania (5%), and Michigan (4.5%). Producers reported sending at least 718,000 t of silica to Canada and 318,000 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 2003, 9.5% 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 2003 increased by about 86% compared with the amount exported in 2002, and the associated value increased by about 7% (table 8). Most of the increase in exports was attributable to shipments to Asia. China was the leading recipient of U.S. exports. Export distribution was as follows: 34% to China, 31% to Canada, 19% to Mexico, 9% to Japan, and the remainder to

Europe, South America, the Middle East and Africa, and Oceania. The average price of exports decreased to $59 per ton in 2003 from $103 per ton in 2002. In 2003, export prices varied widely by region; exports of higher grade silica to Europe averaged about $608 per ton, and exports to the rest of the world averaged $43 per ton.

The U.S. Census Bureau also reported that imports for consumption of industrial sand and gravel rose to 440,000 t, which was a sharp increase of 76% compared with those of 2002 (table 9). Silica imports vary greatly from year to year but are rather insignificant in relation to total consumption. Mexico supplied 73% of the silica imports, which averaged $8.31 per ton; this price included insurance and freight costs to the U.S. port. The total value of imports was about $9.2 million, with an average of about $21 per ton. Higher priced imports came from Australia, China, Germany, and Japan.

World Review.—New data supplied by foreign governments has 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 110 Mt (table 12). The United States was the leading producer followed, in descending order, by Slovenia, Germany, Belgium, France, Spain, 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 2004 is from 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, and fiberglass. The market share for container glass in the United States is expected to grow steadily. Total demand for all glass sand end uses is expected to grow slowly, probably to the range of 10 to 12 Mt through 2004.

The demand for foundry sand is dependent mainly on automobile and light truck production. Another important factor for the future consumption of virgin foundry sand is the recycling of used foundry sand. The level of recycling is thought to be increasing. Other materials or minerals compete with silica as foundry sand, but these other "sands" usually suffer from a severe price disadvantage. On the basis of these factors, consumption of silica foundry sand in 2004 is expected to be 5.5 Mt, and the consumption range is expected to be 5 to 6 Mt.

Frac sand sales increased in 2003, compared with those of 2002. On the basis of this trend, demand for frac sand is expected to increase modestly during 2004. Demand for frac sand in 2004 is expected to be 2.2 Mt, with a range of 2.1 to 2.2 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 the Southwest, mostly in California and Texas, respectively. Domestic production is expected to continue to meet more than 99% of demand well beyond 2004. 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 hinder the demand for glass sand. 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 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; the latter application is used to hold fractures open in oil wells (Industrial Minerals, 2002a).

Development of more efficient mining and processing methods is expected to continue. This will encourage the mining of lower grade silica sand deposits that are located closer to markets but are not presently mined. Such developments are expected to increase silica sand reserves.

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, 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 U.S. Geological Survey Minerals Yearbook, Metals and Minerals, volume I.

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, 2003, the National Defense Stockpile (NDS) contained about 6,804 kilograms (kg) of natural quartz crystal; a significant amount was sold from the stockpile during the year. 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.

In the latest reports on the inventory of stockpile material, 97,240 kg of natural quartz crystal valued at $365,166 was sold in 2003. 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 2003, no domestic companies reported the production of cultured quartz crystal. CTS Corp. of Carlisle, PA, reported that it was no longer in business as of 2003. P.R. Hoffman Material Processing Co. of Carlisle, PA, has the capacity to produce cultured quartz crystal, but had no production in 2003 (table 1). 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 one-half of the growing vessel is heated to temperatures averaging between 350° C and 400° C; the temperature of the top portion is maintained at 5° C to 50° C lower than that in the bottom one-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 one-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 2003, the USGS collected domestic consumption data for quartz crystal through a survey of 26 U.S. operations that fabricate quartz crystal devices in 10 States. Of the 26 operations, 14 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 was estimated to be about $81 per kilogram in 2003. The average value of lumbered quartz, which is as-grown quartz that has been processed by sawing and grinding, was estimated to be about $176 per kilogram.

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. Some lascas was imported from Brazil in 2003, according to some consumers.

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 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 U.S. Geological Survey Minerals Yearbook, Metals and Minerals, volume I chapters).

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

Production.—In response to a USGS production survey, five of nine domestic firms representing 86% of crude production responded during 2003. Two of the firms reported that they were no longer in operation. 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. Major household uses include sharpening of knives and other cutlery, lawn and garden tools, scissors, and shears. Leading industrial uses include deburring of metal and plastic castings, polishing of metal surfaces, and sharpening and honing of cutting surfaces. Recreational uses include the sharpening of arrowheads, fishhooks, spear points, and sports knives. Craft applications include 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 $292 per ton. The average value of stone products made from crude material was $7.08 per kilogram (table 1).

Foreign Trade.—In 2003, silica stone product exports had a value of about $7.8 million; up from that of 2002. 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 2003.

In 2003, the value of imported silica stone products was $6.3 million; this was an increase of 40% compared with that of 2002. These imports were hand sharpening or polishing stones, which accounted for most of or all the imported silica stone products in 2003. 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 2003, 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 a 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 responded to the USGS survey.

Consumption.—The 2003 USGS annual survey of producers indicates that sales of processed tripoli increased by 3% in quantity to 68,800 t with a value of about $17.7 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 2003, about 16% 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 79%) 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 5% of the tripoli used as a filler and extender. Tripoli is used extensively 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.

Prices.—The average reported unit value of all tripoli sold or used in the United States was $257 per ton in 2003. The average reported unit value of abrasive tripoli sold or used in the United States during 2003 was $194 per ton, and the average reported unit value of filler tripoli sold or used domestically was $282 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.

References Cited

Ceramic Industry, 1998, Silicon-based ceramics: Ceramic Industry, v. 148, no. 6, June, p. 48.
Hutcheson, G.D., 2004, The first nanochips: Scientific American, v. 290, no. 4, April, p. 78.
Industrial Minerals, 1998a, Crystalline silica: Industrial Minerals, no. 367, April, p. 109-117.
Industrial Minerals, 1998b, Synthetic minerals—Part 1: Industrial Minerals, no. 371, August, p. 45-55.
Industrial Minerals, 1998c, Synthetic minerals—Part 2: Industrial Minerals, no. 372, September, p. 57-67.
Industrial Minerals, 2000a, Nippon Silica supplies fuel-efficient tires: Industrial Minerals, no 395, August, p. 11-12.
Industrial Minerals, 2000b, Written in sand—The world of specialty silicas: Industrial Minerals, no. 390, March, p. 49-59.
Industrial Minerals, 2002a, Abrasive bauxite—Giving proppants the nod: Industrial Minerals, no. 418, July, p. 36-41.
Industrial Minerals, 2002b, Breaking the mould—Mineral opportunities in investment casting: Industrial Minerals, no. 419, August, p. 38-43.
Paint and Coatings Industry, 1997, Cristobalite—A unique form of silica: Paint and Coatings Industry, v. 13, no. 8, August, p. 58-62.

Internet Reference Cited

U.S. Department of Labor, Occupational Safety and Health Administration, 2002, Crystalline silica health hazard information, Fact Sheet, accessed July 26, 2004, at URL http://www.osha.gov/OshDoc/data_General_Facts/crystalline-factsheet.pdf.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Abrasives, Manufactured. Ch. in Minerals Yearbook, annual.
Abrasives, Manufactured. Mineral Industry Survey, quarterly.
Garnet, Industrial. Ch. in Minerals Yearbook, annual.
Pumice and Pumicite. Ch. in Minerals Yearbook, annual.
Quartz Crystal. Ch. in Mineral Commodity Summaries, annual.
Silica Sand. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Other

A Stockpile Primer. U.S. Department of Defense, Directorate of Strategic Materials Management, August 1995.
Aggregates Manager, monthly.
Ceramics Industry, monthly.
Electronic Component News, monthly.
Electronic News, weekly.
Electronics, biweekly.
Engineering and Mining Journal, monthly.
Glass International, monthly.
Industrial Minerals, monthly.
Pit & Quarry, monthly.
Rock Products, monthly.
Sand and Gravel. Ch. in Minerals Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.

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

(Thousand metric tons and thousand dollars unless otherwise specified)

		1999	2000	2001	2002	2003
Industrial sand and gravel:[2]						
Sold or used:						
Quantity:						
Sand		26,900	26,800	26,900	25,900	26,300 [3]
Gravel		1,940	1,660	1,060	1,420	1,140
Total		28,900	28,400	27,900	27,300	27,500
Value:						
Sand		510,000	532,000	559,000	554,000	594,000 [3]
Gravel		28,400	24,400	17,600	19,400	15,300
Total		538,000	556,000	576,000	573,000	609,000
Exports:						
Quantity		1,670	1,660	1,540	1,410	2,620
Value		133,000	179,000	163,000	145,000	155,000
Imports for consumption:						
Quantity		211	247	172	250	440
Value		5,590	11,800	11,000	8,650	9,210
Processed tripoli:[4]						
Quantity	metric tons	84,900	72,000	60,500	66,600	68,800
Value		20,200	15,900 [e]	15,000	16,600	17,700
Special silica stone:						
Crude production:						
Quantity	metric tons	697	553	705	748	1,070
Value		183	158	234	240	313
Sold or used:						
Quantity	metric tons	475	312	393	386	513
Value		3,060	4,610	4,040	3,740	3,630
Electronic- and optical-grade quartz crystals, production:						
Mine	metric tons	--	--	--	--	--
Cultured	do.	192	189	W	W	W

[e]Estimated. W Withheld to avoid disclosing company proprietary data. -- Zero.
[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]

	2002				2003			
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	157	1	W	W	145	1	$2,880	(2)
Middle Atlantic	2,050	7	$48,100	8	2,170	8	44,500	8
Midwest:								
East North Central	9,540	35	167,000	29	9,650	35	177,000	29
West North Central	1,570	6	35,700	6	1,820	7	44,400	7
South:								
South Atlantic	4,240	16	88,100	15	4,380	16	93,600	15
East South Central	2,220	8	45,700	8	1,760	6	31,300	5
West South Central	4,110	15	110,000	19	4,230	15	135,000	22
West:								
Mountain	1,360	5	23,600	4	1,200	4	21,900	4
Pacific	2,090	8	55,000	10	2,140	8	58,600	10
Total	27,300	100	573,000	100	27,500	100	609,000	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 1/2 unit.

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

(Thousand metric tons and thousand dollars)

	2002		2003	
State	Quantity	Value	Quantity	Value
Alabama	722	8,990	723	9,180
Arizona	W	W	W	W
Arkansas	W	W	W	W
California	1,800	48,000	1,790	50,100
Colorado	61	W	70	W
Florida	645	8,640	624	7,270
Georgia	606	12,200	590	11,900
Idaho	W	W	W	W
Illinois	4,510	72,800	4,440	72,600
Indiana	W	W	W	W
Iowa	W	W	W	W
Kansas	W	W	W	W
Louisiana	672	13,100	499	17,200
Maryland	W	W	W	W
Michigan	2,210	31,000	2,130	31,400
Minnesota	W	W	W	W
Mississippi	W	W	W	W
Missouri	W	W	586	12,800
Nebraska	W	W	W	W
Nevada	W	W	W	W
New Jersey	1,420	32,700	1,570	32,700
New York	W	W	W	W
North Carolina	1,320	25,600	1,530	26,700
North Dakota	W	W	W	W
Ohio	1,000	28,900	1,120	32,100
Oklahoma	1,320	28,400	1,360	29,700
Pennsylvania	W	W	W	W
Rhode Island	157	W	W	W
South Carolina	831	16,400	655	16,700
Tennessee	1,070	25,700	961	21,800
Texas	1,670	62,200	1,930	81,700
Virginia	W	W	W	W
Washington	W	W	W	W
West Virginia	W	W	W	W
Wisconsin	1,740	32,700	1,930	40,200
Other	5,570	126,000	4,980	115,000
Total	27,300	573,000	27,500	609,000

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 2003, BY SIZE OF OPERATION[1]

Size range	Number of operations	Percentage of total	Quantity (thousand metric tons)	Percentage of total
Less than 25,000	17	13	194	1
25,000 to 49,999	17	13	556	2
50,000 to 99,999	22	17	1,420	5
100,000 to 199,999	20	16	2,600	9
200,000 to 299,999	12	9	2,600	9
300,000 to 399,999	7	5	2,270	8
400,000 to 499,999	10	8	4,000	15
500,000 to 599,999	4	3	2,040	7
600,000 to 699,999	6	4	3,560	13
700,000 and more	10	8	8,250	30
Total	125	100	27,500	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 2003, 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	--	--	--	5	30
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	125

-- Zero.

TABLE 6
INDUSTRIAL SAND AND GRAVEL SOLD OR USED BY U.S. PRODUCERS IN 2003, BY MAJOR END USE[1]

Major use	Northeast			Midwest			South			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)	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	598	$11,700	$19.53	1,430	$16,900	11.86	1,890	$34,800	$18.38	1,070	$23,700	$22.06	4,990	$87,100	$17.45
Flat, plate and window	W	W	18.34	1,020	13,200	12.94	1,570	25,900	16.53	W	W	20.04	3,290	52,800	16.07
Specialty	W	W	27.02	339	6,310	18.61	261	6,470	24.80	W	W	30.44	835	19,200	22.95
Fiberglass, unground	W	W	19.13	334	4,230	12.66	396	7,120	17.98	W	W	22.11	873	14,300	16.35
Fiberglass, ground	--	--	--	W	W	27.38	469	19,200	40.89	W	W	30.00	635	23,700	37.37
Foundry:															
Molding and core, unground	246	4,610	18.76	4,320	62,800	14.53	548	9,640	17.58	77	1,430	18.51	5,190	78,500	15.11
Molding and core, ground	--	--	--	W	W	86.40	W	W	82.50	--	--	--	7	597	85.29
Refractory	W	W	16.90	59	2,200	37.22	W	W	51.67	--	--	--	68	2,660	39.16
Metallurgical:															
Silicon carbide	--	--	--	W	W	29.65	--	--	--	--	--	--	W	W	29.65
Flux for metal smelting	--	--	--	W	W	49.64	W	W	5.18	W	W	7.31	14	98	7.00
Abrasives:															
Blasting	19	725	38.16	173	5,770	33.36	478	14,900	31.26	125	5,890	47.08	796	27,300	34.33
Scouring cleansers, ground	W	W	63.80	8	275	34.38	W	W	57.80	--	--	--	53	2,880	54.26
Sawing and sanding	W	W	23.00	--	--	--	--	--	--	W	W	41.30	W	W	38.25
Chemicals, ground and unground	W	W	23.79	311	4,340	13.96	467	12,000	25.65	W	W	23.50	867	18,400	21.26
Fillers, ground, rubber, paints, putty, etc.	W	W	58.00	297	9,270	31.20	216	28,500	131.89	W	W	38.67	519	38,000	73.30
Whole grain fillers/building products	218	6,870	31.52	441	14,500	32.94	896	20,700	23.06	489	15,900	32.59	2,040	58,000	28.37
Ceramic, ground, pottery, brick, tile, etc.	W	W	52.61	56	3,890	69.46	133	7,000	52.63	W	W	18.55	221	11,500	51.90
Filtration:															
Water, municipal, county, local	W	W	41.87	W	W	41.91	74	3,740	50.54	103	5,690	55.28	257	12,800	49.75
Swimming pool, other	W	W	78.13	14	1,160	83.07	33	2,650	80.21	W	W	43.30	66	4,870	73.76
Petroleum industry:															
Hydraulic fracturing	W	W	92.40	1,550	51,800	33.50	593	35,100	59.17	W	W	52.26	2,160	87,900	40.72
Well packing and cementing	13	610	46.92	3	230	76.67	55	2,100	38.24	--	--	--	70	2,940	42.04
Recreational:															
Golf course, greens and traps	130	2,620	20.16	235	5,300	22.54	270	3,020	11.17	239	6,300	26.34	874	17,200	19.71
Baseball, volleyball, play sand, beaches	W	W	23.03	103	2,920	28.35	71	775	10.92	W	W	18.20	252	5,440	21.60
Traction, engine	33	589	17.85	70	1,020	14.60	48	786	16.38	11	327	29.73	162	2,720	16.81
Roofing granules and fillers	W	W	24.76	W	W	17.57	213	3,340	15.67	--	--	--	261	4,430	16.95
Other, ground silica	3	179	59.66	167	4,870	29.14	47	2,770	58.85	56	1,210	21.68	XX	XX	XX
Other, whole grain	1,050	19,500	18.58	443	9,060	20.46	1,030	10,200	9.92	737	15,400	20.87	XX	XX	XX
Total or average	2,310	47,400	20.52	11,400	220,000	19.36	9,760	251,000	25.68	2,910	75,800	26.06	26,300	594,000	22.54

See footnotes at end of table.

TABLE 6--Continued

INDUSTRIAL SAND AND GRAVEL SOLD OR USED BY U.S. PRODUCERS IN 2003, BY MAJOR END USE[1]

Major use	Northeast Quantity (thousand metric tons)	Northeast Value (thousands)	Northeast Value[2] (dollars per ton)	Midwest Quantity (thousand metric tons)	Midwest Value (thousands)	Midwest Value[2] (dollars per ton)	South Quantity (thousand metric tons)	South Value (thousands)	South Value[2] (dollars per ton)	West Quantity (thousand metric tons)	West Value (thousands)	West Value[2] (dollars per ton)	U.S. total Quantity (thousand metric tons)	U.S. total Value (thousands)	U.S. total Value[2] (dollars per ton)
Gravel:															
Silicon, ferrosilicon	--	--	--	W	W	$4.53	W	W	$14.82	--	--	--	594	$8,490	$14.30
Filtration	W	W	$51.43	W	W	46.30	W	W	40.26	W	W	$33.14	W	W	40.08
Nonmetallurgical flux	--	--	--	W	W	16.53	--	--	--	W	W	9.99	W	W	10.08
Other uses, specified	(3)	(3)	51.43	101	$1,050	10.41	613	$9,560	15.59	420	$4,680	11.15	541	6,800	9.07
Total or average	(3)	(3)	51.43	101	1,050	10.41	613	9,560	15.59	420	4,680	11.15	1,140	15,300	13.47
Grand total or average	2,310	$47,400	20.52	11,500	221,000	19.28	10,400	260,000	25.09	3,330	80,500	24.17	27,500	609,000	22.17

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]Included with "Other, whole grain."

TABLE 7

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

(Thousand metric tons)

Destination	2002	2003	Destination	2002	2003
States:			States--Continued:		
Alabama	798	594	New Jersey	798	1,010
Alaska	(2)	2	New Mexico	105	106
Arizona	298	63	New York	437	392
Arkansas	62	54	North Carolina	1,040	968
California	2,420	2,460	North Dakota	20	27
Colorado	233	276	Ohio	1,460	1,400
Connecticut	54	60	Oklahoma	546	619
Delaware	10	11	Oregon	67	76
District of Columbia	(2)	--	Pennsylvania	1,380	1,380
Florida	741	734	Rhode Island	59	49
Georgia	822	756	South Carolina	472	299
Hawaii	(2)	(2)	South Dakota	11	14
Idaho	423	430	Tennessee	945	838
Illinois	1,840	1,790	Texas	2,000	2,350
Indiana	1,260	1,190	Utah	46	32
Iowa	246	283	Vermont	3	4
Kansas	437	443	Virginia	318	294
Kentucky	281	265	Washington	222	239
Louisiana	745	552	West Virginia	162	153
Maine	(2)	1	Wisconsin	1,090	1,070
Maryland	105	102	Wyoming	133	161
Massachusetts	60	60	Countries:		
Michigan	1,220	1,240	Canada	655	718
Minnesota	320	381	Mexico	338	318
Mississippi	194	141	Other foreign countries	56	25
Missouri	319	298	Other:		
Montana	10	24	Puerto Rico	(2)	--
Nebraska	55	50	U.S. possessions and territories	(2)	(2)
Nevada	52	65	Destination unknown	1,960	2,630
New Hampshire	9	4	Total	27,300	27,500

-- Zero.

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

[2]Less than 1/2 unit.

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

(Thousand metric tons and thousand dollars)

	2002		2003	
Country	Quantity	Value[2]	Quantity	Value[2]
North America:				
Bahamas, The	1	136	1	127
Canada	556	30,100	820	33,500
Mexico	490	16,100	496	17,300
Panama	18	332	10	207
Other	26	1,170	5	1,360
Total	1,090	47,800	1,330	52,400
South America:				
Argentina	20	2,640	25	4,080
Brazil	2	1,500	2	1,240
Colombia	1	134	2	303
Peru	(3)	102	3	429
Uruguay	5	170	2	171
Venezuela	(3)	265	(3)	36
Other	1 r	393 r	(3)	154
Total	29	5,200	34	6,420
Europe:				
Belgium	3	1,510	3	2,730
Denmark	--	--	10	6,280
France	2	1,310	2	7,360
Germany	12	13,300	36	14,000
Italy	(3)	1,100	(3)	66
Netherlands	28	10,600	18	10,500
Russia	(3)	283	3	1,950
Switzerland	1	994	(3)	116
United Kingdom	11	4,520	3	2,610
Other	3	1,530 r	1	561
Total	60	35,100	76	46,200
Asia:				
China	10	5,290	902	3,630
Indonesia	2	970	2	620
Japan	166	19,200	226	19,900
Korea, Republic of	5	2,750	3	1,380
Malaysia	5	3,920	2	2,110
Philippines	(3)	121	3	168
Singapore	6	8,240	4	3,280
Taiwan	10	5,390	12	5,290
Thailand	4	956	(3)	303
Other	1	406 r	3	276
Total	209	47,200	1,160	37,000
Middle East and Africa:				
Algeria	(3)	274	1	1,050
Oman	6	4,650	15	9,590
Saudi Arabia	2	1,690	1	132
South Africa	5	115	(3)	17
Other	2	419	2	680
Total	15	7,150	19	11,500
Oceania:				
Australia	5	1,920	5	1,680
Other	(3)	106	(3)	146
Total	5	2,020	5	1,820
Grand total	1,410	145,000	2,620	155,000

[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 1/2 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	2002 Quantity	2002 C.i.f. value[2]	2003 Quantity	2003 C.i.f. value[2]
Australia	3 r	876	2	779
Canada	58	2,290	109	2,820
Chile	5	991	8	1,370
China	3	2,590	1	546
Germany	(3)	124	(3)	99
Japan	(3)	139	(3)	60
Mexico	180	1,200	319	2,650
Other	(3)	439	1	889
Total	250	8,650	440	9,210

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

Source: U.S. Census Bureau.

TABLE 10
U.S. PRODUCERS OF SPECIAL SILICA STONE PRODUCTS IN 2003

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

SALIENT U.S. ELECTRONIC- AND OPTICAL-GRADE QUARTZ CRYSTAL STATISTICS[1]

		1999	2000	2001	2002	2003
Production:						
Mine	metric tons	--	--	--	--	--
Cultured[e]	do.	192	189	W	W	W
Exports, cultured:[2]						
Quantity	do.	NA [r]	NA [r]	NA [r]	NA [r]	NA
Value	thousands	NA [r]	NA [r]	NA [r]	NA [r]	NA
Imports, cultured:[2]						
Quantity	metric tons	NA [r]	NA [r]	NA [r]	NA [r]	NA
Value	thousands	NA [r]	NA [r]	NA [r]	NA [r]	NA
Consumption, apparent[e]	metric tons	128	146	W	W	W

[e]Estimated. NA Not available. [r]Revised. W Withheld to avoid disclosing company proprietary data. -- Zero.

[1]Data are rounded to no more than three significant digits.

[2]The quartz crystal export and import quantities and values reported in previous years were based on U.S. Census Bureau data that included zirconia and were inadvertently reported to be quartz crystal not including mounted piesoelectric crystals.

TABLE 12

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

(Thousand metric tons)

Country[3]	1999	2000	2001	2002	2003[e]
Argentina	263	496 [r]	891 [r]	280 [r]	300
Australia[e]	2,500	4,266 [4, 5]	4,500 [5]	4,500	4,500
Austria[e]	6,857 [4]	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	75
Brazil, silex[e]	1,600	1,600	1,600	1,600	1,600
Bulgaria[e]	900	900	900	900	900
Cameroon	16	--	--	--	--
Canada, quartz	1,702	1,514 [r]	1,613	1,556	1,556 [p]
Chile[e]	300	300	300	300	300
Croatia	99	96	95 [e]	95 [e]	95
Cuba	91	52	50 [e]	50 [e]	50
Czech Republic	980	985	950 [e]	900 [e]	900
Denmark, sales[e]	43	43	50	60	60
Ecuador	22	28	35 [r]	39 [r]	40
Egypt[e, 5]	600	600	600	600	600
Eritrea	6 [r]	--	-- [r]	(6) [r]	(6)
Estonia	16	34	25 [e]	24 [e]	24
Ethiopia	6	6	6 [e]	6 [e]	6
Finland[e]	73 [4]	73	148	150	155
France[e]	6,500	6,500	6,500	6,500	6,500
Gambia	173	170	170 [e]	170 [e]	170
Germany[e]	10,000	8,500	8,500	8,500	8,500
Greece[e]	90	90	90	90	100
Guatemala	116	173	170 [e]	170 [e]	165
Hungary	490	500	500 [e]	500 [e]	500
Iceland[e]	4	4	4	4	4
India[e]	1,300	1,350	1,400	1,400	1,500
Indonesia[e, 7]	120 [4]	124	124	124	124
Iran[e, 8]	1,000	1,000	1,700	1,700	1,700
Ireland[e]	5	5	5	5	5
Israel	320	300	306 [e]	330 [e]	320
Italy[e]	3,000	3,000	3,000	3,000	3,000
Jamaica	9	7	8	9 [r]	10
Japan	6,088 [r]	6,121 [r]	5,768 [r]	4,893 [r]	4,700
Jordan	131 [r]	118 [r]	122 [r, e]	132 [r, e]	129

See footnotes at end of table.

TABLE 12--Continued
INDUSTRIAL (SILICA) SAND AND GRAVEL: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Thousand metric tons)

Country[3]	1999	2000	2001	2002	2003[e]
Kenya[e]	12	9 [r]	7 [r]	7 [r]	7
Korea, Republic of	1,306	879	900	891 [r]	900
Latvia[e]	50	50	50	50	50
Lithuania[e]	30	30	30	30	30
Malaysia	509	447	575	447 [r]	450
Mexico	1,701	1,803	1,720	1,779 [r]	1,689 [p, 4]
Netherlands[e]	3	5	5	5	5
New Caledonia[e]	40	40	40	40	40
New Zealand	41	47	48 [e]	45 [e]	45
Norway[e]	1,314 [4]	1,300	1,500	1,400	1,500
Pakistan[e]	130	162 [4]	165	165	165
Paraguay[e]	10	25	28	25	26
Peru	90	74	120 [r]	300 [r]	300 [p]
Philippines	64	70	70 [e]	70 [e]	70
Poland	1,418	1,675	1,564	1,486 [r]	1,500 [4]
Portugal[e]	5	5	5	5	5
Serbia and Montenegro[e]	100	100	75	75	75
Slovenia	12,419 [r]	12,526 [r]	11,510 [r]	12,000 [r]	12,000
South Africa	2,170	2,138	2,132	2,262	2,457 [4]
Spain[e]	6,550	6,600	6,500	6,500	6,500
Sweden[e]	500	500	600	600	600
Thailand	532	472	514	781 [r]	750
Turkey	1,211	1,485	1,207 [r]	1,274 [r]	1,300
United Kingdom[e]	4,600	4,500	4,500	4,500	4,500
United States, sold or used by producers	28,900	28,400	27,900	27,300	27,500 [4]
Venezuela	295	422	627	690 [r]	700
Zimbabwe[e, 9]	40	121	28	7	6
Total	111,000 [r]	111,000 [r]	111,000 [r]	110,000 [r]	110,000

[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 25, 2004.

[3]In addition to the countries listed, Angola, Antigua and Barbuda, The Bahamas, China, countries of the Commonwealth of Independent States (CIS), 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 1/2 unit.

[7]The quantities for quartz sand and silica stone, in cubic meters, were as follows: 1999--140,428; 2000-02--145,000 (estimated); and 2003--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 2003, BY GEOGRAPHIC DIVISION