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2011 Minerals Yearbook

SILICA

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Silica

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Four silica categories are covered in this report—industrial sand and gravel, quartz crystal (a form of crystalline silica), special silica stone products, and tripoli. Most of the stone covered in the special silica stone products section is novaculite. The section on tripoli includes other fine-grained, porous silica materials, such as rottenstone, that have similar properties and end uses. Certain silica and silicate materials, such as diatomite and pumice, are covered in other chapters of the U.S. Geological Survey (USGS) Minerals Yearbook, volume I, Metals and Minerals. Trade data in this report are from the U.S. Census Bureau. All percentages were computed using unrounded data.

Industrial Sand and Gravel

Total industrial sand and gravel production in the United States increased to 43.7 million metric tons (Mt) in 2011 from 32.3 Mt in 2010 (table 1). Industrial sand production increased by 37%, and industrial gravel production declined by 40%, compared with that of 2010. During the year, the value of production was \$2 billion—a dramatic increase from that of 2010 and a record high value for industrial sand and gravel production. As in the past several years, the most important driving force in the industrial sand and gravel industry remained the production and sale of hydraulic fracturing sand. Estimated world production of industrial sand and gravel in 2011 was 138 Mt, an 11% increase compared with 2010 production (table 10).

Industrial sand and gravel, often called "silica," "silica sand," and "quartz sand," includes sands and gravels with high silicon dioxide (SiO_2) content. Some examples of end uses for these sands and gravels are in abrasives, filtration, foundry, glassmaking, hydraulic fracturing (frac), and silicon metal applications. The specifications for each use differ, but silica resources for most uses are abundant. In almost all cases, silica mining uses open pit or dredging methods with standard mining equipment. Except for temporarily disturbing the immediate area while operations are active, sand and gravel mining usually has limited environmental impact.

The production increase for silica sand in 2011 was largely attributable to surging demand for frac sand, which resulted in production capacity increases and the opening of many new frac sand operations in the United States. Increased demand was noted for uses such as sand for abrasives, ceramics, filtration, flat glass, foundry uses, hydraulic fracturing, recreation, well packing and cementing, and whole grain silica. Production of the remaining end uses for silica sand in 2011 either remained static or experienced declines compared with those of the previous year. Demand for silica gravel decreased for all end uses.

The increased demand for frac sand was the result of ongoing and increased exploration and production of natural gas and petroleum from various underground shale formations throughout the United States. The addition of new frac sand operations to the USGS voluntary survey of U.S. producers prompted a revision of 2009 and 2010 frac sand production totals. The 2009 frac sand total of 6.53 Mt has been revised to 8.82 Mt and the 2010 frac sand total of 12.1 Mt has been revised to 13.7 Mt (table 1).

In 2011, U.S. Silica Co. filed plans for an initial public offering valued at up to \$200 million in order to help expand production of frac sand (MarketWatch, 2011). In addition to major companies expanding operations for frac sand, many junior companies applied for permits to mine frac sand, particularly in west-central Wisconsin (Elliot, 2011d). By yearend 2011, Wisconsin had 31 sand processing plants, whereas at midyear there were only 18 plants (Financial Times, 2011). Additionally in 2011, Natural Resource Partners purchased 2.8 square kilometers of frac sand reserves in east Texas for \$16.5 million. Coincident with frac sand mining development and production, a number of logistics companies established infrastructure to facilitate increased transportation of frac sand to sites of first use (Elliot, 2011a).

Legislation and Government Programs.—One of the most important issues affecting the industrial minerals industry in recent years has been the potential effect of crystalline silica on human health. Central to the ongoing and often heated debate have been the understanding of the regulations, the implementation of the measurements and actions taken to mitigate exposure to crystalline silica, and appreciation of the impact of such exposure on the future of many industries (Industrial Minerals, 1998). The Occupational Safety and Health Administration (OSHA) created a permissible exposure limit that stipulated the maximum amount of crystalline silica to which workers may be safely exposed during an 8-hour work shift (29 CFR §§1926.55 and 1910.1000). OSHA also established guidelines and training for the proper handling of crystalline silica (Occupational Safety and Health Administration, 2002).

In 2011, OSHA recommended that the permissible exposure limit (PEL) for crystalline silica be reduced to 0.05 milligrams per cubic meter (mg/m^3) PEL from the existing PEL of 0.1 mg/m^3. A decision on the recommendation was expected in 2012 (Elliot, 2011b). During the year, the State of Texas enacted a hydraulic fracturing disclosure law that requires oil and gas producers to disclose the composition of fluids used in hydraulic fracturing. Frac sand is a widely used proppant and one of the main components of hydraulic fracturing fluid (Elliot, 2011c).

Production.—Domestic production data for industrial sand and gravel were developed by the USGS from a voluntary survey of U.S. producers. The USGS canvassed 87 producers with 159 operations known to produce industrial sand and gravel. Of the 159 surveyed operations, 154 (97%) were active, and 4 were idle. The USGS received responses from 79 operations, and their combined production represented 84% of the U.S. total. Production for the 80 nonrespondents was estimated, primarily on the basis of previously reported information, supplemented with worker-hour reports from the Mine Safety and Health Administration (MSHA) and information from State agencies.

The Midwest (East North Central and West North Central divisions) led the Nation with 51% of the 43.7 Mt of industrial sand and gravel produced in the United States, followed by the South (South Atlantic, East South Central, and West South Central divisions) with 39%, the West (Pacific and Mountain divisions) with 6%, and the Northeast (New England and Middle Atlantic) with 4% (table 2).

The leading producing States were, in descending order, Texas, Illinois, Wisconsin, Missouri, Michigan, Oklahoma, North Carolina, and California (table 3). Their combined production represented 61% of the national total. States for which data were withheld in table 3 were not included among the leading producers.

Of the total industrial sand and gravel produced, 89% was produced by 72 operations, each with production of 200,000 metric tons per year (t/yr) or more (table 4). The 10 leading producers of industrial sand and gravel were, in descending order, Unimin Corp.; U.S. Silica Co.; Fairmount Minerals Ltd.; Frac Tech Services International, LLC; Premier Silica, LLC; Badger Mining Corp.; Pattison Sand Co., LLC; Preferred Rocks of Genoa, LLC; Sand Products Corp.; and Cadre Material Products, LLC. Their combined production represented 72% of the U.S. total.

Consumption.—Industrial sand and gravel production reported by producers to the USGS was material used by the producing companies or sold to their customers. Stockpiled material is not reported until consumed or sold. Of the 43.7 Mt of industrial sand and gravel sold or used, 57% was consumed as frac sand and sand for well packing and cementing, and 17% as glassmaking sand (table 6). Foundry uses consumed 11% of industrial sand and gravel consumption. Other leading uses were whole grain fillers and building products (4%) and other whole grain silica (2%).

Minable deposits of industrial sand and gravel occur throughout the United States, and mining companies are located near markets that have traditionally been in the Eastern United States. In some cases, consuming industries are specifically located near a silica resource. The automotive industry was originally located in the Midwest near clay, coal, iron, and silica resources. Therefore, foundry sands have been widely produced in Illinois, Indiana, Michigan, Ohio, and other Midwestern States. In 2011, 88% of foundry sand was produced in the Midwest.

The Ordovician St. Peter Sandstone in the Midwest is a primary source of silica sand for many end uses and is a major source of frac sand as well. Mined in five States, frac sand from the St. Peter Sandstone is within reasonable transport distance to numerous underground shale formations producing natural gas. In 2011, 59% of frac sand was produced in the Midwest.

Producers of industrial sand and gravel were asked to provide statistics on the destination of silica produced at their operations. The producers were asked to list only the quantity of shipments (no value data were collected in this section of the questionnaire) and the State or other location to which the material was shipped for consumption. All States received industrial sand and gravel. The States that received the most industrial sand and gravel were, in descending order, Texas, California, Illinois, Colorado, Pennsylvania, Oklahoma, North Carolina, Arkansas, Indiana, and New Jersey. Producers reported sending 337,000 t of silica to Mexico (table 7). Because some producers did not provide this information, their data were estimated or assigned to the “Destination unknown” category. In 2011, 53% of industrial sand and gravel shipped by producers was assigned to that category.

The total share of silica sold for glassmaking decreased compared with that of 2010 although, sales of sand for flat glass production increased by 4% compared with those in 2010. In 2011, sales to container glass manufacturers declined by 6% compared with those in 2010. On average, in the container glassmaking industry, silica accounts for 60% of raw materials used (Industrial Minerals, 2004). The amount of unground silica sand consumed for fiberglass production decreased by 39% compared with that of 2010, and sales for specialty glass declined by 6%.

The increased demand for frac sand was the result of ongoing and increased exploration and production of natural gas and petroleum from various underground shale formations throughout the United States. In 2011, sales of frac sand increased by 77% compared with those of 2010.

The demand for foundry sand is dependent mainly on automobile and light truck production. Production and sales of automobiles and light trucks increased in 2011. In 2011, sales of foundry sand increased by 50% compared with those of 2010.

Whole grain silica is regularly used in filler-type and building applications. In 2011, consumption of whole-grain fillers for building products was 1.87 Mt, a 3% increase compared with that in 2010.

In 2011, silica sales for chemical production were 707,000 t, a decrease of about 12% compared with those in 2010. Reported sales of silica gravel for silicon and ferrosilicon production, filtration, and other uses decreased by 40% in 2011 compared with those in 2010. The main uses for silicon metal are in the manufacture of silanes and semiconductor-grade silicon and in the production of aluminum alloys.

Transportation.—The increase in frac sand production and sales had a profound effect on the transportation of industrial sand and gravel to sites of first use. Of all industrial sand and gravel produced, 65% was transported by truck from the plant to the site of first sale or use, up 25% from that of 2010; 29% was transported by rail, up from that of 2010; and 6% by unspecified modes of transport.

Prices.—The average value, free on board plant, of U.S. industrial sand and gravel increased to $45.71 per metric ton in 2011, a 32% increase compared with the average value of $34.58 per metric ton in 2010 (table 6). Average values increased for some end uses and decreased for others, but substantial increases for the leading end uses resulted in overall increased unit values. The average unit values for industrial sand and industrial gravel were $45.74 per ton and $41.37 per ton, respectively. The average price for sand ranged from $11.00 per ton for metallurgical flux for metal smelting to $74.24 per ton for sand for municipal water filtration. For gravel, prices ranged from $26.20 per ton for silicon and ferrosilicon to $54.57 per ton for filtration. In any given year, producer prices reported to the USGS for silica commonly ranged from several dollars per ton to hundreds of dollars per ton. Prices for certain highly processed quartz products for specialized end uses, not covered in this chapter, can reach the $50,000-per-ton level. Nationally, sand for municipal water filtration had the highest value ($74.24 per ton), followed by ground sand for ceramics ($57.70 per ton), frac sand ($54.83 per ton), ground sand for foundry molding and core ($50.33 per ton), silica for swimming pool filters ($48.90 per ton), ground sand used as filler for paint, putty, rubber ($44.78 per ton), and ground sand for fiberglass ($43.33 per ton).

By geographic region, the average value of industrial sand and gravel was highest in the Midwest ($50.49 per ton), followed by the South ($42.20 per ton), the Northeast ($40.99 per ton), and the West ($32.30 per ton) (table 6). Prices can vary greatly for similar grades of silica at different locations in the United States, owing to tighter supplies and higher production costs in certain regions of the country. For example, the average value of container glass sand varied from $19.82 per ton in the Midwest to $37.52 per ton in the Northeast.

Foreign Trade.—Exports of industrial sand and gravel in 2011 increased by about 10% compared with the amount exported in 2010, and the associated value increased by 15% (table 8). The increase in exports can be attributed mainly to increased demand from markets in China, Japan, and Mexico. Canada was the leading recipient of U.S. exports, receiving 39% of total industrial sand and gravel exports; Japan, 31%, and Mexico, 16%. The remainder went to many other countries. The average unit value of exports increased to $85.69 per ton in 2011 from $81.82 per ton in 2010. In 2011, export unit values varied widely by region; exports of silica to Africa and the Middle East averaged about $1,500 per ton, and exports to the rest of the world averaged $85.37 per ton.

Imports for consumption of industrial sand and gravel increased to 316,000 t, which were an increase of 139% compared with those of 2010 (table 9). Mexico supplied about 63% of the silica imports, and imports from Mexico averaged $385 per ton; this included cost, insurance, and freight costs to the U.S. port of entry. The total value of imports was $87.9 million, with an average unit value of $278 per ton. Higher priced imports came from Australia, Chile, China, Germany, the Netherlands, and Japan.

World Review.—Based on information provided mainly by foreign governments, world production of industrial sand and gravel was estimated to be 138 Mt (table 10). The United States was the leading producer followed, in descending order, by Italy, Germany, Australia, France, Spain, Turkey, and the United Kingdom. Most countries had some production and consumption of industrial sand and gravel, which are essential to the glass and foundry industries. Because of the great variation in reporting standards, however, obtaining reliable information was difficult. In addition to the countries listed, many other countries were thought to have had some type of silica production and consumption.

Outlook.—U.S. consumption of industrial sand and gravel in 2012 was expected to be 45 to 50 Mt. All forecasts are based on previous performances 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.

Increased demand has been noted in some segments, such as sand for abrasives, ceramics, filtration, flat glass, foundry uses, hydraulic fracturing, recreational sand, well packing and cementing, and whole grain silica. Industrial sand and gravel sales may be constrained by diminished demand owing to the ongoing economic sluggishness and by the rising energy costs for production and transportation of products.

The demand for foundry sand is dependent mainly on automobile and light truck production. Production and sales of automobiles and light trucks increased in 2011 and the trend continued into 2012. Another important factor for the future consumption of virgin foundry sand is the recycling of used foundry sand. The level of recycling is thought to be increasing. Other materials or minerals compete with silica as foundry sand, but these other "sands" usually suffer from a severe price disadvantage. Based on these factors, production of silica foundry sand in 2012 was expected to be 4 Mt.

Frac sand sales increased in 2011 compared with those in 2010. On average, crude oil and natural gas prices fluctuated in 2011 with an overall trend toward higher prices into 2012. Based on this trend, coupled with increased natural gas exploration and production, primarily in the Eastern and Midwestern United States, demand for frac sand was expected to increase during 2012 to 30 Mt.

The United States is the leading producer and a major consumer of silica sand and is self-sufficient in this mined mineral commodity. Most silica sand is produced at deposits in the Midwest and near major markets in the Eastern United States. A significant amount of silica sand also is produced in the West and Southwest, mostly in California and Texas, respectively. Domestic production is expected to continue to meet 97% to 98% of U.S. demand well beyond 2012. Barring further declines in the overall U.S. economy, imports of silica sand from Canada and Mexico, and higher valued material from China are expected to slowly increase.

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 market location is an important factor in determining the economic feasibility of developing a deposit. Consequently, a significant number of relatively small operations supply local markets with a limited number of products.

Several factors could affect supply and demand relationships for silica sand. Further increases in the development of substitute materials for glass and cast metals could reduce demand for foundry and glass sand. These substitutes, which are mainly ceramics and polymers, would likely increase the demand for ground silica, which is used as a filler in plastics; glass fibers, which are used in reinforced plastics; and silica (chemical, ground, or whole-grain), which is used as raw materials for ceramics. Increased efforts to reduce waste and to increase recycling also would be likely to lower the demand for mined glass sand. Recycling of glass cullet has been increasing in most industrialized nations, and recycling has accounted for anywhere from 25% to 70% of the raw material needed for the glass container industry in many countries. It has been estimated that for every 10% of recycled glass cullet used in the melting process for glass container manufacture, energy use will decrease by approximately 2.5%. Glass container weight has been reduced by 25% to 40% in many nations, including the United States, decreasing the amount of industrial sand required for each container (Industrial Minerals, 2004).

Health concerns about the use of silica as an abrasive and stricter legislative and regulatory measures concerning crystalline silica exposure could reduce the demand in many silica markets. The use of silica sand in the abrasive blast industry was being evaluated as a health hazard, and marketers of competing materials, which include garnet, olivine, and slags, encouraged the use of their "safer" abrasive media. In hydraulic fracturing, other materials (such as bauxite-based proppants, ceramic proppants, and resin-coated sand) compete with silica sand, although they are more expensive and not used as extensively as silica sand. Bauxite-based and ceramic proppants exhibit improved performance in deeper, higher pressure formations than silica sand (Industrial Minerals, 2009).

Quartz Crystal

Electronic-grade quartz crystal, also known as cultured quartz crystal, is single-crystal silica with properties that make it uniquely suited for accurate filters, frequency controls, and timers used in electronic circuits. These devices are used for a variety of electronic applications in aerospace hardware, commercial and military navigational instruments, communications equipment, computers, and consumer goods (for example, clocks, games, television receivers, and toys). Such uses generate practically all the demand for electronic-grade quartz crystal. A smaller amount of optical-grade quartz crystal is used for lenses and windows in specialized devices, which include some lasers.

Natural quartz crystal was used in most electronic and optical applications until 1971, when it was surpassed by cultured quartz crystal. Cultured quartz is not a mined mineral commodity. Rather, it is synthetically produced from natural feedstock quartz, termed lascas, which is mined. Mining of lascas in the United States ceased in 1997 owing to competition from less expensive imported lascas, predominantly from mines in Brazil and Madagascar.

It has been estimated that in any given year, approximately 10 billion quartz crystals and oscillators are manufactured and installed worldwide in all types of electronic devices, from automobiles to cellular telephones.

The use of natural quartz crystal for carvings and other gemstone applications has continued; more information can be found in the "Gemstones" chapter of the USGS Minerals Yearbook, volume I, Metals and Minerals.

Legislation and Government Programs.—The strategic value of quartz crystal was demonstrated during World War II when it gained widespread use as an essential component of military communication systems. After the war, natural electronic-grade quartz crystal was officially designated as a strategic and critical material for stockpiling by the Federal Government. Cultured quartz crystal, which eventually supplanted natural crystal in nearly all applications, was not commercially available when acquisition of natural quartz crystal for a national stockpile began.

As of December 31, 2011, the National Defense Stockpile (NDS) contained 7,134 kilograms (kg) of natural quartz crystal. The stockpile has 11 weight classes for natural quartz crystal that range from 0.2 kg to more than 10 kg. The stockpiled crystals, however, are primarily in the larger weight classes. The larger pieces are suitable as seed crystals, which are very thin crystals cut to exact dimensions, to produce cultured quartz crystal. In addition, many of the stockpiled crystals could be of interest to the specimen and gemstone industry. Little, if any, of the stockpiled material is likely to be used in the same applications as cultured quartz crystal.

No natural quartz crystal was sold from the NDS in 2011, and the Federal Government did not intend to dispose of or sell any of the remaining material. Previously, only individual crystals in the NDS inventory that weighed 10 kg or more and could be used as seed material were sold. Brazil traditionally has been the source of such large natural crystals, but changes in mining operations have reduced output.

Quartz crystal is also affected by the regulation of crystalline silica as discussed in the "Legislation and Government Programs" portion of the "Industrial Sand and Gravel" section of this chapter.

Production.—The USGS collects production data for quartz crystal through a survey of the domestic industry. In 2011, no domestic companies reported the production of cultured quartz crystal. During the past several years, cultured quartz crystal was produced predominantly overseas, primarily in Asia.

Consumption.—In 2011, the USGS collected domestic consumption data for quartz crystal through a survey of 23 U.S. operations that fabricate quartz crystal devices in 9 States. Of the 23 operations, 10 responded to the survey. Total U.S. consumption of quartz crystal in 2011, including nonrespondents, was estimated at 1,300 kilograms.

Prices.—The price of as-grown cultured quartz was estimated to be $170 per kilogram in 2011. Lumbered quartz, which is as-grown cultured quartz that has been processed by sawing and grinding, was estimated to be $400 per kilogram in 2011, however prices ranged from $20 per kilogram to more than $900 per kilogram, depending on the application.

Foreign Trade.—The U.S. Census Bureau, which is the major Government source of U.S. trade data, does not provide specific import or export statistics on lascas. The U.S. Census Bureau collects export and import statistics on electronic and optical-grade quartz crystal; however, the quartz crystal export and import quantities and values reported in previous years included zirconia, which was inadvertently reported as quartz crystal, not including mounted piezoelectric crystals.

World Review.—Cultured quartz crystal production was concentrated in China, Japan, and Russia; several companies produced crystal in each country. Other producing countries were Belgium, Brazil, Bulgaria, France, Germany, South Africa, and the United Kingdom. Details concerning quartz operations in China, the Eastern European countries, and most nations of the Commonwealth of Independent States were unavailable. Operations in Russia, however, have significant capacity to produce synthetic quartz.

Outlook.—Continuing growth of the consumer electronics market (for example, automobiles, cellular telephones, electronic games, and personal computers), in the United States, will likely continue to provide consumer outlets for domestically produced quartz crystal devices. The increasing global electronics market may require additional production capacity worldwide. Quartz technology could face competition in the near future with the advent of more cost effective microelectromechanical systems (MEMS). MEMS technology was first developed in 1965 and consisted of silicon on insulated wafers. MEMS technology is physically compatible with existing quartz oscillator products and has better long-term stability performance characteristics for use in automotive, consumer, and computational products, and wireless applications (Partridge, 2006).

Special Silica Stone Products

Silica stone (another type of crystalline silica) products are materials for abrasive tools, such as deburring media, grinding pebbles, grindstones, hones, oilstones, stone files, tube-mill liners, and whetstones. These products are manufactured from novaculite, quartzite, and other microcrystalline quartz rock. This chapter, however, excludes products that are fabricated from such materials by artificial bonding of the abrasive grains (information on other manufactured and natural abrasives may be found in other USGS Minerals Yearbook, volume I, Metals and Minerals chapters).

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

Production.—None of the three domestic firms known to produce special silica stone responded to a USGS production survey in 2011. In recent years, Arkansas accounted for most of the value and quantity of production that was reported. Plants in Arkansas manufactured files, deburring-tumbling media, oilstones, and whetstones.

The industry produced and marketed four main grades of Arkansas whetstone in recent years. The grades range from the high-quality black hard Arkansas stone down to Washita stone. In general, the black hard Arkansas stone has a porosity of 0.07% and a waxy luster, and Washita stone has a porosity of 16% and resembles unglazed porcelain.

Consumption.—The domestic consumption of special silica stone products comprises a combination of craft, household, industrial, and leisure uses. The leading household use is for sharpening knives and other cutlery, lawn and garden tools, scissors, and shears. Major industrial uses include deburring metal and plastic castings, polishing metal surfaces, and sharpening and honing cutting surfaces. The major recreational use is in sharpening arrowheads, fishhooks, spear points, and sports knives. The leading craft application is sharpening tools for engraving, jewelry making, and woodcarving. Silica stone files also are used in the manufacture, modification, and repair of firearms.

Prices.—In 2011, the average value of crude material suitable for cutting into finished products was estimated to be \$3,700 per ton.

Foreign Trade.—In 2011, silica stone product exports had a value of \$11.05 million, down slightly from that in 2010. These exports were categorized as “hand sharpening or polishing stones” by the U.S. Census Bureau. This category accounted for most of or all the silica stone products exported in 2011.

In 2011, the value of imported silica stone products was \$11.3 million, up by 27% from that in 2010. These imports were hand sharpening or polishing stones, which accounted for most of or all the imported silica stone products in 2011. A portion of the finished products that were imported may have been made from crude novaculite produced in the United States and exported for processing.

Outlook.—Consumption patterns for special silica stone were not expected to change significantly during the next several years. Most of the existing markets are well defined, and the probability of new uses being created is low.

Tripoli

Tripoli, broadly defined, includes extremely fine grained crystalline silica in various stages of aggregation. Grain sizes usually range from 1 to 10 micrometers (μm), but particles as small as 0.1 to 0.2 μm are common. Commercial tripoli contains 98% to 99% silica and minor amounts of alumina (as clay) and iron oxide. Tripoli may be white or some shade of brown, red, or yellow depending on the percentage of iron oxide.

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

Production.—In 2011, three U.S. firms were known to produce and process tripoli. American Tripoli, Inc. closed their operation in Ottawa County, OK, in 2010, but operated a mine and produced finished material in Newton County, MO. Malvern Minerals Co. in Garland County, AR, produced crude and finished material from novaculite. Unimin Specialty Minerals Inc. in Alexander County, IL, produced crude and finished material. Of the three U.S. firms, two responded to the USGS survey. Production for the nonrespondent was estimated based on reports from previous years and supplemented with worker-hour reports from MSHA.

Consumption.—It was estimated that sales of processed tripoli decreased by 33% in quantity to 73,700 t with a value of \$16.5 million (table 1).

Tripoli has unique applications as an abrasive because of its hardness and its grain structure, which lacks distinct edges and corners. It is a mild abrasive, which makes it suitable for use in toothpaste and tooth-polishing compounds, industrial soaps, and metal- and jewelry-polishing compounds. The automobile industry uses it in buffing and polishing compounds for lacquer finishing.

The end-use pattern for tripoli has changed significantly in the past 41 years. In 1970, nearly 70% of the processed tripoli was used as an abrasive. In 2011, 8% of tripoli output was used as an abrasive. Tripoli was mostly used as a filler and extender in enamel, caulking compounds, linings, paint, plastic, rubber, and other products. In 2011, the primary use of tripoli (89%) was as a filler and extender. The remaining 3% was in brake friction products and refractories.

Price.—The average unit value of all tripoli sold or used in the United States was estimated to be \$224 per ton in 2011. The average unit value of abrasive-grade tripoli sold or used in the United States during 2011 was estimated to be \$204 per ton, and the average unit value of filler-grade tripoli sold or used domestically was estimated to be \$241 per ton.

Outlook.—Consumption patterns for tripoli were not expected to change significantly during the next several years. Most of the existing markets are well defined, and the probability of new uses being created is low.

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

(Thousand metric tons and thousand dollars unless otherwise specified)

		2007	2008	2009	2010	2011
Industrial sand and gravel:[2]						
Sold or used:						
Quantity:						
Sand		29,000	29,300	26,900 r	31,700 r	43,400
Gravel		1,010	1,110	565	582	348
Total		30,100	30,400	27,500 r	32,300 r	43,700
Value:						
Sand		810,000	909,000	921,000 r	1,130,000 r	1,980,000
Gravel		21,300	28,000	21,000	14,900	14,400
Total		832,000	937,000	942,000 r	1,150,000 r	2,000,000
Exports:						
Quantity		3,020	3,100	2,150	3,950	4,330
Value		242,000	260,000	175,000	323,000	371,000
Imports for consumption:						
Quantity		511	355	95	132 r	316
Value		24,000	23,500	8,080	19,300 r	87,900
Processed tripoli:[3]						
Quantity	metric tons	96,400	132,000	79,700	110,000	73,700
Value		17,400	17,100	16,400	20,000	16,500
Special silica stone:						
Crude production:						
Quantity	metric tons	231	W	W	W	W
Value		1,020	W	W	W	W
Sold or used:						
Quantity	metric tons	508	W	W	W	W
Value		823	W	W	W	W

[r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Excludes Puerto Rico.
[3]Includes amorphous silica and Pennsylvania rottenstone.

TABLE 2
INDUSTRIAL SAND AND GRAVEL SOLD OR USED IN THE UNITED STATES, BY GEOGRAPHIC DIVISION[1]

	2010				2011			
Geographic region[2]	Quantity (thousand metric tons)	Percentage of total	Value (thousands)	Percentage of total	Quantity (thousand metric tons)	Percentage of total	Value (thousands)	Percentage of total
Northeast:								
New England	127	(3)	$6,380	1	123	(3)	$6,110	(3)
Middle Atlantic	1,440	5	47,000	5	1,540	4	62,100	3
Midwest:								
East North Central	11,000 r	33	399,000 r	33	14,700	34	714,000	36
West North Central	4,870 r	15	178,000 r	16	7,480	17	405,000	20
South:								
South Atlantic	3,480	12	93,400	9	3,460	8	101,000	5
East South Central	1,290	4	40,900	4	1,400	3	27,000	1
West South Central	7,900 r	23	321,000 r	26	12,200	28	592,000	30
West:								
Mountain	500	2	14,000	1	1,180	3	39,300	2
Pacific	1,680	6	49,900	5	1,670	4	52,900	3
Total	32,300 r	100	1,150,000 r	100	43,700	100	2,000,000	100

[r]Revised.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Sales region equivalent to U.S. Census Bureau Geographic Division as follows: New England (CT, MA, ME, NH RI, VT); Middle Atlantic (NJ, NY, PA); East North Central (IL, IN, MI, OH, WI); West North Central (IA, KS, MN, MO, NE, ND, SD); South Atlantic (DC, DE, FL, GA, MD, NC, SC, VA, WV); East South Central (AL, KY, MS, TN); West South Central (AR, LA, OK, TX); Mountain (AZ, CO, ID, MT, NM, NV, UT, WY); Pacific (AK, CA, HI, OR, WA).
[3]Less than ½ unit.

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

(Thousand metric tons and thousand dollars)

State	2010 Quantity	2010 Value	2011 Quantity	2011 Value
Alabama	386	10,400	352	10,500
Arizona	W	W	W	W
Arkansas	W	W	W	W
California	1,320	39,400	1,300	40,800
Colorado	W	W	W	W
Florida	173	3,980	180	4,370
Georgia	670	17,800	655	19,600
Idaho	W	W	W	W
Illinois	5,080 r	183,000 r	6,160	311,000
Indiana	W	W	W	W
Iowa	W	W	W	W
Kansas	W	W	W	W
Louisiana	629	25,600	550	23,700
Maryland	--	--	--	--
Michigan	1,350 r	31,700 r	1,830	67,500
Minnesota	1,940	100,000	W	W
Mississippi	--	--	--	--
Missouri	782 r	28,700 r	1,970	101,000
Nebraska	W	W	W	W
Nevada	W	W	W	W
New Jersey	918	33,600	974	34,400
New Mexico	--	--	--	--
New York	W	W	W	W
North Carolina	1,400	30,900	1,330	35,300
North Dakota	W	W	W	W
Ohio	821	27,800	1,100	54,000
Oklahoma	2,060 r	64,800 r	1,780	69,600
Pennsylvania	524	13,400	W	W
Rhode Island	W	W	W	W
South Carolina	530	14,700	451	16,700
Tennessee	907	30,500	1,050	16,500
Texas	4,480 r	202,000 r	7,000	337,000
Virginia	W	W	W	W
Washington	W	W	W	W
West Virginia	277	17,300	W	W
Wisconsin	3,660 r	156,000 r	5,510	280,000
Other	11,400	359,000	19,700	948,000
Total	32,300 r	1,150,000 r	43,700	2,000,000

[r]Revised. W Withheld to avoid disclosing company proprietary data; included in "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 2011, BY SIZE OF OPERATION[1]

Size range	Number of operations	Percentage of total	Quantity (thousand metric tons)	Percentage of total
Less than 25,000	22	14	220	(2)
25,000 to 49,999	18	13	576	2
50,000 to 99,999	18	12	1,040	3
100,000 to 199,999	20	13	2,380	5
200,000 to 299,999	19	12	4,240	9
300,000 to 399,999	9	7	2,910	6
400,000 to 499,999	2	1	876	2
500,000 to 599,999	9	6	4,470	11
600,000 to 699,999	8	5	4,620	10
700,000 and more	25	16	22,400	51
Total	150	100	43,700	100

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Less than ½ unit.

TABLE 5
NUMBER OF INDUSTRIAL SAND AND GRAVEL OPERATIONS AND PROCESSING PLANTS IN THE UNITED STATES IN 2011, BY GEOGRAPHIC DIVISION

	Mining operations on land				
Geographic region	Stationary	Portable	Stationary and portable	Dredging operations	Total active operations
Northeast:					
New England	1	--	--	--	1
Middle Atlantic	5	--	1	2	8
Midwest:					
East North Central	40	--	--	2	42
West North Central	11	--	1	3	15
South:					
South Atlantic	17	1	--	3	21
East South Central	7	--	--	2	9
West South Central	32	--	1	4	37
West:					
Mountain	5	--	--	--	5
Pacific	11	--	--	--	11
Total	129	1	3	16	150

-- Zero.

TABLE 6
INDUSTRIAL SAND AND GRAVEL SOLD OR USED BY U.S. PRODUCERS IN 2011, BY MAJOR END USE[1]

Major use	Northeast Quantity (thousand metric tons)	Northeast Value (thousands)	Northeast Unit value[2] (dollars per ton)	Midwest Quantity (thousand metric tons)	Midwest Value (thousands)	Midwest Unit value[2] (dollars per ton)	South Quantity (thousand metric tons)	South Value (thousands)	South Unit value[2] (dollars per ton)	West Quantity (thousand metric tons)	West Value (thousands)	West Unit value[2] (dollars per ton)	U.S. total Quantity (thousand metric tons)	U.S. total Value (thousands)	U.S. total Unit value[2] (dollars per ton)
Sand:															
Glassmaking:															
Containers	W	W	$37.52	641	$12,700	$19.82	1,990	$56,000	$28.16	668	$17,000	$25.46	3,710	$101,000	$27.26
Flat, plate and window	W	W	48.58	697	20,900	29.93	1,320	27,500	20.90	481	12,400	25.75	2,630	67,100	25.55
Specialty	W	W	48.72	159	6,910	43.46	127	3,250	25.56	W	W	54.83	391	15,300	39.15
Fiberglass, unground	W	W	3.27	W	W	21.16	174	5,690	32.71	49	737	15.04	366	9,260	25.29
Fiberglass, ground	--	--	--	W	W	79.20	381	16,200	42.62	W	W	56.29	393	17,000	43.33
Foundry:															
Molding and core, unground	68	$2,480	36.51	4,100	152,000	37.06	472	16,800	35.53	38	283	7.45	4,670	171,000	36.65
Molding and core, ground	--	--	--	W	W	49.00	(3)	W	--	--	--	--	W	W	50.33
Refractory	W	W	13.00	W	W	64.00	67	1,920	28.72	(3)	(3)	--	69	2,000	29.00
Metallurgical, flux for metal smelting	--	--	--	--	--	--	W	W	22.50	W	W	8.13	W	W	11.00
Abrasives:															
Blasting	W	W	56.95	24	1,620	67.58	351	15,100	42.91	95	1,540	16.16	512	20,600	40.25
Chemicals, ground and unground	W	W	41.00	167	7,630	45.68	521	20,000	38.36	16	556	34.75	707	28,300	40.02
Fillers, ground, rubber, paints, putty, etc.	W	W	54.50	W	W	44.50	W	W	45.03	W	W	51.60	175	7,840	44.78
Whole-grain fillers/building products	329	12,900	39.20	522	25,800	49.40	543	19,800	36.52	480	16,000	33.41	1,870	74,600	39.80
Ceramic, ground, pottery, brick, tile, etc.	W	W	$71	14	970	69.29	41	1,460	35.71	W	W	40.00	106	6,120	57.70
Filtration:															
Water, municipal, county, local	44	2,450	55.77	537	40,600	75.62	52	4,550	87.46	17	646	38.00	650	48,300	74.24
Swimming pool, other	13	671	51.62	24	1,150	48.00	24	1,090	45.46	W	W	63.50	63	3,080	48.90
Petroleum industry:															
Hydraulic fracturing[4]	W	W	43.84	14,400	817,000	56.78	9,040	473,000	52.35	694	34,500	48.67	24,300	1,330,000	54.83
Well packing and cementing	4	462	115.50	50	3,400	68.02	488	19,000	38.91	17	283	16.65	559	23,100	41.39
Recreational:															
Golf course, greens and traps	52	2,270	43.60	128	4,600	35.93	261	4,420	16.93	108	3,220	29.84	548	14,500	26.48
Baseball, volleyball, play sand, beaches	36	1,690	47.00	35	854	24.40	74	2,360	31.84	14	473	33.79	159	5,380	33.81
Traction, engine	7	318	45.43	21	451	21.48	29	528	18.21	14	695	49.64	71	1,990	28.04
Roofing granules and fillers	W	W	49.21	67	1,410	21.10	345	9,110	26.40	64	1530	23.94	504	13,400	26.65
Other, ground silica	W	W	47.00	156	6,840	28.17	42	1,830	35.71	W	W	29.33	35	1,190	32.28
Other, whole grain	1,100	44,000	11.15	370	12,200	39.62	456	8,880	19.35	97	2,300	14.53	898	20,800	23.21
Total or average	1,650	67,200	40.75	22,100	1,120,000	50.54	16,800	709,000	42.20	2,850	92,200	32.32	43,400	1,980,000	45.74
Gravel:															
Silicon, ferrosilicon	--	--	--	--	--	--	157	4,120	26.23	2	48	24.00	159	4,170	26.20
Filtration	W	W	80.22	W	W	34.87	6	763	108.86	--	--	--	47	2,570	54.57
Other uses, specified	W	W	--	W	W	--	103	6,320	--	1	13	--	142	7,670	--
Total or average	13	930	71.54	66	2,210	33.42	266	11,200	42.10	3	61	20.33	348	14,400	41.37
Grand total or average	1,660	68,200	40.99	22,200	1,120,000	50.49	17,100	720,000	42.20	2,860	92,200	32.30	43,700	2,000,000	45.71

W Withheld to avoid disclosing company proprietary data; for sand, included in "Other, whole grain"; for gravel, included in "Total or average." -- Zero.

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

[2]Calculated using unrounded data.

[3]Less than ½ unit.

[4]Revisions for 2009 and 2010 are reported in text, page 66.1

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

(Thousand metric tons)

Destination	2010	2011	Destination	2010	2011
States:			States—Continued:		
Alabama	341	W	New Jersey	W	W
Alaska	W	W	New Mexico	68	W
Arizona	W	W	New York	W	W
Arkansas	410	623	North Carolina	W	W
California	1,260	1,300	North Dakota	230	330
Colorado	W	W	Ohio	425	259
Connecticut	W	W	Oklahoma	754	W
Delaware	W	W	Oregon	W	W
District of Columbia	W	W	Pennsylvania	1,270	1,140
Florida	W	254	Rhode Island	W	W
Georgia	614	W	South Carolina	W	W
Hawaii	W	W	South Dakota	W	3
Idaho	W	W	Tennessee	639	W
Illinois	1,500	W	Texas	4,350	5,920
Indiana	712	W	Utah	W	W
Iowa	W	W	Vermont	W	W
Kansas	W	W	Virginia	206	W
Kentucky	189	W	Washington	W	W
Louisiana	W	406	West Virginia	W	W
Maine	W	W	Wisconsin	W	W
Maryland	W	W	Wyoming	W	W
Massachusetts	W	W	Countries:		
Michigan	359	W	Canada	322	W
Minnesota	W	W	Mexico	174	337
Mississippi	W	W	Other	W	W
Missouri	W	W	Other:		
Montana	W	15	Puerto Rico	W	--
Nebraska	W	W	U.S. possessions and territories	--	W
Nevada	W	W	Destination unknown	18,400 r	23,100
New Hampshire	W	W	Total	32,300 r	43,700

[r]Revised. W Withheld to avoid disclosing company proprietary data; included in "Total." -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 8

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

(Thousand metric tons and thousand dollars)

Destination	2010 Quantity	2010 Value[2]	2011 Quantity	2011 Value[2]
Africa and the Middle East:				
Egypt	(3)	91	(3)	117
Israel	(3)	204	(3)	378
Other	2 r	1,390 r	--	995
Total	2 r	1,680	1	1,490
Asia:				
China	133	82,400	239	98,100
Hong Kong	2	584	1	329
Japan	1,270	51,300	1,340	48,700
Korea, Republic of	18	3,790	9	5,380
Singapore	4	1,420	2	966
Taiwan	1	1,010	7	1,830
Other	3	1,450	2	1,690
Total	1,430	142,000	1,600	157,000
Europe:				
Belgium	2	1,390	2	1,320
Germany	105	39,000	134	41,000
Italy	1	167	(3)	145
Netherlands	115	7,630	15	8,090
Russia	(3)	140	(3)	13
United Kingdom	2	2,340	2	2,880
Other	6	12,300	93	8,290
Total	229	62,900	246	61,700
North America:				
Bahamas, The	1	198	(3)	97
Canada	1,750	68,800	1,700	87,800
Mexico	480	36,300	702	47,700
Trinidad and Tobago	(3)	93	1	133
Other	12	1,970	20	1,870
Total	2,250	107,000	2,420	138,000
Oceania:				
Australia	3	1,390	23	1,250
New Zealand	(3)	74	1	71
Total	3	1,460	24	1,320
South America:				
Argentina	21	3,710	18	4,780
Brazil	1	1,350	3	1,010
Colombia	2	501	6	3500
Peru	15	1,980	15	2,110
Venezuela	(3)	133	1	412
Other	1	412	1	457
Total	40	8,080	44	12,300
Grand total	3,950	323,000	4,330	371,000

[r]Revised. -- Zero.

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

[2]Free alongside ship value of material at U.S. port of export. Based on transaction price, includes all charges incurred in placing material alongside ship.

[3]Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 9
U.S. IMPORTS FOR CONSUMPTION OF INDUSTRIAL
SAND, BY COUNTRY[1]

(Thousand metric tons and thousand dollars)

Country	2010 Quantity	2010 Value[2]	2011 Quantity	2011 Value[2]
Australia	1 r	1,160	2	943
Canada	103	4,080	106	5,860
Chile	--	--	1	162
China	(3)	281	1	684
Germany	(3)	671	(3)	529
Japan	(3)	105	(3)	19
Mexico	26	11,500	198	76,300
Netherlands	--	--	(3)	62
Other	2	1,490 r	8	3,340
Total	132 r	19,300 r	316	87,900

[r]Revised. -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Cost, insurance, and freight value of material at U.S. port of entry. Based on purchase price; includes all charges (except U.S. import duties) in bringing material from foreign country to alongside carrier.
[3]Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 10

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

(Thousand metric tons)

Country[3]	2007	2008	2009	2010	2011[e]
Algeria	254	243	118	84	100
Argentina	457	473	364	531 [r]	425
Australia[e]	5,300	5,500 [r]	5,600 [r]	5,300	5,600
Austria	1,915 [r]	2,175 [r]	1,200 [r]	939	1,500
Belgium[e]	1,800	1,800	1,800	1,800	1,800
Belize[e]	12	12	12	12 [r]	12
Bosnia and Herzegovina	671	702	525 [r]	495 [r]	1,100
Brazil, silex[e]	2	2	2	2	2
Bulgaria	551	734	657	660 [e]	660
Canada, quartz	1,987	1,979	1,296	1,171	1,431 [4]
Chile	1,234	1,401	1,405	1,326 [r]	1,237 [4]
Croatia	148	150 [e]	278	241	240
Cuba[e]	21	29	16	16	16
Czech Republic, foundry sand	1,792 [r]	1,853 [r]	1,364	1,361 [r]	1,350
Denmark, sales[e]	60	60	60	60	60
Ecuador[e]	34 [r]	25 [r]	74 [r]	-- [r]	--
Egypt[5]	1,725	1,612	1,342	1,757	1,800
Eritrea	1,000 [r]	1,000 [r]	1,000 [r]	1,000 [r]	1,000
Estonia, industrial sand	--	--	--	36	36
Ethiopia[6]	6	7	31 [r]	70 [r]	70
Finland	2,958	3,160	2,241	2,250	2,250
France[e]	5,000	5,000	5,000	5,000	5,000
French Guyana[e]	1,500	1,500	1,500	1,500	1,500
Gambia	712	1,065	1,062 [r]	1,121 [r]	1,200
Germany	8,382	8,186	6,453	7,234 [r]	7,770
Greece	100 [e]	65	38	38 [e]	38
Guatemala	68	65	36	62	62
Guyana[7]	715	684	479	652	652 [p, 4]
Hungary, foundry and glass sand	337	320	196	180	200
Iceland[e]	4	4	4	4	4
India[e]	1,600	1,700	1,700	1,800	1,800
Indonesia[e]	35 [r]	38 [r]	32 [r, 4]	36 [r]	37
Iran[e, 8]	2,000	2,000	1,500	1,500	1,500
Iraq	(9)	19	18	(9)	20
Ireland[e]	5	5	5	5	5
Israel	220	195	163	198	200
Italy[e]	14,000	14,000	19,759 [4]	19,800	19,800
Jamaica	14	15	7	13	13
Japan	4,314	3,664	2,856	3,078	2,900
Jordan	628	23	298	300 [e]	300
Kenya[e]	14 [r]	16 [r]	15 [r]	16 [r]	16
Korea, Republic of	2,227	1,757	455	535	500
Latvia	4,285	2,223	1,339	1,359	1,360
Lithuania	45	38	42	67	67
Malaysia	719	1,467	630	932	900
Mexico	2,950	2,779	2,484	2,608 [r]	2,570 [4]
Moldova[e]	272 [4]	200	150	195	200
Netherlands[e]	5	5	5	5	5
New Zealand	86	49	43	113 [r]	100
Nigeria	--	26	32	30 [e]	30
Norway[e]	1,500	1,500	1,500	1,500	1,200
Paraguay[e]	25	25	25	25	26
Peru[e]	900	900	900	900	900
Philippines	221	270	284	296 [r]	300
Poland	2,268	2,398	2,127 [r]	2,458 [r]	2,460
Portugal[e]	5	5	5	5	5
Romania[e]	520	520	520	520	520
Saudi Arabia	820 [e]	799	709	820	900

See footnotes at end of table.

TABLE 10—Continued

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

(Thousand metric tons)

Country[3]	2007	2008	2009	2010	2011[e]
Serbia[e]	-- r	-- r	-- r	-- r	--
Slovakia	591	619	502	500 e	500
Slovenia	350 e	354	327	330 e	325
South Africa	3,385 r	3,342 r	2,306 r	2,905 r	2,900
Spain[e]	5,000	5,000	5,000	5,000	5,000
Sri Lanka	70	61	60	68	65
Sweden[e]	700	700	700	700	700
Thailand	844	496	500	500 e	500
Turkey	4,998	2,423	4,499	4,000 e	5,000
United Kingdom	4,909	4,777	3,755	3,760 e	3,760
United States, sold or used by producers	30,100	30,400	27,500 r	32,300 r	43,700 4
Venezuela[e]	500	500	500	500	500
Total	129,000 r	124,000 r	116,000 r	124,000 r	138,000

[e]Estimated. [p]Preliminary. [r]Revised. -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through July 1, 2012.

[3]In addition to the countries listed, Angola, Antigua and Barbuda, The Bahamas, and countries of the Commonwealth of Independent States produce industrial sand, but current available information is inadequate to formulate reliable estimates of output levels. Based on estimates of glass end use consumption, China is the world's leading producer of industrial sand; however, available information is inadequate to formulate reliable estimates of output levels.

[4]Reported figure.

[5]Fiscal years beginning July 1 of that stated.

[6]Ethiopian calendar year ending July 7 of that stated.

[7]Source: Guyana Geology and Mines Commission and the Bank of Guyana.

[8]Fiscal years beginning March 21 of that stated.

[9]Less than ½ unit.