SILICA

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Four silica categories are covered in this report—industrial sand and gravel, quartz crystals, 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 pumice and diatomite, are covered in other chapters of the U.S. Geological Survey (USGS) Minerals Yearbook.

Industrial Sand and Gravel

Total industrial sand and gravel production decreased by 1.7% to 27.9 million metric tons (Mt) in 2001 compared with that of 2000 (table 1). Compared with those of 2000, industrial sand production increased by less than 1%, and gravel production decreased by about 35%. Exports decreased by about 7% compared with those of 2000, and imports decreased by 30% to 172,000 metric tons (t).

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 in glassmaking; for foundry, abrasive, and hydraulic fracturing (frac) applications; and for many other industrial uses. 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 mining methods with standard mining equipment. Except for temporarily disturbing the immediate area while mining operations are active, sand and gravel mining usually has limited environmental impact.

The production increase for silica sand was minimal after several years of increasing demand for sand for many uses, including 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. Decreases in the total production of silica can be attributed in part to overall flat demand and the decline of growth in the economy in 2001. However, overall value rose by about 3.5%.

***Legislation and Government Programs.*—**The regulation of respirable silica continued to concern miners and consumers of many minerals that contain crystalline silica, especially the industrial sand and gravel industry. One of the most important issues to have had an impact on the industrial minerals industry in recent times has been the question of crystalline silica and its effect on human health. Central to the ongoing and often heated debate has been the understanding and implementation of the measurements, regulations, 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).

***Production.*—**Domestic production data for industrial sand and gravel were derived by the USGS from a voluntary survey of U.S. producers. The USGS canvassed 70 producers with 160 operations known to produce industrial sand and gravel. Of the 160 surveyed operations, 132 (82%) were active and 28 were idle. The USGS received responses from 111 operations, and their combined production represented about 77% of the U.S. total. Production for the 41 nonrespondents was estimated, usually based on 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 region (east north-central and west north-central divisions) continued to lead the Nation with about 41% of the 27.9 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 13% (table 2, fig. 1).

The eight leading producing States, in descending order, were Illinois, Michigan, Texas, California, Wisconsin, New Jersey, Oklahoma, and North Carolina (table 3). Their combined production represented about 59% of the national total. Of the 36 States producing in 2001, 17 had increased production, 15 had decreased production, and 4 stayed about even compared with 2000. Texas, Florida, Idaho, and Minnesota reported the largest increases, and North Carolina, Oklahoma, New Jersey, and Ohio reported the largest decreases.

About 81% of the total industrial sand and gravel was produced by 50 operations, each with production of more than 200,000 tons per year (t/yr) (tables 4, 5). The 10 leading producers of industrial sand and gravel, in descending order, were 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., Construction Aggregates Corp., and Owens-Illinois, Inc. Their combined production from 72 operations represented 75% of the U.S. total.

***Consumption.*—**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 27.9 Mt of industrial sand and gravel sold or used, about 37% was consumed as glassmaking sand and 21% as foundry sand (table 6). Other important uses were frac sand (5.7%) and abrasive sand (5.2%). Building products, a broad category that includes nonskid flooring, paints, putty, and stucco, consumed about 9.3% of industrial sand and gravel production.

Exploitable resources of industrial sand and gravel occur throughout the United States, and successful mining companies are responding to market locations, which have traditionally been in the Eastern United States. Occasionally, 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 auto industry was originally located in the Midwest near clay, coal, iron, and silica resources. Therefore, foundry sands have been greatly exploited in Illinois, Indiana, Michigan, Ohio, and other Midwestern States. In 2001, more than 83% of foundry sand was produced in the Midwestern region.

Conversely, the glass industry had to locate plants where it could minimize the shipping distance of finished glass products (container, flat, etc.). Hence, glass plants were more evenly distributed. In 2001, 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.

Some improvements in data collection affected the distribution by market segment for glass sand. Some sand consumption formerly attributed to container and fiberglass production was placed in the flat and specialty segments. Therefore, 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 statistics portray.

The share of silica sold for all types of glassmaking as a percentage of all silica sold was about 37%. This percentage has remained stable compared with that of 2000. In 2001, sales to container glass manufacturers decreased by less than 1% compared with those of 2000. The amount of sand consumed for fiberglass production increased by 20% compared with 2000.

In 2001, sales of sand for flat glass production decreased by about 11% compared with those of 2000. In the South region, consumption for flat glass decreased by 22%, and in the Midwest region, there was a 4% increase.

Specialty glass consists of many segments, but the largest portion of it is laboratory and lighting glass (light bulbs, fluorescent, etc.). Specialty laboratory glass also makes up part of the apparatus 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 using basalt and diabase (rock wool), glass (glass wool), or blast furnace slag (slag wool) (Industrial Minerals, 1998c).

Silica is used in ceramics in whole-grain and ground forms. Generally, whole-grain silica is used about 22% to 32% in the ceramic body of sanitaryware (sinks, toilets, urinals, etc.). Ground silica is used to decrease viscosity and the expansion coefficient in ceramic glazes and other ceramic applications. A typical glaze composition consists of about 25% quartz or silica. In 2001, about 175,000 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. Silicon carbide's thermal conductivity and expansion coefficient make it especially useful in the refractory industry (Industrial Minerals, 1998c). Applications for silicon carbide include wear parts (such as seal rings, slide bearings, shafts, and dynamic pressure) or composite bearings used in a variety of pumps. The global market for silicon nitride, based on powder use, is estimated to be 300,000 t/yr. Primary markets for hybrid bearings, which are based on these materials, are machine tool spindles, aerospace components, and such instruments as dental drills, vacuum systems, and gyroscopes. Other markets for silicon nitride include engine components and cutting tools (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. Other silica (whole grain and ground) uses include nonskid flooring, paints, putty, stucco, and other building product applications. Silica also is used in paint because it offers acid, scrubbing, and wear resistance. As segregated for this survey, consumption in 2001 of whole-grain filler was about 2.3 Mt and of ground silica for filler was 258,000 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 driving the increased demand for sodium silicate is the zeolite industry, which uses sodium silicate in synthetic zeolite production.

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

Specialty silicas are usually produced by means of chemical and thermal processing of natural silica, 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, fumed silica, fused silica and quartz, organofunctional silanes, precipitated silica, silica gels, silicones, and ultra-high-purity silica. These silicas are used in a variety of industries and products, including 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.

Pyrogenic, or fumed, silica forms tridimensional polymers used as thixotropic agents and in silicons and silanes and is widely used as a coating agent for filler-grade calcium carbonate (Industrial Minerals, 1998d). 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 "Chemicals," "Silicon metal," and possibly "Glassmaking, specialty." In 2001, silica sales for chemical production were

739,000 t, increasing by 2.2% compared with those of 2000. Reported sales of silica gravel for silicon and ferrosilicon production decreased by about 8% in 2001 compared with those of 2000. The main uses for silicon metal are in the manufacture of silanes and semiconductor-grade silicon and in the production of aluminum alloys.

Optical fiber production involves a series of highly sophisticated manufacturing methods. For the optical fiber, a glass core is required with a high refractive index, surrounded by glass with a lower refractive index. 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, 1998c).

High-purity fused silica used by the electronics industry is typically at least 99.95% SiO_2 and has a very low expansion coefficient, high electromagnetic radiation transparency, and good insulation properties.

By reacting sodium silicate with hydrochloric acid, synthetic precipitated silica and silica gel are produced. Precipitated silica has been used increasingly in tires but 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 seem to prefer the “green” tires made with precipitated silica and it is used in 70% to 80% of tires for passenger cars (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. Additionally, Nippon Silica Industrial Co., Ltd., (a subsidiary of Tosoh Corp. of Japan) expects to double its capacity to produce precipitated silica for energy-saving tires to 40,000 t/yr by 2003 (Tosoh Corp., 2000§[1]). 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, 62% was transported by truck from the plant to the site of first sale or use, up from 61% in 2000; 35% was transported by rail, down from 36% in 2000; 3%, by waterway; and 1% was not transported. Because most of the producers did not report shipping distances or cost per metric ton per mile, transportation cost data are not available.

Prices.—Compared with the average value of 2000, the average value, free on board (f.o.b.) plant, of U.S. industrial sand and gravel increased by 5.5% to $20.64 per metric ton in 2001 (table 6). The average unit values for industrial sand and industrial gravel were $20.80 per ton and $16.57 per ton, respectively. The average price for sand ranged from $10.83 per ton for metallurgical flux to $84.72 per ton for ground fillers. For gravel, prices ranged from $11.50 per ton for nonmetallurgical flux to $22.03 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 used as fillers for rubber, paint, and putty had the highest value ($84.72 per ton), followed by ground sand for foundry molding and core ($84.20 per ton), silica for swimming pool filters ($68.06 per ton), sand for well packing and cementing ($65.81 per ton), ground sand for ceramics ($57.12 per ton), ground sand for fiberglass ($46.01 per ton), abrasives for sawing and sanding ($36.01 per ton), and ground sand for scouring cleansers ($35.62 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, regulations, health concerns, and competition from other materials.

By geographic region, the average value of industrial sand and gravel was highest in the South ($23.18 per ton), followed by the West ($22.33 per ton), the Northeast ($21.61 per ton), and the Midwest ($17.56 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 $28.46 per ton in the Northeast to $20.72 per ton in the South. Tighter supplies and higher production costs in the Northeast and much greater competition in the South 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) and to which State or other location the material was shipped for consumption. Because some producers did not provide this information, their data were estimated or assigned to the “Destination unknown” category. In 2001, 8.6% of industrial sand and gravel shipped by producers was assigned to the “Destination unknown” category.

The States that received the most industrial sand and gravel, in descending order, were California (9.1%), Texas (7.1%), Illinois (6.9%), Ohio (5.1%), Pennsylvania (4.5%), and Michigan (4.3%). With the exception of Alaska, all States received industrial sand and gravel. Producers reported sending at least 874,000 t of silica to Canada and 286,000 t to Mexico (table 7).

Foreign Trade.—Based on U.S. Census Bureau data, exports of industrial sand and gravel in 2001 decreased by 7.2% compared with the amount exported in 2000, and the associated value decreased by about 9.1% (table 8). Most of the decrease in exports was attributable to decreased shipments to Europe and Asia. For the fifth consecutive year, Mexico was the largest recipient of U.S. exports. Export distribution was as follows: 42% to Mexico, 21% to Japan, 20% to Canada, 9% to Europe, and the remainder to Africa, the Middle East, Oceania, and South America. The average price of exports dropped to $106 per ton in 2001 from $108 per ton in 2000. The decrease in price reflected increased exports of higher grade silica to Europe, which averaged about $339 per ton. Excluding Europe, other exports averaged $81 per ton in 2001.

The U.S. Census Bureau also reported that imports for consumption of industrial sand and gravel dropped to 172,000 t, a decrease of 30% from imports in 2000 (table 9). Silica imports vary greatly from year to year but are always rather insignificant in relation to total consumption. Canada supplied 87% of the silica imports for 2001, averaging about $17 per ton (including insurance and freight cost to the U.S. port). The total

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

value of imports was $11 million, with an average of $64 per ton. Higher priced imports came from Australia, China, Germany, and Japan.

World Review.—Based on information provided mainly by foreign governments, world production of industrial sand and gravel was estimated to be 95 Mt. The United States was the leading producer, followed by Germany, Austria, France, Spain, Australia and the United Kingdom in descending order. 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 (table 12).

Outlook.—The forecast range of total U.S. demand for industrial sand and gravel in 2002 is 26 to 28 Mt. Demand 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 are expected to vary from market to market. Growth that might come in some segments, such as flat and specialty glass, will be offset by reductions in sales for container glass and possibly fiberglass. The trend towards decreasing market share for container glass in the United States is expected to continue.

Total demand for glass sand is expected to grow slowly through 2002, probably to the range of 10 to 12 Mt.

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, though not clear, is thought to be increasing. Other materials or minerals compete with silica as foundry sand, but these other “sands” usually suffer a severe price disadvantage. On the basis of these factors, consumption of silica foundry sand in 2002 is expected to be 6.3 Mt, and the demand range is expected to be 6 to 7 Mt.

Frac sand sales increased by about 17% in 2001, compared with those of 2000. Domestic crude oil production was up slightly in 2001; however, the number of active drilling rigs was down from 2000 levels. On the basis of these factors, demand for frac sand is expected to remain about level during 2002. Demand for frac sand in 2002 is expected to be 1.5 Mt, with a range of 1.3 to 1.6 Mt.

For specialty silicas, the source of the silica is usually through the chemical and silicon- metal categories, which will probably see better-than-average growth, in the 2%-to-4%-per-year range. This positive forecast would be tempered if the specialty silicas producers use a silica source other than industrial sand and gravel. Because the process for each type of silica is highly variable and certainly not well advertised, determining the natural source and the processing method for each of the silicas or silicates is difficult.

Specialty silicas are increasingly recognized as having reinforcing properties as fillers in various manufactured products. The average growth of specialty silicas in the United States is about 4% per year. Consumption in 2003 is expected to be 35,000 t of fumed and precipitated silica fillers (Industrial Minerals, 1998b). Another forecaster also projects 4% per year growth for specialty silicas, with fastest growth for fumed silica at 5%, precipitated and colloidal silica at 4%, and silica gel at 3.5% (Chemical Market Report, 1998).

The United States is the largest producer and consumer of silica sand and is self-sufficient in this commodity. Most of it is produced at premier deposits and near major markets in the Eastern United States. A significant amount of silica sand is also produced in the West and Southwest, mostly in California and Texas. Domestic production is expected to continue to meet more than 99% of demand well beyond 2001. Imports, mostly from Canada, 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, mainly polymers and ceramics, would likely increase the demand for ground silica, which is used as a filler in plastics; for glass fibers, which are used in reinforced plastics; and for silica (chemical, whole grain, or ground), which is used to manufacture ceramics. Also, increased efforts to reduce waste and to increase recycling could hinder demand for glass sand. With advances in high-tech materials and specialty silicas, however, consumption of silica sand may increase for fiberoptics and other silicon and glass compounds. Although developments could cause 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 demand in many silica markets. The use of silica sand in the abrasive blast industry was being questioned as a health hazard as marketers of competing materials, including garnet, olivine, and slags, encouraged the use of their “safer” abrasive media.

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 frequency controls, timers, and filters in electronic circuits. These devices are used for a variety of electronic applications in aerospace hardware, communications equipment, computers, consumer goods (e.g., clocks, games, television receivers, and toys), and military and commercial navigational instruments. Such uses generate practically all demand for electronic-grade quartz crystal. A lesser amount of optical-grade quartz crystal is used for lenses and windows in specialized devices, including some lasers.

Natural quartz crystal primarily was used in 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. The use of quartz crystal for such applications is covered in the gemstones chapter of the USGS Minerals Yearbook.

Legislation and Government Programs.—The strategic value of quartz crystal was demonstrated during World War II when it gained wide 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, 2001, the National Defense Stockpile (NDS) contained about 105,557 kilograms (kg) of natural quartz crystal. The stockpile has 11 weight classes for natural quartz crystal ranging from 200 grams (g) to more than 10,000 g. The stockpiled crystals, however, are primarily in the larger weight classes. The larger pieces are suitable as seed crystals 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.

With cultured quartz crystal displacing natural quartz crystal in most applications, the Federal Government continued to assess its stockpile goals for the latter material. In the latest reports on the inventory of stockpile material, no quartz crystals were designated for disposal in 2001. No natural quartz crystal was sold in 2001. 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 its output.

Quartz crystal, a form of crystalline silica, 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 review.

Production.—The USGS collects production data for quartz crystal through a survey of the domestic industry. In 2001, the industry consisted of three cultured quartz crystal producers. One of the growers responded to the annual survey, and the other two were estimated based on previously reported figures. Commencing in the last quarter of 2001 and the first quarter of 2002, Crystal Quartz Canada Inc. of Vancouver, British Columbia, Canada, entered into a long-term supply contract for lascas with North American cultured quartz crystal producers. Crystal Quartz Canada Inc. has a large reserve of high-purity lascas and currently [2001] is the only lascas producer in North America known to supply the North American cultured quartz crystal industy (Bruce M. Rykiss, chief executive officer, Crystal Quartz Canada Inc., written commun., 2002).

The following U.S. companies produced cultured quartz crystal during 2001: CTS Corp. of Carlisle, PA; Sawyer Research Products Inc. of Eastlake, OH; and Thermo Dynamics Corp. of Merriam, KS. P.R. Hoffman Material Processing Co. of Carlisle, PA, has the capacity to produce cultured quartz crystal but had no production in 2001. Sawyer Research Products Inc. and Thermo Dynamics Corp. produced crystal bars for domestic and foreign firms in the crystal- device-fabrication industry. CTS Corp. produced quartz crystal for internal consumption and domestic device fabricators.

The above-mentioned companies produced cultured quartz crystal by using a hydrothermal process in large pressure vessels known as autoclaves. Seed crystals (very thin crystals cut to exact dimensions) are mounted on racks and suspended in the upper growth region of the vessel. Lascas, 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 from 75% to 85% of its volume. The bottom 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 less, 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 other types of crystal; 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 then attached, and the crystals are mounted in suitable holders. The final assembly, called a quartz crystal unit, is ready for insertion into an electronic circuit.

Consumption.—In 2001, the USGS collected domestic consumption data for quartz crystal through a survey of 27 U.S. operations that fabricate quartz crystal devices in 10 States. These operations represented virtually all domestic consumption. Of the 27 operations, 14 responded to the survey. Of the 14 companies that responded to the survey, 1 company reported going out of business. Consumption for nonrespondents was estimated based on reports from previous years.

Quartz crystal is used in piezoelectric and optical applications. The piezoelectric effect is achieved when a suitable electrical signal applied to a quartz wafer makes the wafer vibrate mechanically throughout the bulk of the material at a characteristic natural resonance frequency.

Quartz resonators are uniquely suitable for aerospace, commercial, and military bandpass filter applications that require very high selectivity or for oscillator applications that require very high stability. In addition, for many applications requiring 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 too thinly 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. Relatively small quantities of cultured quartz crystal are used directly in optical applications. Quartz crystal also has uses involving 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 $51 per kilogram in 2001. The average value of lumbered quartz, which is as-grown quartz that has been processed by sawing and grinding, was estimated to be about $187 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 and Germany in 2001, according to some consumers. Imports and exports of all electronic-grade quartz crystal are listed in table 11.

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

Outlook.—Because the demand for quartz crystal devices will probably continue to grow, quartz crystal production will probably remain strong well into the future. The trend towards importing quartz could have a negative affect on domestic quartz growers. Growth of the consumer electronics market (e.g., 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 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 artificially bonding of the abrasive grains. Information on other manufactured and natural abrasives may be found in other USGS Minerals Yearbook chapters.

Special silica stone, a crystalline silica, 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 review.

Production.—In response to a USGS production survey, eight of nine domestic firms reported that they quarried certain silica materials and manufactured silica stone products during 2001. Data for the remaining producer 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. Tumbling-grinding media were produced in Wisconsin (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 the sharpening of knives and other cutlery, such as lawn and garden tools, scissors, and shears. Leading industrial uses include the deburring of metal and plastic castings, the polishing of metal surfaces, and the sharpening and honing of cutting surfaces. Recreational uses include the sharpening of arrowheads, fish hooks, spear points, and sports knives. Craft applications include sharpening tools for engraving work, jewelry making, and wood carving. Also, silica stone files are used in the manufacture, modification, and repair of firearms.

Price.—The average value of crude material suitable for cutting into finished products was $332 per ton. The average value of stone products made from crude material was $10.29 per kilogram (table 1).

Foreign Trade.—In 2001, silica stone product exports had a value of about $5.8 million, down slightly from that of 2000. These exports were categorized as "hand sharpening or polishing stones" by the DOC. This category accounted for most, if not all, the silica stone products exported in 2001.

In 2001, the value of imported silica stone products was at least $3.9 million, up by 2.6% compared with that of 2000. These imports were hand-sharpening or polishing stones, which accounted for most of or all the imported silica stone products in 2001. A portion of the finished products that were imported may have been made from crude novaculite produced within 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, comprises 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 review.

Production.—In 2001, 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, 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 2001 USGS annual survey of producers indicates that sales of processed tripoli decreased by 16% in quantity to about 60,000 t with a value of $15 million (table 1).

Tripoli has unique applications as an abrasive owing to its hardness and because its grain structure lacks distinct edges and corners. It is a mild abrasive, making 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 2001, about 20% of tripoli output was used as an abrasive. The remainder was used as filler and extender in enamel, caulking compounds, paint, plastic, rubber, and in brake friction products, linings, refractories, and other products.

The primary use of tripoli today is as a filler and extender in paints. These applications may account for as much as 85% of the tripoli used as a filler and extender. 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.

Price.—The average reported value of all tripoli sold or used in the United States was $249 per ton in 2001. The average reported value of abrasive tripoli sold or used in the United States during 2001 was $188 per ton; the average reported value of filler tripoli sold or used domestically was $279 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/

		1997	1998	1999	2000	2001
Industrial sand and gravel: 2/						
Sold or used:						
Sand:						
Quantity	thousand metric tons	26,300	26,400	26,900	26,800	26,900
Value	thousands	$485,000	$491,000	$510,000	$532,000	$559,000
Gravel:						
Quantity	thousand metric tons	2,170	1,790	1,940	1,660	1,060
Value	thousands	$26,300	$22,200	$28,400	$24,400	$17,600
Total:						
Quantity	thousand metric tons	28,500	28,200	28,900	28,400	27,900
Value	thousands	$511,000	$513,000	$538,000	$556,000	$576,000
Exports:						
Quantity	thousand metric tons	980	2,400	1,670	1,660	1,540
Value	thousands	$134,000	$148,000	$133,000	$179,000	$163,000
Imports for consumption:						
Quantity	thousand metric tons	39	44	211	247	172
Value	thousands	$3,200	$2,750	$5,590	$11,800	$11,000
Processed tripoli: 3/						
Quantity	metric tons	81,300	79,600	84,900	72,000	60,500
Value	thousands	$16,400	$16,900	$20,200	$15,900 e/	$15,000
Special silica stone:						
Crude production:						
Quantity	metric tons	843	649	697	553	705
Value	thousands	$224	$184	$183	$158	$234
Sold or used:						
Quantity	metric tons	445	438	475	312	393
Value	thousands	$2,560	$3,440	$3,060	$4,610	$4,040
Electronic and optical-grade quartz crystals, production:						
Mine	thousand kilograms	450	--	--	--	--
Cultured	do.	355	185	192	189	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 amorphous silica and Pennsylvania rottenstone.

TABLE 2
INDUSTRIAL SAND AND GRAVEL SOLD OR USED IN THE UNITED STATES, BY GEOGRAPHIC REGION 1/

	2000				2001			
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	104	(2/)	W	W	138	(2/)	W	W
Middle Atlantic	2,400	8	$51,500	9	2,160	8	$49,600	9
Midwest:								
East north-central	10,100	35	170,000	31	9,960	36	170,000	29
West north-central	1,420	5	28,700	5	1,480	5	31,200	5
South:								
South Atlantic	4,270	15	92,400	17	4,090	15	86,300	15
East south-central	2,260	8	43,100	8	2,240	8	43,200	8
West south-central	4,440	16	96,400	17	4,330	16	118,000	20
West:								
Mountain	1,360	5	22,600	4	1,380	5	24,100	4
Pacific	2,090	7	51,300	9	2,140	8	54,600	9
Total	28,400	100	556,000	100	27,900	100	576,000	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)

State	2000 Quantity	2000 Value	2001 Quantity	2001 Value
Alabama	731	10,100	743	9,420
Arizona	W	W	W	W
Arkansas	W	W	W	W
California	1,810	45,200	1,840	47,700
Colorado	65	W	W	W
Florida	510	6,320	598	7,520
Georgia	651	12,500	W	W
Idaho	W	W	W	W
Illinois	4,430	71,600	4,460	72,100
Indiana	W	W	W	W
Iowa	29	W	35	1,590
Kansas	W	W	W	W
Louisiana	648	12,300	637	11,900
Maryland	W	W	W	W
Michigan	2,520	27,800	2,530	30,000
Minnesota	W	W	W	W
Mississippi	W	W	W	W
Missouri	W	W	W	W
Nebraska	W	W	W	W
Nevada	609	W	609	W
New Jersey	1,690	35,700	1,580	34,800
New Mexico	W	W	W	W
New York	W	W	W	W
North Carolina	1,480	28,300	1,300	26,000
North Dakota	1	W	W	W
Ohio	1,210	32,800	1,120	30,700
Oklahoma	1,480	30,700	1,360	28,200
Pennsylvania	W	W	W	W
Rhode Island	104	W	138	W
South Carolina	755	18,600	694	15,900
Tennessee	W	W	W	22,900
Texas	1,750	45,200	1,850	70,000
Virginia	W	W	W	W
Washington	W	W	W	W
West Virginia	W	W	W	W
Wisconsin	1,790	36,200	1,710	W
Other	6,150	143,000	6,720	167,000
Total	28,400	556,000	27,900	576,000

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 2001, 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	173	1
25,000 to 49,999	17	13	587	2
50,000 to 99,999	29	22	1,890	7
100,000 to 199,999	19	14	2,670	10
200,000 to 299,999	13	10	2,800	10
300,000 to 399,999	4	3	1,370	5
400,000 to 499,999	15	11	6,050	22
500,000 to 599,999	6	5	2,990	11
600,000 to 699,999	4	3	2,350	8
700,000 and more	8	6	7,030	25
Total	132	100	27,900	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 2001, BY GEOGRAPHIC REGION

Geographic region	Mining operations on land: Stationary	Portable	Stationary and portable	No plants or unspecified	Dredging operations	Total active operations
Northeast:						
New England	1	--	--	--	--	1
Middle Atlantic	8	1	--	--	5	14
Midwest:						
East north-central	25	--	--	--	6	31
West north-central	4	--	--	--	6	10
South:						
South Atlantic	18	--	--	2	7	27
East south-central	8	--	--	--	3	11
West south-central	12	--	--	--	9	21
West:						
Mountain	7	--	--	--	--	7
Pacific	9	--	--	--	1	10
Total	92	1	--	2	37	132

-- Zero.

TABLE 6
INDUSTRIAL SAND AND GRAVEL SOLD OR USED BY U.S. PRODUCERS IN 2001, BY MAJOR END USE 1/

Major use	Northeast: Quantity (thousand metric tons)	Northeast: Value (thousand dollars)	Northeast: Value 3/ (dollars per metric ton)	Midwest: Quantity (thousand metric tons)	Midwest: Value (thousand dollars)	Midwest: Value 3/ (dollars per metric ton)	South: Quantity (thousand metric tons)	South: Value (thousand dollars)	South: Value 3/ (dollars per metric ton)
Sand:									
Glassmaking:									
Containers	W	W	18.70	1,200	13,800	11.47	1,570	25,100	15.99
Flat (plate and window)	W	W	17.14	1,290	14,000	10.92	1,730	28,100	16.21
Specialty	W	W	26.23	W	W	16.60	311	7,080	22.77
Fiberglass (unground)	--	--	--	397	5,520	13.88	W	W	16.18
Fiberglass (ground)	--	--	--	W	W	46.55	W	W	45.96
Foundry:									
Molding and core	W	W	18.75	4,850	65,900	13.58	627	10,600	16.93
Molding and core (ground)	--	--	--	W	W	80.66	W	W	97.78
Refractory	W	W	27.86	W	W	23.74	W	W	34.36
Metallurgical:									
Silicon carbide	--	--	--	W	W	18.91	--	--	--
Flux for metal smelting	--	--	--	--	--	--	W	W	5.38
Abrasives:									
Blasting	36	2,800	78.51	205	6,080	29.61	1,070	30,300	28.26
Scouring cleansers (ground)	W	W	63.80	W	W	10.92	W	W	116.59
Sawing and sanding	W	W	22.33	--	--	--	--	--	--
Chemicals (ground and unground)	W	W	20.60	W	W	13.46	315	8,920	28.31
Fillers (ground), rubber, paints, putty, etc.	W	W	13.43	146	10,200	69.47	W	W	108.77
Whole grain fillers/building products	221	6,710	30.29	515	12,700	24.56	1,120	21,100	18.95
Ceramic (ground), pottery, brick, tile, etc.	W	W	56.86	W	W	74.05	116	5,680	48.90
Filtration:									
Water (municipal, county, local, etc.)	34	1,430	41.77	73	3,180	43.71	186	5,410	29.06
Swimming pool, other	31	1,330	43.13	W	W	79.48	47	686	14.66
Petroleum industry:									
Hydraulic fracturing	--	--	--	1,030	33,900	32.98	W	W	54.97
Well packing and cementing	--	--	--	W	W	730.40	W	W	65.77
Recreational:									
Golf course (greens and traps)	W	W	16.35	254	3,620	14.24	415	4,430	10.65
Baseball, volleyball, play sand, beaches	72	1,260	17.64	W	W	34.98	W	W	10.29
Traction (engine)	33	603	18.10	79	921	11.64	47	686	14.66
Roofing granules and fillers	W	W	24.12	W	W	16.22	129	2,520	19.58
Other (ground silica)	W	W	49.10	130	7,510	57.71	442	27,000	61.15
Other (whole grain)	1,870	35,400	19.05	1,160	22,100	19.04	1,840	57,200	29.15
Total or average	2,290	49,600	21.61	11,300	199,000	17.60	9,970	235,000	23.57

See footnotes at end of table.

TABLE 6--Continued

INDUSTRIAL SAND AND GRAVEL SOLD OR USED BY U.S. PRODUCERS IN 2001, BY MAJOR END USE 1/

Major use	Northeast Quantity (thousand metric tons)	Northeast Value (thousand dollars)	Northeast Value 3/ (dollars per metric ton)	Midwest Quantity (thousand metric tons)	Midwest Value (thousand dollars)	Midwest Value 3/ (dollars per metric ton)	South Quantity (thousand metric tons)	South Value (thousand dollars)	South Value 3/ (dollars per metric ton)
Gravel:									
Silicon, ferrosilicon	--	--	--	W	W	25.29	629	10,800	14.49
Filtration	(5/)	(5/)	71.33	W	W	14.37	45	1,170	26.20
Nonmetallurgical flux	--	--	--	W	W	9.51	--	--	--
Other uses, specified	(5/)	(5/)	10.87	104	1,410	13.49	19	213	11.01
Total or average	(5/)	(5/)	16.69	104	1,410	13.49	693	12,200	17.61
Grand total or average	2,290	49,600	21.61	11,400	201,000	17.56	10,700	247,000	23.18

Major use	West Quantity (thousand metric tons)	West Value (thousand dollars)	West Value 3/ (dollars per metric ton)	U.S. total 2/ Quantity (thousand metric tons)	U.S. total 2/ Value (thousand dollars)	U.S. total 2/ Value 3/ (dollars per metric ton)
Sand:						
Glassmaking:						
Containers	W	W	20.23	4,540	73,700	16.22
Flat (plate and window)	W	W	16.79	3,730	54,200	14.51
Specialty	W	W	29.71	810	17,700	21.88
Fiberglass (unground)	W	W	24.65	779	11,800	15.11
Fiberglass (ground)	--	--	--	369	17,000	46.01
Foundry:						
Molding and core	W	W	20.70	5,820	83,100	14.27
Molding and core (ground)	--	--	--	(4/)	(4/)	84.20
Refractory	W	W	23.47	31	883	28.20
Metallurgical:						
Silicon carbide	--	--	--	(4/)	(4/)	18.91
Flux for metal smelting	W	W	10.88	400	4,330	10.83
Abrasives:						
Blasting	142	5,910	41.65	1,460	45,100	30.99
Scouring cleansers (ground)	--	--	--	(4/)	(4/)	35.62
Sawing and sanding	W	W	38.53	(4/)	(4/)	36.01
Chemicals (ground and unground)	W	W	21.34	739	15,500	20.93
Fillers (ground), rubber, paints, putty, etc.	W	W	29.99	258	21,800	84.72
Whole grain fillers/building products	485	15,900	32.82	2,340	56,400	24.14
Ceramic (ground), pottery, brick, tile, etc.	--	--	--	175	9,990	57.12
Filtration:						
Water (municipal, county, local, etc.)	110	5,320	48.27	403	15,300	38.03
Swimming pool, other	W	W	16.81	102	6,970	68.06
Petroleum industry:						
Hydraulic fracturing	W	W	37.99	1,600	64,800	40.50
Well packing and cementing	--	--	--	93	6,100	65.81
Recreational:						
Golf course (greens and traps)	W	W	24.57	1,090	16,600	15.32
Baseball, volleyball, play sand, beaches	W	W	19.30	314	7,210	22.96
Traction (engine)	8	199	25.83	170	2,410	14.43
Roofing granules and fillers	W	W	15.69	206	4,060	19.74
Other (ground silica)	W	W	33.42	XX	XX	XX
Other (whole grain)	2,780	51,300	15.81	XX	XX	XX
Total or average	3,520	78,700	22.33	26,900	559,000	20.80
Gravel:						
Silicon, ferrosilicon	(5/)	(5/)	30.80	631	10,900	17.23
Filtration	(5/)	(5/)	14.33	137	3,010	22.03
Nonmetallurgical flux	(5/)	(5/)	11.02	79	913	11.50
Other uses, specified	(5/)	(5/)	14.33	214	2,790	12.99
Total or average	(5/)	(5/)	14.86	1,060	17,600	16.57
Grand total or average	3,520	78,700	22.33	27,900	576,000	20.64

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/ Total U.S. sand quantity and value do not include gravel data withheld by footnote 5.

3/ Calculated using unrounded data.

4/ Included in "Total or average."

5/ Withheld to avoid disclosing company proprietary data; included with "Other (whole grain)."

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

(Thousand metric tons)

Destination	2000	2001	Destination	2000	2001
States:			States--Continued:		
Alabama	899	784	New Jersey	870	899
Alaska	--	--	New Mexico	67	128
Arizona	328	307	New York	451	372
Arkansas	127	57	North Carolina	789	1,040
California	1,780	2,550	North Dakota	47	20
Colorado	613	170	Ohio	1,600	1,420
Connecticut	92	52	Oklahoma	623	649
Delaware	11	18	Oregon	63	62
District of Columbia	(2/)	2	Pennsylvania	1,390	1,260
Florida	450	677	Rhode Island	7	66
Georgia	915	851	South Carolina	618	208
Hawaii	(2/)	--	South Dakota	92	5
Idaho	395	432	Tennessee	891	978
Illinois	1,900	1,930	Texas	2,020	1,980
Indiana	1,030	1,070	Utah	29	38
Iowa	258	199	Vermont	2	3
Kansas	446	435	Virginia	504	305
Kentucky	377	318	Washington	171	202
Louisiana	814	833	West Virginia	294	283
Maine	1	(2/)	Wisconsin	1,020	1,040
Maryland	96	122	Wyoming	66	142
Massachusetts	16	64	Countries:		
Michigan	1,340	1,200	Canada	934	874
Minnesota	380	319	Mexico	195	286
Mississippi	183	268	Other foreign countries	66	40
Missouri	305	466	Other:		
Montana	34	11	Puerto Rico	--	(2/)
Nebraska	14	29	U.S. possessions and territories	(2/)	3
Nevada	51	47	Destination unknown	2,750	2,400
New Hampshire	1	6	Total	28,400	27,900

-- 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)

	2000		2001	
Country	Quantity	Value 2/	Quantity	Value 2/
North America:				
Bahamas, The	14	330	1	134
Canada	319	30,400	305	32,000
Mexico	609	20,900	650	22,100
Panama	15	501	18	427
Other	7	1,340	3	611
Total	964	53,400	977	55,300
South America:				
Argentina	8	1,500	18	2,740
Brazil	3	1,750	2	1,190
Colombia	2	470	(3/)	82
Peru	8	388	3	128
Venezuela	11	1,270	3	1,190
Other	(3/)	325	1	327
Total	32	5,700	27	5,660
Europe:				
Belgium	26	2,800	3	1,870
France	54	4,830	64	11,700
Germany	27	14,500	20	17,800
Italy	1	2,420	4	2,420

See footnotes at end of table.

TABLE 8--Continued
U.S. EXPORTS OF INDUSTRIAL SAND AND GRAVEL, BY COUNTRY 1/

(Thousand metric tons and thousand dollars)

Country	2000 Quantity	2000 Value 2/	2001 Quantity	2001 Value 2/
Europe--Continued:				
Netherlands	33	8,720	31	9,420
Switzerland	25	1,160	1	708
United Kingdom	4	4,350	23	4,660
Other	12	5,300 r/	3	1,980
Total	182	44,100	149	50,600
Asia:				
China	16	5,920	6	3,760
Indonesia	18	1,200	2	836
Japan	313	34,700	325	19,200
Korea, Republic of	12	4,230	13	5,110
Malaysia	31	1,290	2	1,900
Singapore	40	10,900	17	6,060
Taiwan	14	7,550	11	6,870
Thailand	4	915	3	693
Other	16 r/	2,090 r/	1	655
Total	464	68,800	380	45,000
Middle East and Africa:				
Algeria	(3/)	65	1	563
Saudi Arabia	(3/)	46	1	610
Other	14 r/	2,560 r/	(3/)	482
Total	14	2,670	2	1,660
Oceania:				
Australia	7	4,550	9	4,750
Other	1	215	(3/)	125
Total	8	4,770	9	4,870
Grand total	1,660	179,000	1,540	163,000

r/ Revised.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Free alongside ship value of material at U.S. port of export; based on price of transaction, 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	2000 Quantity	2000 Value 2/	2001 Quantity	2001 Value 2/
Australia	50	3,620	3	1,300
Canada	181	2,120	149	2,510
Chile	2	255	4	744
China	4	4,830	5	5,450
Germany	(3/)	209	(3/)	192
Japan	(3/)	159	(3/)	100
Mexico	9	117	(3/)	4
Trinidad and Tobago	--	--	9	207
Other	1	493	2	508
Total	247	11,800	172	11,000

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Cost, insurance, and freight value of material at U.S. port of entry; based on purchase price and includes all charges (except U.S. import duties) in bringin materials 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 2001

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.
Buffalo Stone Corp., Hot Springs, AR	Tumbling and sizing novaculite	Metal finishing media deburring media.
Dan's Whetstone Co., Inc., Hot Springs, AR	Stone cutting and finishing	Whetstones and oilstones.
Do.	Quarry	Crude novaculite.
Hall's Arkansas Oilstones, Inc., Pearcy, AR	Stone cutting and finishing	Whetstones and oilstones.
The Kraemer Co., 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/

(Thousand kilograms and thousand dollars)

	1997	1998	1999	2000	2001
Production:					
Mine	450	--	--	--	--
Cultured e/	355	185	192	189	W
Exports (cultured): 2/					
Quantity	74	63	90	74	38
Value	31,100	24,300	25,400	22,800	10,600
Imports (cultured): 2/					
Quantity	63	47	26	31	14
Value	11,700	12,200	11,000	14,300	8,390
Consumption, apparent e/	343	169	128	146	W

e/ Estimated. W Withheld to avoid disclosing company proprietary data. -- Zero.
1/ Data are rounded to no more than three significant digits.
2/ Excludes mounted piezoelectric crystals.

TABLE 12
INDUSTRIAL (SILICA) SAND AND GRAVEL: WORLD PRODUCTION BY COUNTRY 1/ 2/

(Thousand metric tons)

Country 3/	1997	1998	1999	2000	2001 e/
Argentina	145 r/	462 r/	263 r/	280 r/ e/	280
Australia e/	2,500	2,500	2,500	4,266 r/ 4/ 5/	4,500 4/
Austria	6,000 e/	6,329	6,857	6,800 e/	6,800
Belgium e/	1,900 r/	1,800 r/	1,800 r/	1,800 r/	1,800
Bosnia and Herzegovina e/	50	50	50	50	50
Brazil (silex) e/	1,600 r/	1,600 r/	1,600 r/	1,600 r/	1,600
Bulgaria	557	893	900 e/	900 e/	900
Cameroon e/	12	13	12	12	12
Canada (quartz)	1,896	1,905	1,702	1,946	1,950
Chile e/	300	300	300	300	300
Croatia	98	112 r/	99 r/	96 r/	95
Cuba	93 r/	95 r/	91 r/	100 r/ e/	100
Czech Republic	994 r/	827 r/	980 r/	985 r/	950
Denmark (sales) e/	43 r/	43 r/	43 r/	43 r/	50
Ecuador	43	40	22 r/	28 r/	28
Egypt 4/	505	574	600 e/	600 e/	600
Eritrea	(6/) r/	-- r/	10 r/	-- r/	10
Estonia	19 r/	20 r/	16 r/	34 r/	35
Ethiopia	7 e/	7 e/	6 r/	6 r/	6
Finland e/	30	30	73 5/	70	75

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/	1997	1998	1999	2000	2001 e/
France e/	6,560 5/	6,500	6,500	6,500	6,500
Gambia, The	303 r/	270 r/	173 r/	170 r/	170
Germany e/	9,800 r/	10,000 r/ 5/	10,000 r/	8,500 r/	8,500
Greece	96	90	90 e/	90 e/	90
Guatemala	50 r/ e/	50 e/	46 r/	69 r/	69
Hungary	328 7/	241 7/	490 r/	500 r/	500
Iceland e/	4	4	4	4	4
India	1,400	1,265	1,300 e/	1,350 e/	1,400
Indonesia	636	145 r/	120 r/ 8/	124 r/ e/ 8/	124 8/
Iran e/ 9/	1,000	1,000	1,000	1,000	1,000
Ireland e/	5	5	5	5	5
Israel	275 r/	257 r/	320 r/	300 r/	306
Italy e/	3,000	3,000	3,000	3,000	3,000
Jamaica	12	6	9 r/	7 r/	7
Japan	3,306	3,049	2,764	2,746 r/	2,538 5/
Jordan	NA	NA	52	47	49
Kenya e/	13	12 r/	12	12 r/	12
Korea, Republic of	1,222	1,257	1,306 r/	879 r/	900
Latvia e/	50	50	50	50	50
Lithuania e/	30	30	30	30	30
Malaysia	950	473	509	500 e/	500
Mexico	1,564	1,733	1,701 r/	1,803 r/	1,720 5/
Netherlands e/	24	5	3	5	5
New Caledonia e/	40	40	40	40	40
New Zealand e/	26 5/	25	25	25	25
Norway	1,000 r/ e/	1,000	1,314 r/	1,300 r/ e/	1,500
Pakistan e/	165	122	130	162 5/	160
Paraguay e/	10	10	10	10	10
Peru	83 r/	96 r/	90 r/	74 r/	74
Philippines	21	16	64 r/	70 r/	70
Poland	1,124 r/	1,375 r/	1,418 r/	1,400 r/ e/	1,400
Portugal e/	5	5	5	5	5
Serbia and Montenegro	200	200	100 e/	100 e/	75
Slovenia	200 r/	200	200	200	200
South Africa	2,463 r/	2,223 r/	2,170 r/	2,138 r/	2,132 5/
Spain e/	5,800	6,200	6,550	6,600	6,500
Sweden e/	500	500	500	500	600
Thailand	516	324	532 r/	472 r/	500
Turkey	843 r/	1,138 r/	1,211 r/	1,485 r/	1,400
United Kingdom e/	4,800	4,662 r/ 5/	4,600 r/	4,500 r/	4,500
United States (sold or used by producers)	28,500	28,200	28,900	28,500	27,900 5/
Venezuela	798	344 r/	295 r/	331 r/	330
Zimbabwe 10/	52	10	-- e/	-- e/	--
Total	94,600 r/	93,700 r/	95,500 r/	95,500 r/	95,100

e/ Estimated. r/ Revised. NA Not available. -- Zero.
1/ Table includes data available through July 2, 2002.
2/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.
3/ In addition to the countries listed, Angola, Antigua and Barbuda, The Bahamas, China, Iraq, and Saudi Arabia, among others, produce industrial sand, but current available information is not adequate to formulate estimates of production levels.
4/ Fiscal years beginning July 1 of that stated.
5/ Reported figure.
6/ Less than 1/2 unit.
7/ Source: U.S. Geological Survey Minerals Yearbook 1998, v. III.
8/ The quantities for quartz sand and silica stone, in cubic meters, were as follows: 1999--140,428 (reported); 2000--145,000 (estimated); and 2001--145,000 (estimated).
9/ Fiscal years beginning March 21 of that stated.
10/ Includes rough and ground quartz as well as silica sand.

FIGURE 1
PRODUCTION OF INDUSTRIAL SAND AND GRAVEL IN THE UNITED STATES IN 2001, BY GEOGRAPHIC DIVISION