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 that have similar properties and end uses, such as rottenstone. 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 28.4 million metric tons (Mt) in 2000 compared with that of 1999 (table 1). Compared with those of 1999, industrial sand production decreased by less than 1%, and gravel production decreased by about 14%. Exports decreased by less than 1% compared with those of 1999, and imports increased by 17% to 247,000 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 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 decrease 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 production and sale of silica can be attributed in part to the decline of growth in the economy in 2000.

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, the regulations, and the actions taken with regard to exposure to crystalline silica and, most significantly, the 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 69 producers with 154 operations known to produce industrial sand and gravel. Of the 154 surveyed operations, 130 (84%) were active, and 24 were idle. The USGS received responses from 112 operations, and their combined production represented about 78% of the U.S. total. Production for the 31 nonrespondents was estimated, usually based on previously reported information supplemented

Silica in the 20th Century

In 1902, 10 States reported production of "glass sand" for glassmaking, engine or traction sand, furnace sand, building sand, and miscellaneous uses. A total of 1.7 million metric tons valued at $1.42 million was reported. The commercial production of glass sand was reported from the States of Illinois, Indiana, Maryland, Massachusetts, Missouri, New Jersey, New York, Ohio, Pennsylvania, and West Virginia. Besides silica sand, various silica stones were used as abrasive material. The value of grindstones produced in 1900 was $710,000, breaking the old record set in 1882. The production of infusorial earth and tripoli was 3,280 tons valued at $24,000. The production of millstones in 1900 was the largest since 1889, but the industry was still of insignificant importance compared with where it had been 20 years earlier. The substitution of the roller process for buhrstone in flour mills had practically eliminated the use of buhrstones for that purpose. The value of the oilstones and whetstones made in the United States in 1900 was $174,000, a decrease from 1899, when the largest production in the history of the industry had occurred.

In 2000, the United States was the largest producer and consumer of industrial silica, which included industrial sand and gravel, tripoli, special silica stone, and electronic- and optical-grade quartz crystal. U.S. production of industrial sand and gravel amounted to 28.4 million tons. U.S. exports of industrial sand and gravel totaled 1.66 million tons. Silica was arguably one of the most versatile industrial minerals in the 20th century. The most important uses of industrial silica were as glass sand, ceramics, and foundry sand. Other uses included metallurgical applications, abrasives, fillers, filtration, and hydraulic fracturing of rock formations to improve recovery in oil wells. Additionally, electronic-grade quartz crystal was used to accurately control frequency, in timers, and in filters in aerospace hardware, communications equipment, computers, consumer goods (e.g., clocks, games, television receivers, and toys), and navigation instruments.

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 40% of the 28.4 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 about 39% and the West (Pacific and mountain divisions) with 12% (table 2, figure 1).

The eight leading producing States, in descending order, were Illinois, Michigan, California, Wisconsin, Texas, New Jersey, North Carolina, and Oklahoma (table 3). Their combined production represented about 60% of the national total. Production remained relatively stable in all these States, except New Jersey and Texas, which had increased production from 1999 to 2000. Of the 36 States producing in 2000, 18 had increased production, 17 had decreased production, and 1 stayed about even compared with 1999. Mississippi, Texas, and New Jersey reported the largest increases, and Minnesota, Idaho, New York, and Arizona reported the largest decreases.

About 82% of the total industrial sand and gravel was produced by 51 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., Construction Aggregates Corp., Simplot Industries Inc., Little Six Corp., and Manley Brothers, Inc. Their combined production from 59 operations represented 76% of the U.S. total.

Unimin Corp. purchased the operation of Owen Illinois, Inc. of Amador County, CA, in July. The operation, near Ione, CA, processes silica from a kaolin/silica deposit, and most of the silica has traditionally been used for container glass manufacturing, although the amount of silica sold for other uses has been increasing. Unimin also operates a silica mine and plant near Byron, in Contra Costa County, CA.

In July, CSR America, Inc. purchased Florida Crushed Stone Co., which included Montgomery Sand Co. in Montgomery County, GA. The Mount Vernon, GA, operation produced both construction and industrial sand and gravel.

Oglebay Norton Specialty Minerals, Inc. purchased the Franklin Industrial Minerals operation in Cleveland County, NC. The plant is near Kings Mountain, NC, and processes silica from a weathered pegmatite that contains feldspar, kaolin, mica, and silica. Much of the sand is a feldspathic sand that is suitable for ceramics, glassmaking, and other uses in which alumina content is desirable.

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 28.4 Mt of industrial sand and gravel sold or used, about 38% was consumed as glassmaking sand and 22% as foundry sand (table 6). Other important uses were abrasive sand (4.6%) and frac sand (4.9%). Building products, a broad category that includes nonskid flooring, paints, putty, and stucco, consumed about 7.4% 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 2000, over 80% 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 2000, 43% of glass sand was produced in the South; 30%, in the Midwest; 15%, in the West; and 12%, 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. Because of this improvement, 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 reflects 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 a little more than 38%. This percentage has remained stable compared with that of 1999. In 2000, sales to container glass manufacturers decreased by 8% compared with those of 1999. The amount of sand consumed for fiberglass production dropped by 4.8% compared with 1999.

In 2000, sales of sand for flat glass production increased by nearly 2.7% compared with those of 1999. In the South region, consumption for flat glass increased by 1.8%, and in the Midwest region, there was a 1.6% decrease.

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 2000, about 278,000 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).

The production of industrial-grade silicon carbide was on the order of 800,000 t/yr. 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, which is 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 instruments such as dental drills, vacuum systems, and gyroscopes. Other markets for silicon nitride include engine components and cutting tools (Ceramic Industry, 1998).

Silica is also 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 is also used in paint because it offers acid, scrubbing, and wear resistance. As segregated for this survey, consumption in 2000 of whole-grain filler was about 2.1 Mt and of ground silica for filler was 159,000 t.

Cristobalite, a high-temperature silica mineral, is made from quartz 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 traffic paints (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 its 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 for 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 2000, silica sales for chemical production were 723,000 t, a decrease of 4.6% compared with those of 1999. Reported sales of silica gravel for silicon and ferrosilicon production increased by about 7% in 2000 compared with those of 1999. 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, 2000a). 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, 2000b). Although these tires reportedly produce greater gas mileage, deficiencies in tread wear and 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, 61% was transported by truck from the plant to the site of first sale or use, down from 62% in 1999; 36% was transported by rail, up from 35% in 1999; 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 1999, the average value, free on board (f.o.b.) plant, of U.S. industrial sand and gravel increased by 4.7% to $19.57 per metric ton in 2000 (table 6). The average unit values for industrial sand and industrial gravel were $19.87 per ton and $14.69 per ton, respectively. The average price for sand ranged from $6.50 per ton for metallurgical flux to $114.62 per ton for ground fillers. For gravel, prices ranged from $8.97 per ton for nonmetallurgical flux to $23.36 per ton for filtration. Producer prices reported to the USGS for silica commonly ranged from several dollars to hundreds of dollars per metric 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 per metric ton ($114.62), followed by silica for swimming pool filters ($68.29), ground sand for ceramics ($51.94), ground sand for fiberglass ($43.05), ground sand for scouring cleansers ($37.47), refractory foundry sand ($36.11), abrasives for sawing and sanding ($35.56), and sand for hydraulic fracturing ($34.75).

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 per ton of industrial sand and gravel was highest in the West ($21.38), followed by the South ($21.15), the Northeast ($20.60), and the Midwest ($17.29) (table 6). Prices can vary greatly for similar grades of silica at different locations in the United States. For example, the average value per ton of glass sand varied from $20.02 in the West to $14.98 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) 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 2000, 9.7% of industrial sand and gravel shipped by producers was assigned to the "Destination unknown" category.

The States receiving the most industrial sand and gravel were, in descending order, Texas (7.1%), Illinois (6.7%), California (6.3%), Ohio (5.6%), Pennsylvania (4.9%), and Michigan (4.7%). With the exception of Alaska, all States received industrial sand and gravel. Producers reported sending at least 934,000 t of silica to Canada and 195,000 t to Mexico (table 7).

Foreign Trade.—Based on U.S. Census Bureau data, exports of industrial sand and gravel in 2000 decreased by 0.6% compared with the amount exported in 1999, and the associated value increased by about 35% (table 8). Most of the decrease in exports was attributable to decreased shipments to Mexico and Canada. For the fourth consecutive year, Mexico was the largest recipient of U.S. exports. Export distribution was as follows: 37% to Mexico, 28% to Asia, 19% to Canada, 11% to Europe, and the remainder to Africa, the Middle East, Oceania, and South America. The average price per ton of exports rose to $108 in 2000 from $80 in 1999. The increase in price reflected increased exports of higher grade silica, which averaged about $242 per ton, to Europe. Excluding Europe, other exports averaged $91 per ton in 2000.

The U.S. Census Bureau also reported that imports for consumption of industrial sand and gravel rose to 247,000 t, an increase of 17% from imports in 1999 (table 9). Silica imports vary greatly from year to year but are always rather insignificant in relation to total consumption. Canada supplied 73% of the silica imports for 2000, averaging about $12 per ton (including insurance and freight cost to the U.S. port). The total value of imports was $11.8 million, with an average of $48 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 96 Mt. The United States was the leading producer, followed in descending order by Germany, Austria, Spain, and France. Most countries in the world had some production and consumption of industrial sand and gravel, which is 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 2001 is 28 to 30 Mt. Demand is expected to be about 29 Mt. All forecasts are based on previous performances for this commodity within various end uses, contingency factors considered relevant to the future of the commodity, and forecasts made by analysts and producers in the various markets.

Sales of glass sand 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 the 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 2001, 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 2001 is expected to be 6.3 Mt, and the demand range is expected to be 6 to 7 Mt.

Frac sand sales declined by about 4% in 2000, compared with those of 1999. Domestic crude oil prices fluctuated during 2000, and domestic crude oil production was down from 1999 levels. On the basis of these factors, demand for frac sand is expected to remain about level during 2001. Demand for frac sand in 2001 is expected to be 1.4 Mt, with a range of 1.3 to 1.5 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 Australia, Canada, and Europe, 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, pushed use of their “safer” abrasive media.

Development of more efficient mining and processing methods is expected to continue. This will encourage the development 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 for manufacturing 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 as 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 the latter for a national stockpile began.

As of December 31, 2000, the National Defense Stockpile (NDS) contained about 105,309 kilograms (kg) of natural quartz crystal with a reported market value of about $696,000. The stockpile has 11 weight classes for natural quartz crystal ranging from 200 grams to more than 10,000 grams. 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.

As cultured quartz crystal displaced 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. No natural quartz crystal was sold in 2000. 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 subsection 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 2000, 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.

The following U.S. companies produced cultured quartz crystal during 2000: Sawyer Research Products Inc. of Eastlake, OH; Thermo Dynamics Corp. of Merriam, KS; and CTS Corp. of Carlisle, PA. P.R. Hoffman Material Processing Co. of Carlisle, PA, has the capacity to produce cultured quartz crystal but had no production in 2000. Sawyer and Thermo Dynamics produced crystal bars for domestic and foreign firms in the crystal device fabrication industry. CTS 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 2000, the USGS collected domestic consumption data for quartz crystal through a survey of 26 U.S. operations in 9 States that fabricate quartz crystal devices. These operations represented virtually all the domestic consumption. Of the 26 operations, 18 responded to the survey. Consumption for nonrespondents was estimated based on reports from previous years.

Quartz crystal is used in piezoelectric and optical applications. The piezoelectric effect is achieved when a suitable electrical signal applied to a quartz wafer makes the wafer vibrate mechanically throughout the bulk of the material at a characteristic natural resonance frequency. Quartz resonators are uniquely suitable for aerospace, commercial, and military bandpass filter applications that require very high selectivity or for oscillator applications that require very high stability. In addition, for many applications 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 with the 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 acoustical 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 $23 per kilogram in 2000. The average value of lumbered quartz, which is as-grown quartz that has been processed by sawing and grinding, was estimated to be about $143 per kilogram. As noted above, the estimated average market value of the unprocessed quartz crystal in the NDS in 2000 was about $7 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 Germany in 2000, 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 effect 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 artificial 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 subsection of the industrial sand and gravel section of this review.

Production.—In response to a USGS production survey, 9 of 10 domestic firms reported that they quarried certain silica materials and manufactured silica stone products during 2000. 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 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 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 $286 per ton. The average value of stone products made from crude material was $14.76 per kilogram.

Foreign Trade.—In 2000, silica stone product exports had a value of about $6.4 million, unchanged from that of 1999. These exports were categorized as "hand sharpening or polishing stones" by the DOC. This category accounted for most of, if not all, the silica stone products exported in 2000.

In 2000, the value of imported silica stone products was at least $3.8 million, down by 39% compared with that of 1999. These imports were hand-sharpening or polishing stones, which accounted for most of or all of the imported silica stone products in 2000. 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, but particles as small as 0.1 to 0.2 micrometer 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, a crystalline silica, is also affected by the regulation of crystalline silica as discussed in the legislation and government programs subsection of the industrial sand and gravel section of this review.

Production.—In 2000, 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 2000 USGS annual survey of producers indicates that sales of processed tripoli decreased by 15% in quantity to 72,000 t with a value of $15.9 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 2000, about 24% 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 eases application 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 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 $221 per ton in 2000. The average reported value of abrasive tripoli sold or used in the United States during 2000 was $183 per ton; the average reported value of filler tripoli sold or used domestically was $265 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/

		1996	1997	1998	1999	2000
Industrial sand and gravel: 2/						
Sold or used:						
Sand:						
Quantity	thousand metric tons	25,500	26,300	26,400	26,900	26,800
Value	thousands	$473,000	$485,000	$491,000	$510,000	$532,000
Gravel:						
Quantity	thousand metric tons	2,240	2,170	1,790	1,940	1,660
Value	thousands	$24,100	$26,300	$22,200	$28,400	$24,400
Total sold or used:						
Quantity	thousand metric tons	27,800	28,500	28,200	28,900	28,400
Value	thousands	$497,000	$511,000	$513,000	$538,000	$556,000
Exports:						
Quantity	thousand metric tons	1,430	980	2,400	1,670	1,660
Value	thousands	$113,000	$134,000	$148,000	$133,000	$179,000
Imports for consumption:						
Quantity	thousand metric tons	7	39	44	211	247
Value	thousands	$1,500	$3,200	$2,750	$5,590	$11,800
Processed tripoli: 3/						
Quantity	thousand metric tons	79,600	81,300	79,600	84,900	72,000
Value	thousands	$18,400	$16,400	$16,900	$20,200	$15,900
Special silica stone:						
Crude production:						
Quantity	metric tons	854	843	649	697	553
Value	thousands	$222	$224	$184	$183	$158
Sold or used:						
Quantity	metric tons	410	445	438	475	312
Value	thousands	$4,050	$2,560	$3,440	$3,060	$4,610
Electronic and optical-grade quartz crystals:						
Production:						
Mine	thousand kilograms	435	450	--	--	--
Cultured	do.	327	355	185	192	189

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Puerto Rico excluded from all industrial sand and gravel statistics.
3/ Includes amorphous silica and Pennsylvania rottenstone.

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

	1999				2000			
Geographic region	Quantity (thousand metric tons)	Percentage of total	Value (thousands)	Percent of total	Quantity (thousand metric tons)	Percent of total	Value (thousands)	Percentage of total
Northeast:								
New England	155	1	2,790	1	104	(2/)	W	W
Middle Atlantic	2,380	8	46,800	9	2,400	8	51,500	9
Midwest:								
East north-central	10,100	35	164,000	30	10,100	35	170,000	31
West north-central	1,880	6	36,700	7	1,420	5	28,700	5
South:								
South Atlantic	4,200	15	87,800	16	4,270	15	92,400	17
East south-central	2,040	7	35,000	7	2,260	8	43,100	8
West south-central	4,360	15	87,700	16	4,440	16	96,400	17
West:								
Mountain	1,770	6	29,500	5	1,360	5	22,600	4
Pacific	2,040	7	48,400	9	2,090	7	51,300	9
Total	28,900	100	538,000	100	28,400	100	556,000	100

W Withheld to avoid disclosing company proprietary data; included with "Northeast: 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	1999 Quantity	1999 Value	2000 Quantity	2000 Value
Alabama	687	9,780	731	10,100
Arizona	268	3,720	W	W
Arkansas	W	W	W	W
California	1,790	43,700	1,810	45,200
Colorado	W	W	65	W
Florida	509	6,370	510	6,320
Georgia	612	11,100	651	12,500
Idaho	711	11,200	W	W
Illinois	4,460	71,100	4,430	71,600
Indiana	175	1,860	W	W
Iowa	W	W	29	W
Kansas	W	W	W	W
Louisiana	636	10,400	648	12,300
Maryland	W	W	W	W
Michigan	2,550	28,100	2,520	27,800
Minnesota	W	W	W	W
Mississippi	W	W	W	W
Missouri	W	W	W	W
Nebraska	W	W	W	W
Nevada	W	W	609	W
New Jersey	1,580	32,100	1,690	35,700
New Mexico	W	W	W	W
New York	W	W	W	W
North Carolina	1,470	27,300	1,480	28,300
North Dakota	W	W	1	W
Ohio	1,150	30,700	1,210	32,800
Oklahoma	1,470	30,900	1,480	30,700
Pennsylvania	W	W	W	W
Rhode Island	W	W	104	W
South Carolina	769	18,400	755	18,600
Tennessee	W	W	W	W
Texas	1,620	37,100	1,750	45,200
Virginia	W	W	W	W
Washington	W	W	W	W
West Virginia	W	W	W	W
Wisconsin	1,730	32,000	1,790	36,200
Other	6,710	133,000	6,150	143,000
Total	28,900	538,000	28,400	556,000

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 2000, BY SIZE OF OPERATION 1/

Size range	Number of operations	Percentage of total	Quantity (thousand metric tons)	Percentage of total
Less than 25,000	18	14	194	(2/)
25,000 to 49,999	12	9	384	1
50,000 to 99,999	28	22	1,900	7
100,000 to 199,999	21	16	2,700	9
200,000 to 299,999	12	9	2,580	9
300,000 to 399,999	8	6	2,540	9
400,000 to 499,999	10	8	3,680	13
500,000 to 599,999	8	6	4,450	16
600,000 to 699,999	6	5	3,550	12
700,000 and more	7	5	6,440	23
Total	130	100	28,400	100

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

TABLE 5
NUMBER OF INDUSTRIAL SAND AND GRAVEL OPERATIONS AND PROCESSING PLANTS IN THE UNITED STATES IN 2000, BY GEOGRAPHIC REGION

	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	8	1	--	--	4	13
Midwest:						
East north-central	24	--	--	--	7	31
West north-central	4	--	--	--	6	10
South:						
South Atlantic	16	--	--	2	8	26
East south-central	7	--	--	--	4	11
West south-central	10	--	1	--	10	21
West:						
Mountain	7	--	--	--	--	7
Pacific	8	--	1	--	1	10
Total	85	1	2	2	40	130

-- Zero.

TABLE 6

INDUSTRIAL SAND AND GRAVEL SOLD OR USED BY U.S. PRODUCERS IN 2000, BY MAJOR END USE 1/

(Thousand metric tons and thousand dollars, unless otherwise specified)

	Northeast			Midwest			South			West			U.S. total		
Major use	Quantity	Value	Value per ton 2/	Quantity	Value	Value per ton 2/	Quantity	Value	Value per ton 2/	Quantity	Value	Value per ton 2/	Quantity	Value	Value per ton 2/
Sand:															
Glassmaking:															
Containers	W	W	$18.21	1,340	14,100	$10.55	1,360	22,100	$16.28	W	W	$19.49	4,580	71,800	$15.69
Flat (plate and window)	W	W	16.90	1,230	14,500	11.78	2,240	35,600	15.88	W	W	16.65	4,190	62,100	14.82
Specialty	W	W	24.72	W	W	15.74	535	13,200	24.75	W	W	27.44	1,130	25,000	22.14
Fiberglass (unground)	19	225	11.67	W	W	14.54	117	1,990	16.97	W	W	17.67	519	7,820	15.07
Fiberglass (ground)	--	--	--	W	W	45.25	W	W	42.85	--	--	--	434	18,700	43.05
Foundry:															
Molding and core	W	W	18.58	5,030	67,600	13.43	776	12,600	16.18	W	W	22.30	6,160	87,000	14.11
Refractory	W	W	47.32	82	3,120	37.99	W	W	33.59	--	--	--	175	6,310	36.11
Metallurgical:															
Silicon carbide	--	--	--	W	W	11.82	--	--	--	--	--	--	W	W	11.82
Flux for metal smelting	--	--	--	--	--	--	W	W	5.83	W	W	6.61	W	W	6.50
Abrasives:															
Blasting	41	1,740	41.85	227	6,100	26.86	974	25,000	25.65	141	5,710	40.47	1,380	38,500	27.85
Scouring cleansers (ground)	W	W	58.08	W	W	36.25	W	W	108.12	--	--	--	W	W	37.47
Sawing and sanding	W	W	22.05	--	--	--	W	W	93.73	W	W	37.97	W	W	35.56
Chemicals (ground and unground)	W	W	20.01	W	W	14.05	328	9,130	27.83	W	W	20.11	723	15,400	21.31
Fillers (ground), rubber, paints, putty, etc.	W	W	44.04	110	8,680	78.67	W	W	236.64	W	W	28.54	159	18,200	114.62
Whole grain fillers/building products	227	7,030	30.99	488	14,600	29.82	936	17,400	18.59	458	14,100	30.66	2,110	53,000	25.14
Ceramic (ground), pottery, brick, tile, etc.	W	W	45.34	113	6,820	60.14	163	7,560	46.42	W	W	26.13	278	14,400	51.94
Filtration:															
Water (municipal, county, local, etc.)	W	W	49.99	W	W	41.19	166	3,150	18.95	114	5,060	44.24	369	12,200	32.95
Swimming pool, other	22	1,290	59.14	W	W	77.04	23	1,950	83.71	W	W	39.13	73	5,000	68.29
Petroleum industry:															
Hydraulic fracturing	W	W	34.13	848	28,600	33.73	W	W	36.33	W	W	38.09	1,370	47,500	34.75
Well packing and cementing	--	--	--	W	W	28.11	W	W	17.63	(3/)	36	46.59	W	W	26.34
Recreational:															
Golf course (greens and traps)	W	W	15.87	W	W	23.25	365	3,610	9.90	247	5,780	23.36	948	16,000	16.92
Baseball, volleyball, play sand, beaches	115	1,880	16.39	W	W	23.05	110	1,410	12.76	W	W	17.35	429	7,920	18.45
Traction (engine)	W	W	24.96	90	1,080	12.10	66	889	13.56	W	W	24.16	168	2,290	13.61
Roofing granules and fillers	24	573	23.94	W	W	17.75	119	2,170	18.33	W	W	20.91	196	3,800	19.40
Other (ground silica)	(4/)	(4/)	44.04	42	1,850	44.12	430	26,000	60.47	23	752	32.64	XX	XX	XX
Other (whole grain)	2,050	38,800	18.89	1,890	31,700	17.99	1,350	32,600	24.19	1,880	36,000	19.19	XX	XX	XX
Total or average	2,500	51,500	20.60	11,500	199,000	17.29	10,100	216,000	21.52	2,860	67,400	23.55	26,800	532,000	19.87
Gravel:															
Silicon, ferrosilicon	--	--	--	W	W	23.15	W	W	17.77	--	--	--	690	12,300	17.81
Filtration	(4/)	(4/)	70.42	W	W	11.74	50	1,530	30.46	W	W	30.59	157	3,660	23.36
Nonmetallurgical flux	--	--	--	W	W	16.54	--	--	--	W	W	8.82	347	3,110	8.97
Other uses, specified	(4/)	(4/)	10.87	(4/)	(4/)	12.02	860	14,100	16.34	594	6,480	10.91	XX	XX	XX
Total or average	(4/)	(4/)	25.30	(4/)	(4/)	12.02	910	15,600	17.12	594	6,480	10.91	1,660	24,400	14.69
Grand total or average	2,500	51,500	20.60	11,500	199,000	17.29	11,000	232,000	21.15	3,460	73,900	21.38	28,400	556,000	19.57

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; may not add to totals shown.

2/ Calculated using unrounded data.

3/ Less than one unit.

4/ 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	1999	2000	Destination	1999	2000
States:			States--Continued:		
Alabama	761	899	New Jersey	1,010	870
Alaska	(2/)	--	New Mexico	67	67
Arizona	407	328	New York	570	451
Arkansas	63	127	North Carolina	954	789
California	2,290	1,780	North Dakota	9	47
Colorado	254	613	Ohio	1,580	1,600
Connecticut	92	92	Oklahoma	673	623
Delaware	13	11	Oregon	79	63
District of Columbia	(2/)	(2/)	Pennsylvania	1,410	1,390
Florida	507	450	Rhode Island	68	7
Georgia	791	915	South Carolina	257	618
Hawaii	(2/)	(2/)	South Dakota	5	92
Idaho	614	395	Tennessee	997	891
Illinois	1,600	1,900	Texas	2,080	2,020
Indiana	1,030	1,030	Utah	62	29
Iowa	391	258	Vermont	2	2
Kansas	373	446	Virginia	319	504
Kentucky	336	377	Washington	185	171
Louisiana	707	814	West Virginia	209	294
Maine	1	1	Wisconsin	826	1,020
Maryland	96	96	Wyoming	16	66
Massachusetts	73	16	Countries:		
Michigan	1,760	1,340	Canada	644	934
Minnesota	245	380	Mexico	97	195
Mississippi	167	183	Other foreign countries	29	66
Missouri	361	305	Other:		
Montana	31	34	Puerto Rico	(2/)	--
Nebraska	69	14	U.S. possessions and territories	(2/)	(2/)
Nevada	35	51	Destination unknown	3,670	2,750
New Hampshire	3	1	Total	28,900	28,400

-- 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)

Country	1999 Quantity	1999 Value 2/	2000 Quantity	2000 Value 2/
North America:				
Bahamas, The	(3/)	90	14	330
Canada	360	26,600	319	30,400
Mexico	820	23,800	609	20,900
Panama	16	497	15	501
Other	5	695 r/	7	1,340
Total	1,200	51,600	964	53,400
South America:				
Argentina	5	1,190	8	1,500
Brazil	1	924	3	1,750
Colombia	1	293	2	470
Peru	2	220	8	388
Venezuela	15	1,040	11	1,270
Other	1	238	(3/)	325
Total	25	3,900	32	5,700
Europe:				
Belgium	10	2,780	26	2,800
Finland	6	776	1	1,750
France	106	3,100	54	4,830
Germany	26	11,000	27	14,500
Netherlands	13	7,100	33	8,720
Switzerland	(3/)	231	25	1,160
Turkey	(3/)	49	--	--
United Kingdom	4	2,200	4	4,350
Other	14	3,600 r/	12	5,970
Total	179	30,800	182	44,100
Asia:				
China	7	2,790	16	5,920
Indonesia	2	668	18	1,200
Japan	155	20,300	313	34,700
Korea, Republic of	5	3,700	12	4,230
Malaysia	14	573	31	1,290
Philippines	(3/)	205	14	488
Singapore	27	6,920	40	10,900
Taiwan	11	6,150	14	7,550
Thailand	21	690	4	915
Other	9 r/	640 r/	2	1,600
Total	251	42,600	464	68,800
Middle East and Africa:				
Egypt	(3/)	15	7	269
Israel	6	221	4	214
Oman	5	3,090	3	1,740
Other	(3/) r/	393 r/	(3/)	452
Total	12	3,720	14	2,670
Oceania:				
Australia	2	579	7	4,550
Other	(3/)	9	1	215
Total	2	588	8	4,770
Grand total	1,670	133,000	1,660	179,000

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ F.a.s. 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	1999 Quantity	1999 Value 2/	2000 Quantity	2000 Value 2/
Australia	6	1,000	50	3,620
Canada	111	2,100	181	2,120
Chile	--	--	2	255
China	(3/)	255	4	4,830
Germany	(3/)	232	(3/)	209
Japan	3	146	(3/)	159
Mexico	88	1,120	9	117
Sweden	1	502	--	--
Other	2	239 r/	1	493
Total	211	5,590	247	11,800

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ C.i.f. value of material at U.S. port of entry; based on purchase price and includes all charges (except U.S. import duties) incurred 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 2000

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.
Eagle Mountain Whetstone Co., Pearcy, AR	Stone cutting and finishing	Whetstones and oilstones.
Hall's Arkansas Oilstones, Inc., Pearcy, AR	do.	Do.
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)

	1996	1997	1998	1999	2000
Production:					
Mine	435	450	--	--	--
Cultured e/	327	355	185	192	189
Exports (cultured): 2/					
Quantity	89	74	63	90	74
Value	22,200	31,100	24,300	25,400	22,800
Imports (cultured): 2/					
Quantity	42	63	47	26	31
Value	9,480	11,700	12,200	11,000	14,300
Apparent consumption e/	280	343	169	128	146

e/ Estimated. -- 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/	1996	1997	1998	1999	2000
Argentina	244	257	260 e/	250 e/	250
Australia e/	2,500	2,500	2,500	2,500	2,500
Austria	6,012	6,000 r/ e/	6,329 r/	6,857 r/	6,800
Belgium e/	2,300	2,300	2,400	2,400	2,400
Bosnia and Herzegovina e/	50	50	50	50	50
Brazil e/	2,700	2,700	2,700	2,700	2,700
Bulgaria	832	557	893	900 e/	900
Cameroon e/	12	12	13	12	12
Canada	1,558	1,896	1,905	1,702 r/	1,946 p/ 4/
Chile e/	300	300	300	300	300
Croatia	44	98	50	50 e/	50
Cuba e/	300	300	300	300	300
Czech Republic	2,486	1,800	2,000	2,000 e/	2,000
Denmark (sales) e/	50	50	50	50	50
Ecuador	24	43	40 e/	40 e/	40
Egypt 5/	850 r/	505 r/	574 r/	600 r/ e/	600
Eritrea e/	1,481 4/	1,500	1,500	1,000	1,000
Estonia e/	25	25	25	25	25
Ethiopia e/	6	7	7	7	7
Finland	31	30 e/	30 e/	73 r/	70
France e/	6,550	6,560 4/	6,500	6,500	6,500
Gambia	450 e/	452	303	270	250
Germany e/	5,503 4/	6,000 e/	6,000	7,000	7,000
Greece	87 r/	96	90	90 r/	90
Guatemala e/	47 4/	49	50	50	50
Hungary 6/	325	328	241	250	250
Iceland e/	4	4	4	4	4
India	1,534	1,400	1,265	1,300 e/	1,350
Indonesia	300 e/	636	293	300 e/	300
Iran e/ 7/	1,000	1,000	1,000	1,000	1,000
Ireland e/	6	5	5	5	5
Israel e/	225	225	225	225	225
Italy e/	2,950 4/	3,000	3,000	3,000	3,000
Jamaica	16	12	6 e/	6	6
Japan	3,557	3,306	3,049	2,764 r/	2,800
Kenya e/	13	13	13	12	12
Korea, Republic of	1,690	1,222	1,257	1,305	1,300
Latvia e/	50	50	50	50	50
Lithuania e/	33	30	30	30	30
Malaysia	1,168 r/	950 r/	473 r/	509 r/	500
Mexico	1,425	1,564	1,733	1,800 e/	1,800
Netherlands e/	24 r/	24 r/	5 r/	3 r/	5
New Caledonia e/	40	40	40	40	40
New Zealand	24	26	25 e/	25 e/	25
Norway	960	900 e/	1,000 e/	1,000 e/	1,000
Pakistan e/	165	165	122	130	162 4/
Panama e/	23	-- r/	-- r/	-- r/	--
Paraguay e/	10	10	10	10	10
Peru	1,672	1,631	1,600 e/	1,600 e/	1,600
Philippines	31 r/	21 r/	16 r/	64 r/	70 4/
Poland	137	290	236	250 e/	250
Portugal e/	5	5	5	5	5
Serbia and Montenegro	239	200	200	100 e/	100
Slovenia	210	210	200	200 e/	200
South Africa	2,168	2,439	2,273	2,163	2,100
Spain e/	5,300	5,800	6,200 r/	6,550 r/	6,600
Sweden e/	1,500	500	500	500	500
Thailand	447	516	324	350 r/ e/	350
Turkey	779	900	1,107	1,100 e/	1,100
United Kingdom e/	4,816 4/	4,800	4,800	4,000	4,000
United States (sold or used by producers)	27,800	28,500	28,200	28,900	28,400 4/

See footnotes at end of table.

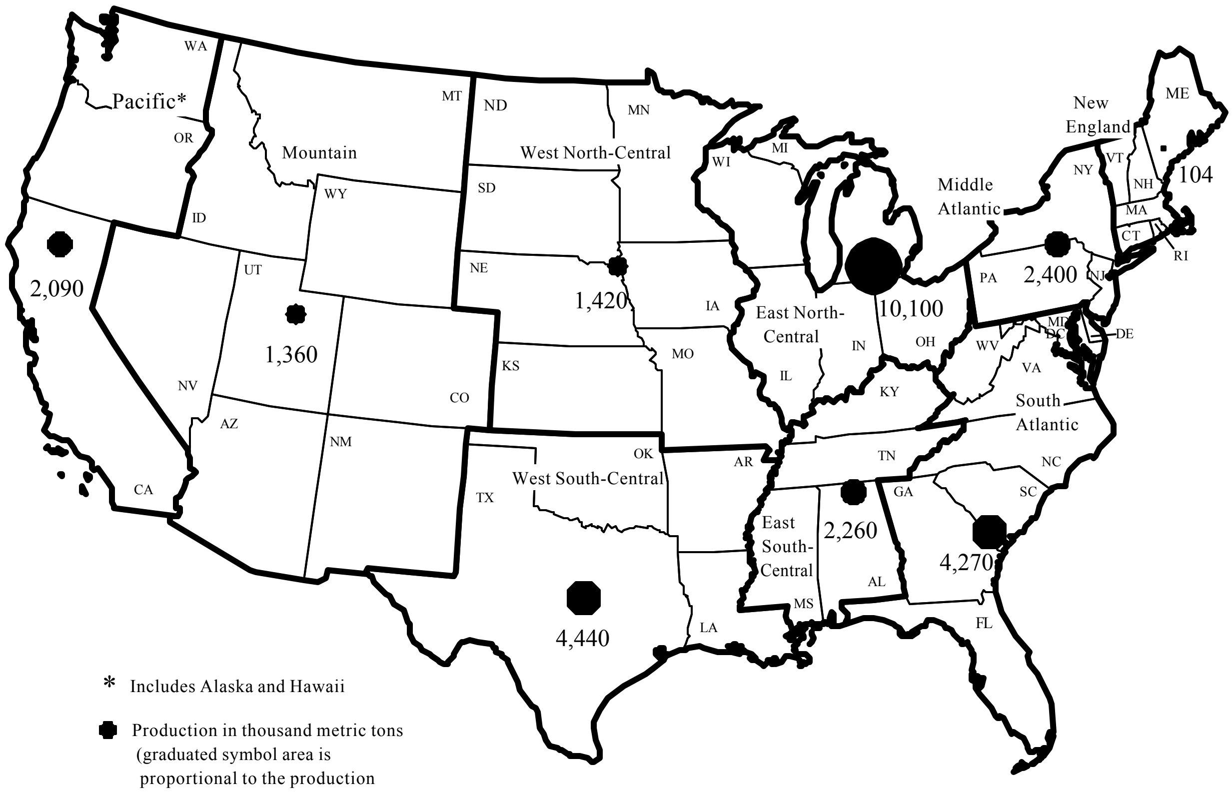
TABLE 12--Continued
INDUSTRIAL (SILICA) SAND AND GRAVEL: WORLD PRODUCTION BY COUNTRY 1/ 2/

(Thousand metric tons)

Country 3/	1996	1997	1998	1999	2000
Venezuela	763	798	611	650 e/	650
Zimbabwe 8/	96	52	10	-- e/	--
Total	96,000 r/	96,000 r/	95,000 r/	96,000 r/	96,000

e/ Estimated. p/ Preliminary. r/ Revised. -- Zero.
1/ Table includes data available through July 2, 2001.
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, and China, among others, produce industrial sand, but current available information is not adequate to formulate estimates of production levels.
4/ Reported figure.
5/ Fiscal years beginning July 1 of that stated.
6/ For the reported volumetric quantity, see the U.S. Geological Survey Minerals Yearbook 1998, v. III.
7/ Fiscal years beginning March 21 of that stated.
8/ Includes rough and ground quartz as well as silica sand.

FIGURE 1
PRODUCTION OF INDUSTRIAL SAND AND GRAVEL IN THE UNITED STATES IN 2000, BY GEOGRAPHIC DIVISION



* Includes Alaska and Hawaii

Production in thousand metric tons (graduated symbol area is proportional to the production tonnage.)