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 increased 2.5% to 28.9 million metric tons (Mt) in 1999 compared with that of 1998 (table 1). Compared with those of 1998, industrial sand production was up by about 2 % and gravel production increased by about 8%. Exports decreased about 30% compared with those of 1998, and imports increased to 211,000 metric tons (t), almost 5 times the amount of imports in 1998.

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.

Production increases were the result of improved 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, also significantly increased.

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, 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 76 producers with 146 operations known to produce industrial sand and gravel. Of the 146 surveyed operations, 136 (93%) were active and 10 were idle. The USGS received responses from 105 operations and their combined production represented about 86% of the U.S. total. Production for the 35 nonrespondents was estimated usually on the basis of previously reported information supplemented with man-hour reports from the U.S. Department of Labor’s Mine Safety and Health Administration and information from State agencies.

The Midwest Region (East North Central and West North Central Divisions) continued to lead the Nation with about 41% of the 28.9 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 about 37%, and the West (Pacific and Mountain Divisions) with 13% (figure 1 and table 2).

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 58% of the national total. Notable production changes took place in all these States, except California and Wisconsin, which were virtually unchanged from 1998 to 1999. Of the 37 States producing in 1999, 16 had increased production, 14 stayed about even, and 7 had decreased production compared with 1998. Arkansas, Michigan, and Minnesota reported the largest increases, and New Jersey, South Carolina, and Texas reported the largest decreases.

About 81% of the total industrial sand and gravel was produced by 51 operations, each with an annual production of more than 200,000 tons (tables 4 and 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., Construction Aggregates Corp., Short Mountain Silica Co., and Owens-Illinois, Inc. Their combined production from 56 operations represented 76% of the U.S. total.

U.S. Silica purchased several properties in New Jersey from Unimin in April. These plants produced construction and industrial grades of sand and gravel. Those plants producing industrial sand and gravel included the operations near the towns of Cedar Lake, Holly City, Mauricetown, and Port

Elizabeth.

Unimin obtained the rights to a mining property formerly operated by WHIBCO, Inc. near Lugoff, SC. The property was adjacent to Unimin's operation and the two properties are now merged as one and operated by Unimin.

Badger Mining reported the merger of their two operations in Green Lake County, WI. The former St. Marie operation is now included as part of the Fairwater division.

The Ashton Co. reported the closure of the Camp Grant operation. Camp Grant, near Mammoth, AZ, had produced silica gravel for copper smelting. The operation was discontinued because of the closure of of BHP Copper, Inc. near San Manuel, AZ.

Cherry Creek Sand Specialties Co., near Denver, CO, reported the closure of their mine in 1998. The land has been sold for the construction of a new school.

Another operation removed from the 1999 survey was Martin Marietta Aggregates Inc.'s Mount Meigs sand and gravel plant, Montgomery County, AL, which the company reported went out of business in December 1998.

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 28.9 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 (4.8%) and frac sand (4.8%). A broad category, building products, which includes nonskid flooring, paints, putty, and stucco consumed about 7.2% of industrial sand and gravel prodution.

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 1999, 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 1999, 41% of glass sand was produced in the South; 32%, 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 for 1999 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 just over 38%. This is slightly less than that of 1998 and was attributable to decreased sales of silica for container and fiber glass production. In 1999, sales to container glass manufacturers decreased by 8.6% compared with those of 1998. The amount of sand consumed for fiberglass production dropped 27% compared with 1998.

Flat glass continued to be a good growth prospect for silica sales. In 1999, sales of sand for flat glass production increased by nearly 25% compared with those of 1998. In the South region, consumption for flat glass increased 35% and in the Midwest region there was a 23% 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 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 because ground silica is used as ultrafine powder. 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. Mineral wool is produced from 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 in the ceramic body of sanitaryware (sinks, toilets, urinals, etc.), about 22% to 32%. 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 1999, about 230,000 tons 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 makes it especially useful in the refractory industry (Industrial Minerals, 1998c).

The annual production of industrial-grade silicon carbide was on the order of 800,000 t. 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. Primary market for hybrid bearings, which is 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 1999 of whole-grain filler was about 2 Mt and ground silica for filler was 272,000 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) includes 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 1999, silica sales for chemical production were 758,000 t, an increase of 8.9% compared with those of 1998. Reported sales of silica gravel for silicon and ferrosilicon production decreased by about 17% in 1999 compared with those of 1998. 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. European consumers seem to prefer the “green” tires made with precipitated silica. 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 flatting agents in coatings, mainly high-solid, low-volatile organic compound coatings.

Recycling.—Recycling of silica sands was limited to some foundry sands, particularly those used for making cores and molds with no-bake resin-bonded sands; some abrasive and airblasting sands; and cullet that substitutes for batch mix, including industrial sand. Most glass recycling was restricted to container glass, with green and amber cullet consumed in greater amounts for container glass production because it is more difficult to use cullet in flint batch mixes. All types of container glass, however, are suitable for fiberglass production. The manufacturers of fiberglass insulation probably represent the largest secondary market for recycled glass containers in the United States.

Recycling of glass containers was estimated to be 34.8% of consumption in the United States in 1998, down from 35.2% in 1997. This included glass used in glascrete (cullet used in portland and asphalt concrete) and glass containers that were refilled (Glass Packaging Institute, oral commun., August 1999). The price for cullet varied on basis of region and grade [flint (colorless), brown (amber), or green]. The 1998 recycling statistics are the latest available from the Glass Packaging Institute, although they reported that 1999 recycling was probably slightly lower than in 1998 (Container Recycling Report, 2000).

As the proportion of cullet used in glass production increases, so does the degree of quality required. Contamination of cullet by ceramics and nonmagnetic materials is an increasing concern. Because of the increased use of recycled glasses, restrictions on the iron and chromium levels in glass sands have become stricter, and the proportion of refractory particles allowed has been reduced to almost zero. The acceptable iron oxide content of a typical glass silica sand is now as low as 0.015% to 0.02% for flint glass manufacture and 0.1% to 0.15% for colored glass. Additionally, recycling of amber and green glass was substantially greater than flint glass, and, therefore, lower grade silica sands are in less demand.

In the field of foundry sand recycling, Indianapolis Casting Corp. has developed an automated sand- and dust-handling mixing system. The system mixes spent molding sand and dust and produces a stable, usable, and consistent material suitable for commercial applications, including asphalt, cement manufacturing, concrete, and road fill (Rock Products, 1998).

Silica refractories are rarely recycled because they must be crushed and ground, and the process generates silica dust. Controlling the dust according to hazardous material regulations makes the recycling prohibitively expensive.

International trends toward increased recycling of glass and foundry sands and innovative ideas on recycling other materials should influence greater recycling of silica products.

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, down from 63% in 1998; 35% was transported by rail, up from 34% in 1999; 2%, 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 1998, the average value, free on board (f.o.b.) plant, of U.S. industrial sand and gravel increased 2.6% to $18.64 per metric ton in 1999 (table 6). The average unit values for industrial sand and industrial gravel were $18.93 and $14.67 per ton, respectively. The average price for sand ranged from $6.46 for metallurgical flux to $76.66 per ton for ground fillers. For gravel, prices ranged from $12.22 for nonmetallurgical flux to $18.33 for ferrosilicon and silicon production. 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 level. Nationally, ground sand used as fillers for rubber, paint, and putty, etc., had the highest value per metric ton ($76.66), followed by silica for swimming pool filters ($68.76), silica for well packing and cementing ($62.10), ground sand for ceramics ($56.54), ground sand for scouring cleansers ($45.47), ground sand for fiberglass ($38.39), sand for hydraulic fracturing ($32.26), and sand for municipal water filtration ($30.90).

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 ($20.47), followed by the South ($19.86), the Northeast ($19.55), and the Midwest ($16.79) (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 markedly—from $19.40 in the West to $12.11 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.—Starting with this report, 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 1999, 12.7% of industrial sand and gravel shipped by producers was assigned to the "destination unknown" category.

The largest receiving States for industrial sand and gravel were, in descending order, California (7.9%), Texas (7.2%), Michigan, (6.1%), Illinois (5.5%), Ohio (5.5%), and Pennsylvania (4.9%). Every State and the District of Columbia received industrial sand and gravel. Producers reported sending at least 644,000 t of silica to Canada and 97,000 t to Mexico (table 7).

Foreign Trade.—On the basis of U.S. Census Bureau data, exports of industrial sand and gravel in 1999 decreased about 30% compared to the amount exported in 1998, and the associated value decreased by about 10% (table 8). Most of the decrease in exports was attributable to decreased shipments to Mexico, where exports dropped by one-half from those of 1998. For the third consecutive year, Mexico was the largest recipient of U.S. exports. Export distribution was as follows: 49% went to Mexico; 22%, Canada; 15%, Asia; 11%, Europe; and the remainder, Africa, Central America, the Middle East, Oceania, and South America. The average price, per ton, of exports rose to $80 in 1999 from $62 in 1998. The increase in price reflected increased exports of higher grade silica, which averaged about $170 per ton, to Asia. Excluding Asia, other exports averaged $64 per ton in 1999.

Census also reported that imports for consumption of industrial sand and gravel rose to 211,000 t, nearly five times the amount of imports for 1998 (table 9). Silica imports vary greatly from year to year but are always rather insignificant in relation to total consumption. Canada supplied 53% of the silica imports for 1999, averaging about $19 per ton (including insurance and freight cost to the U.S. port). The total value of imports was $5.59 million, with an average of $26 per ton. Higher priced imports came from Australia, Germany, Japan, and Sweden.

World Review.—On the basis of information provided mainly by foreign Governments, world production of industrial sand and gravel was estimated to be 107 Mt. The United States was the leading producer, followed by Paraguay, Germany, France, Austria, and Spain, in descending order. 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 13).

Outlook.—The forecast range of total U.S. demand for industrial sand and gravel in 2000 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 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. Demand for glass sand in 2000 is forecast to be 11 Mt, with a 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 2000 is expected to be 6.4 Mt, and the demand range is expected to be 6 to 7 Mt.

Frac sand sales increased by nearly 23% in 1999, compared with that of 1998. The increased sales were attributable to higher crude oil prices. Oil and gas prices increased in 1999, which encouraged the stimulation of marginal oilfields, a primary consumer of frac sand. On the basis of these factors, demand for frac sand is expected to remain about level during 2000. Demand for frac sand in 2000 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 growth 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 annual growth of specialty silicas in the United States is about 4%. Expected consumption in 2003 will 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 among the market economy countries 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 2000. 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 the 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, 1999, the National Defense Stockpile (NDS) contained about 107,000 kilograms of natural quartz crystal with a reported market value of about $1 million. The stockpile has 11 weight classes for natural quartz crystal ranging from 200 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. On the basis of figures reported for 1998 and 1999, no natural quartz crystal was sold in 1999. Previously, only individual crystals in the NDS inventory that weighed 10 kilograms 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 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 1999, the industry consisted of four cultured quartz crystal producers. Two 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 1999: Sawyer Research Products Inc. of Eastlake, OH; Thermo Dynamics Corp. of Merriam, KS; CTS Corp. of Carlisle, PA; and P.R. Hoffman Material Processing Co. of Carlisle, PA. 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. CTS, which had planned to stop growing cultured quartz in 1998, decided in 1999 that they would reverse that decision and resumed growing quartz in 1999. P.R. Hoffman reported external sales.

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, 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° and 400° C; the temperature of the top portion is maintained at 5° to 50° C less, depending upon the mineralizer used. At these temperatures, the solution expands and creates an 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.

The processing of 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.—The USGS collected 1999 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, 17 responded to the survey. Consumption for nonrespondents was estimated on the basis of previous years' reports.

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 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 important 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 $50 per kilogram in 1999. The average value of lumbered quartz, which is as-grown quartz that has been processed by sawing and grinding, was estimated to be about $250 per kilogram. As noted above, the estimated average market value of the unprocessed quartz crystal in the NDS in 1999 was about $9 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 1999, according to some consumers. Imports and exports of all electronic-grade quartz crystal are listed in table 12.

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 sourcing quartz from foreign sources, 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 markets for domestic production. The growing global electronics market may require additional production capacity worldwide.

Special Silica Stone Products

Silica stone products are abrasive tools-materials, 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 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 1999. 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 11).

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 the the 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 value of crude material suitable for cutting into finished products varied from $196 to $551 per ton in 1999. The average value was $249 per ton. The average value of stone products made from crude material was $6.44 per kilogram.

Foreign Trade.—In 1999, silica stone product exports had a value of at least $6.4 million, a 8.5% increase compared with those of 1998. 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 1999.

In 1999, the value of imported silica stone products was at least $6.2 million, nearly 2.5 times those of 1997. These imports were hand-sharpening or polishing stones, which accounted for most of or all of the imported silica stone products in 1999. 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 1999, 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., Garland County, AR, produced crude and finished material from novaculite. Harbison-Walker Refractories Co., 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 1999 USGS annual survey of producers indicates that sales of processed tripoli increased 6.7% in quantity to 84,900 t with a value of $20.2 million (tables 1, 10).

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 29 years. In 1970, nearly 70% of the processed tripoli was used as an abrasive. In 1999, slightly less than 18% of tripoli output was used as an abrasive. The remainder was used as filler and extender in enamel, caulking compounds, paint, plastic, and rubber and in brake friction products, linings, refractories, or other products.

The primary use of tripoli today is used 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 $238 per ton in 1999. The average reported value of abrasive tripoli sold or used in the United States during 1999 was $171 per ton; the average reported value of filler tripoli sold or used domestically was $262 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/

		1995	1996	1997	1998	1999
Industrial sand and gravel: 2/						
Sold or used:						
Sand:						
Quantity	thousand metric tons	26,300	25,500	26,300	26,400	26,900
Value	thousands	$480,000	$473,000	$485,000	$491,000	$510,000
Gravel:						
Quantity	thousand metric tons	1,880	2,240	2,170	1,790	1,940
Value	thousands	$21,900	$24,100	$26,300	$22,200	$28,400
Total:						
Quantity	thousand metric tons	28,200	27,800	28,500	28,200	28,900
Value	thousands	$502,000	$497,000	$511,000	$513,000	$538,000
Exports:						
Quantity	thousand metric tons	1,870	1,430	980	2,400	1,670
Value	thousands	$106,000	$113,000	$134,000	$148,000	$133,000
Imports for consumption:						
Quantity	thousand metric tons	59	7	39	44	211
Value	thousands	$2,730	$1,500	$3,200	$2,750	$5,590
Processed tripoli: 3/						
Quantity	thousand metric tons	80,100	79,600	81,300	79,600	84,900
Value	thousands	$10,500	$18,400	$16,400	$16,900	$20,200
Special silica stone:						
Crude production:						
Quantity	metric tons	501	854	843	649	697
Value	thousands	$270	$222	$224	$184	$183
Sold or used:						
Quantity	metric tons	419	410	445	438	475
Value	thousands	W	$4,050	$2,560	$3,440	$3,060
Electronic and optical-grade quartz crystals:						
Production:						
Mine	thousand kilograms	435	435	450	--	--
Cultured	do.	351	327	355	185	192

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/ 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/

	1998				1999			
Geographic region	Quantity (thousand metric tons)	Percent of total	Value (thousands)	Percent of total	Quantity (thousand metric tons)	Percent of total	Value (thousands)	Percent of total
Northeast:								
New England	113	(2/)	2,440	(2/)	155	1	2,790	1
Middle Atlantic	2,510	10	47,500	9	2,380	8	46,800	9
Midwest:								
East North Central	9,950	35	160,000	31	10,100	35	164,000	30
West North Central	1,470	5	27,800	5	1,880	6	36,700	7
South:								
South Atlantic	4,220	15	84,000	16	4,200	15	87,800	16
East South Central	2,020	7	33,900	7	2,040	7	35,000	7
West South Central	4,260	15	87,300	17	4,360	15	87,700	16
West:								
Mountain	1,670	6	23,300	5	1,770	6	29,500	5
Pacific	2,000	7	46,100	9	2,040	7	48,400	9
Total	28,200	100	513,000	100	28,900	100	538,000	100

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	1998		1999	
	Quantity	Value	Quantity	Value
Alabama	757	9,910	687	9,780
Arizona	307	3,290	268	3,720
Arkansas	W	W	W	W
California	1,740	40,400	1,790	43,700
Colorado	W	W	W	W
Florida	525	6,150	509	6,370
Georgia	608	10,900	612	11,100
Idaho	710	8,470	711	11,200
Illinois	4,580	71,100	4,460	71,100
Indiana	W	W	175	1,860
Iowa	W	W	W	W
Kansas	W	W	W	W
Louisiana	623	12,100	636	10,400
Maryland	W	W	W	W
Massachusetts	W	W	W	W
Michigan	2,390	25,700	2,550	28,100
Minnesota	W	W	W	W
Mississippi	W	W	W	W
Missouri	W	W	W	W
Nebraska	W	W	W	W
Nevada	W	W	W	W
New Jersey	1,800	34,400	1,580	32,100
New Mexico	--	--	W	W
New York	W	W	W	W
North Carolina	1,440	24,100	1,470	27,300
North Dakota	W	W	W	W
Ohio	1,110	27,700	1,150	30,700
Oklahoma	1,380	29,600	1,470	30,900
Pennsylvania	W	W	W	W
Rhode Island	W	W	W	W
South Carolina	881	20,700	769	18,400
Tennessee	999	17,100	W	W
Texas	1,760	38,500	1,620	37,100
Virginia	W	W	W	W
Washington	W	W	W	W
West Virginia	W	W	W	W
Wisconsin	1,750	34,500	1,730	32,000
Other	4,870	97,900	6,710	133,000
Total	28,200	513,000	28,900	538,000

W Withheld to avoid disclosing company proprietary data; included with "Other." -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 4
INDUSTRIAL SAND AND GRAVEL PRODUCTION IN THE UNITED
STATES IN 1999, BY SIZE OF OPERATION 1/

Size range	Number of operations	Percent of total	Quantity (thousand metric tons)	Percent of total
Less than 25,000	16	12	168	1
25,000 to 49,999	13	10	483	2
50,000 to 99,999	29	21	1,870	6
100,000 to 199,999	25	19	3,180	11
200,000 to 299,999	13	10	2,770	10
300,000 to 399,999	7	5	2,250	8
400,000 to 499,999	10	7	4,050	14
500,000 to 599,999	8	6	3,870	13
600,000 to 699,999	4	3	2,480	9
700,000 and over	9	7	7,770	27
Total	134	100	28,900	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 1999, 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	2
Middle Atlantic	6	--	2	--	4	12
Midwest:						
East North Central	21	--	2	1	8	32
West North Central	4	--	--	--	7	11
South:						
South Atlantic	15	--	1	2	8	26
East South Central	7	--	--	--	4	11
West South Central	9	--	--	1	10	20
West:						
Mountain	7	1	--	--	1	9
Pacific	8	1	1	--	1	11
Total	78	2	6	4	44	134

-- Zero.

TABLE 6
INDUSTRIAL SAND AND GRAVEL SOLD OR USED BY U.S. PRODUCERS IN 1999, 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	$18.11	1,470	15,400	$10.50	1,440	22,700	$15.74	W	W	$19.78	4,980	77,500	$15.57
Flat (plate and window)	W	W	16.69	1,250	14,500	11.64	2,200	34,800	15.78	W	W	17.31	4,080	60,000	14.72
Specialty	W	W	24.22	W	W	15.96	W	W	25.01	W	W	30.91	948	20,600	21.74
Fiberglass (unground)	W	W	13.23	335	4,320	12.91	147	2,890	19.65	W	W	23.18	562	8,870	15.77
Fiberglass (ground)	--	--	--	W	W	26.13	W	W	41.96	--	--	--	439	16,800	38.39
Foundry:															
Molding and core	W	W	19.41	4,990	65,500	13.12	909	13,900	15.27	W	W	21.97	6,230	85,800	13.79
Refractory	--	--	--	67	1,890	28.30	W	W	19.01	W	W	23.44	71	1,960	27.84
Metallurgical:															
Silicon carbide	--	--	--	W	W	26.52	--	--	--	--	--	--	W	W	26.52
Flux for metal smelting	--	--	--	--	--	--	W	W	5.52	W	W	6.61	W	W	6.46
Abrasives:															
Blasting	42	1,550	36.61	232	5,950	25.64	979	22,200	22.69	136	4,410	32.49	1,390	34,100	24.56
Scouring cleansers (ground)	W	W	54.86	W	W	44.69	W	W	107.60	--	--	--	W	W	45.47
Sawing and sanding	W	W	21.22	--	--	--	--	--	--	--	--	--	W	W	21.22
Chemicals (ground and unground)	W	W	19.99	W	W	14.28	362	9,030	24.96	W	W	19.41	758	15,300	20.22
Fillers (ground), rubber, paints, putty, etc.	--	--	--	W	W	88.34	W	W	77.72	W	W	42.65	272	20,900	76.66
Whole grain fillers/building products	273	7,180	26.33	621	16,000	25.77	810	17,000	21.05	388	11,300	29.21	2,090	51,600	24.63
Ceramic (ground), pottery, brick, tile, etc.	--	--	--	117	7,110	60.89	W	W	52.18	W	W	27.01	228	12,900	56.54
Filtration:															
Water (municipal, county, local, etc.)	W	W	39.08	58	1,980	34.37	174	3,620	20.79	W	W	43.84	365	11,300	30.90
Swimming pool, other	16	1,030	65.11	14	1,050	76.64	10	652	63.87	--	--	--	40	2,730	68.76
Petroleum industry:															
Hydraulic fracturing	--	--	--	1,040	32,300	31.10	W	W	34.97	W	W	38.82	1,430	46,000	32.26
Well packing and cementing	--	--	--	7	446	67.38	W	W	43.40	W	W	27.56	8	494	62.10
Recreational:															
Golf course (greens and traps)	W	W	23.99	329	6,240	18.98	466	4,380	9.39	W	W	23.56	1,190	18,700	15.72
Baseball, volleyball, play sand, beaches	W	W	15.66	56	943	16.72	54	357	6.55	W	W	13.13	226	3,050	13.46
Traction (engine)	W	W	16.09	79	860	10.91	62	828	13.34	W	W	24.17	187	2,540	13.59
Roofing granules and fillers	W	W	21.10	W	W	17.38	111	1,670	15.03	W	W	16.11	194	3,160	16.32
Other (ground silica)	(3/)	(3/)	54.86	207	11,100	53.42	527	26,600	50.46	52	2,030	38.79	XX	XX	XX
Other (whole grain)	2,210	39,900	17.52	956	13,600	13.42	1,450	34,800	21.63	2,310	48,700	39.10	XX	XX	XX
Total or average	2,540	49,600	19.55	11,800	199,000	16.84	9,710	195,000	20.13	2,880	66,400	23.03	26,900	510,000	18.93
Gravel:															
Silicon, ferrosilicon	--	--	--	W	W	13.90	607	11,000	18.07	W	W	36.74	642	11,800	18.33
Filtration	(3/)	(3/)	69.96	W	W	10.95	77	1,440	18.79	--	--	--	159	2,820	17.71
Nonmetallurgical flux	--	--	--	--	--	--	--	--	--	672	8,210	12.22	672	8,210	12.22
Other uses, specified	--	--	--	W	W	12.38	209	2,650	12.69	W	W	13.07	464	5,620	12.11
Total or average	(3/)	(3/)	69.96	115	1,320	11.45	893	15,000	16.87	921	11,500	12.45	1,940	28,400	14.67
Grand total or average	2,540	49,600	19.55	11,900	200,000	16.79	10,600	210,000	19.86	3,810	77,900	20.47	28,900	538,000	18.64

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; may not add to totals shown.

2/ Calculated using unrounded data.

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

TABLE 7
INDUSTRIAL SAND AND GRAVEL SOLD OR USED, BY DESTINATION IN 1999 1/

(Thousand metric tons)

Destination	Quantity
States:	
Alabama	761
Alaska	(2/)
Arizona	407
Arkansas	63
California	2,290
Colorado	254
Connecticut	92
Delaware	13
District of Columbia	(2/)
Florida	507
Georgia	791
Hawaii	(2/)
Idaho	614
Illinois	1,600
Indiana	1,030
Iowa	391
Kansas	373
Kentucky	336
Louisiana	707
Maine	1
Maryland	96
Massachusetts	73
Michigan	1,760
Minnesota	245
Mississippi	167
Missouri	361
Montana	31
Nebraska	69
Nevada	35
New Hampshire	3
New Jersey	1,010
New Mexico	67
New York	570
North Carolina	954
North Dakota	9
Ohio	1,580
Oklahoma	673
Oregon	79
Pennsylvania	1,410
Rhode Island	68
South Carolina	257
South Dakota	5
Tennessee	997
Texas	2,080
Utah	62
Vermont	2
Virginia	319
Washington	185
West Virginia	209
Wisconsin	826
Wyoming	16
Countries:	
Canada	644
Mexico	97
Other foreign countries	29
Other:	
Puerto Rico	(2/)
U.S. possessions and territories	(2/)
Destination unknown	3,670
Total	28,900

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	1998 Quantity	1998 F.a.s. value 2/	1999 Quantity	1999 F.a.s. value 2/
North America:				
Canada	395	24,300	360	26,600
Mexico	1,660	42,900	820	23,800
Panama	16	509	16	497
Other	19	2,010	5	785
Total	2,090	69,800	1,200	51,600
South America:				
Argentina	4	1,080	5	1,190
Brazil	2	972	1	924
Colombia	9 r/	408 r/	1	293
Peru	4	201	2	220
Venezuela	4	965	15	1,040
Other	1 r/	461 r/	1	238
Total	24 r/	4,080	25	3,900
Europe:				
Belgium	19	1,850	10	2,780
Finland	6	591	6	776
France	68	3,220	106	3,100
Germany	10	6,530	26	11,000
Netherlands	12	7,980	13	7,100
Turkey	11	106	(3/)	49
United Kingdom	6	2,240	4	2,200
Other	10	2,870	14	3,830
Total	142	25,400	179	30,800
Asia:				
China	10	833	7	2,790
Japan	33	26,600	155	20,300
Korea, Republic of	13	3,780	5	3,700
Malaysia	(3/)	144	14	573
Singapore	21	5,430	27	6,920
Taiwan	11	4,750	11	6,150
Thailand	1	272	21	690
Other	5	2,090	11	1,510
Total	93	43,400	251	42,600
Middle East and Africa:				
Israel	44	1,280	6	221
Oman	4	2,480	5	3,090
Other	8	1,050	1	408
Total	56	4,810	12	3,720
Oceania:				
Australia	1	372	2	579
Other	(3/)	31	(3/)	9
Total	1	403	2	588
Grand total	2,400	148,000	1,670	133,000

r/ Revised.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Value of material at U.S. port of 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	1998 Quantity	1998 C.i.f. value 2/	1999 Quantity	1999 C.i.f. value 2/
Australia	16	879	6	1,000
Canada	8	545	111	2,100
Germany	(3/)	343	(3/)	232
Japan	(3/)	120	3	146
Mexico	19	237	88	1,120
Sweden	1	498	1	502
Other	(3/)	131 r/	2	494
Total	44	2,750	211	5,590

r/ Revised.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Value of material at U.S. port of entry; based on purchase price and includes all charges (except U.S. import duties) in bringing material from foreign country to alongside carrier.
3/ Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 10
PROCESSED TRIPOLI SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE 1/ 2/

Use		1995	1996	1997	1998	1999
Abrasives	metric tons	19,300	W	W	W	W
Value	thousands	$2,920	W	W	W	W
Filler 3/	metric tons	60,700	W	W	W	W
Value	thousands	$7,580	W	W	W	W
Total quantity	metric tons	80,100	79,600	81,300	79,600	84,900
Total value	thousands	$10,500	$18,400	$16,400	$16,900	$20,200

W Withheld to avoid disclosing company proprietary data.
1/ Includes amorphous silica and Pennsylvania rottenstone.
2/ Data are rounded to no more than three significant digits; may not add to totals shown.
3/ Includes silica used in brake lining manufacturing, friction products, refractories, and other unspecified uses.

TABLE 11
U.S. PRODUCERS OF SPECIAL SILICA STONE PRODUCTS IN 1999

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:		
Hot Springs, AR	Stone cutting and finishing	Whetstones and oilstones.
Pearcy, AR	Quarry	Do.
Do.	do.	Crude novaculite.

TABLE 12
SALIENT U.S. ELECTRONIC- AND OPTICAL-GRADE QUARTZ CRYSTAL STATISTICS 1/

(Thousand kilograms and thousand dollars)

	1995	1996	1997	1998	1999
Production:					
Mine	435	435	450	--	--
Cultured e/	351	327	355	185	192
Exports (cultured): 2/					
Quantity	35	89	74	63	90
Value	10,900	22,200	31,100	24,300	25,400
Imports (cultured): 2/					
Quantity	47	42	63	47	26
Value	10,800	9,480	11,700	12,200	11,000
Apparent consumption e/	363	280	343	169	128

e/ Estimated. -- Zero.
1/ Data are rounded to no more than three significant digits.
2/ Excludes mounted piezoelectric crystals.

TABLE 13
INDUSTRIAL (SILICA) SAND AND GRAVEL: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons)

Country 3/	1995	1996	1997	1998	1999 e/
Argentina	286	244	257 r/	260 r/ e/	250
Australia e/	2,500	2,500	2,500	2,500	2,500
Austria	7,503	6,012	6,500 e/	6,000 e/	6,000
Belgium e/	2,500	2,300	2,300	2,400	2,400
Bosnia and Herzegovina e/	50	50	50	50 r/	50
Brazil e/	2,700	2,700	2,700	2,700	2,700
Bulgaria	707	832	557	893	900
Canada	1,689	1,558	1,896 r/	1,905 r/	1,994 p/ 4/
Chile e/	300	300	300	300	300
Croatia	32 r/	44	98	50 r/	50
Cuba e/	300	300	300	300	300
Czech Republic	1,993	2,486	1,800 r/	2,000 r/	2,000
Denmark (sales) e/	50	50	50	50	50
Ecuador	26	24	43	40 e/	40
Egypt e/ 5/	740 4/	750	750	750	750
Estonia e/	25	25	25	25	25
Finland	30	31	30 e/	30 e/	30
France e/	6,100	6,550	6,560 4/	6,500	6,500
Germany	7,315	5,503	6,000 e/	6,000 e/	7,000
Greece	68	88	96 r/	90 r/ e/	80
Guatemala	55	47	49	50 e/	50
Hungary 6/	320	325	328	241 r/	250
Iceland e/	5	4	4	4	4
India	1,222	1,534	1,400 r/	1,265 r/	1,300
Indonesia	279	300 e/	636 r/	293 r/	300
Iran e/ 7/	1,000	1,000	1,000	1,000	1,000
Ireland e/	7	6	5	5	5
Israel e/	223 4/	225	225	225	225
Italy e/	3,000	2,950 4/	3,000	3,000	3,000
Jamaica	16	16	12	6 r/ e/	6
Japan	3,734	3,557	3,306	3,049 r/	2,778 4/
Kenya e/	12	13	13 r/	13 r/	12
Korea, Republic of	1,718	1,690	1,222	1,257 r/	1,305 4/
Latvia e/	64 4/	50	50	50	50
Lithuania e/	46 4/	33	30	30	30
Malaysia	288	269	205 e/	200 e/	275 4/
Mexico	1,293	1,425	1,564	1,733 r/	1,800
Netherlands e/	23,159 4/	24,000	24,000	5,000	3,000
New Caledonia e/	40	40	40	40	40
New Zealand	31	24	26	25 e/	25
Norway	963	960	900 e/	1,000 e/	1,000
Pakistan e/	170	165	165	122 r/	130
Panama e/	23	23	23	23	23
Paraguay e/	2,000	10,000	10,000	10,000	10,000
Peru	1,271	1,672	1,631	1,600 r/ e/	1,600
Philippines e/	800	800	800	800	800
Poland	1,143	137	290 r/	236 r/	250
Portugal e/	5	5	5	5	5
Serbia and Montenegro	195	239	200	200 r/	100
Slovenia	210 e/	210	210	200 r/	200
South Africa	2,180	2,168 r/	2,439 r/	2,273 r/	2,163 4/
Spain	5,105 r/	5,300 r/	5,800 r/ e/	6,000 r/ e/	6,000
Sweden e/	1,500	1,500	500	500	500
Thailand	326	447	516	324 r/	250
Turkey 8/	755	779	900 r/	1,107 r/	1,100
United Kingdom e/	4,200	4,816 4/	4,800	4,800	4,000
United States (sold or used by producers)	28,200	27,800	28,500	28,200	28,900 4/
Venezuela	598 r/	763	798 r/	611 r/	650
Zimbabwe 9/	172	96	52 r/	10 r/	--
Total	121,000 r/	128,000 r/	128,000 r/	108,000 r/	107,000

e/ Estimated. p/ Preliminary. r/ Revised. -- Zero.

1/ Table includes data available through July 2, 2000.

2/ World totals, U.S. data, and estimated data are rounded to no more than 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.

TABLE 13--Continued
INDUSTRIAL (SILICA) SAND AND GRAVEL: WORLD PRODUCTION BY COUNTRY 1/ 2/

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/ Washed product.
9/ Includes rough and ground quartz as well as silica sand.

FIGURE 1
PRODUCTION OF INDUSTRIAL SAND AND GRAVEL IN THE UNITED STATES IN 1999, BY GEOGRAPHIC DIVISION