

# DIATOMITE

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Diatomite is a chalk-like, soft, friable, earthy, very fine-grained, siliceous sedimentary rock, usually light in color (white if pure, commonly buff to gray in nature, and reportedly rarely even black). It is very finely porous, very low in density (floating on water at least until saturated), and essentially chemically inert in most liquids and gases. It also has low thermal conductivity and a rather high fusion point. Diatomaceous earth (often shortened to “D.E.”) is a common alternate name but logically more appropriate for the unconsolidated or less lithified sediment. Many sediments and sedimentary rocks are somewhat diatomaceous. The deposits result from an accumulation in oceans or fresh waters of the amorphous silica (opal,  $\text{SiO}_2 \cdot n\text{H}_2\text{O}$ ) cell walls of dead diatoms that are microscopic single-cell aquatic plants (algae). The fossilized skeletal remains—a pair of symmetrical shells (frustules)—vary in size from less than 1 micron to more than 1 millimeter but are typically 10 to 200 microns across and have a broad variety of delicate, lacy, perforated shapes from discs and balls to ladders, feathers, and needles. There are more than 10,000 species of extinct and living diatoms, some of which live in marshes and even on moist bark, but they are most abundant in sunlit water constantly enriched with suitable nutrients and dissolved silica. Live cells are covered by a jelly, and masses appear as brownish water or films on stream bottoms. Blooms of algae (diatoms) in coastal waters have caused severe pollution, and some species produce domoic acid, a nerve poison that, if ingested, quickly causes death to many fauna. (Accessed May 13, 1998, at URL: <http://hjs.geol.uib.no/diatoms/hazards>).

Diatomite is also known as kieselgur (a German name compounded from the words for flint and for an earthy sediment in water) and as tripolite after an occurrence near Tripoli, Libya. In some government trade and tariff documents, “tripolite” is the short term for a longer description of “siliceous fossil meals...” used more generally in the several separate codes covering diatomite as a powder or as a block, natural or heat treated. An impure (up to 30% clay) Danish variety is called moler. There is confusion between diatomaceous earth and infusorial earth, which is logically more appropriate for the skeletal remains of infusoria (ciliata) or radiolaria, both minute aquatic single-cell animals (protozoa) having opaline silica as a shell (test); apparently such deposits are uncommon. Diatomite i.e., tripolite, is often also confused with tripoli, a lightweight, light-colored, very friable, very porous sedimentary rock that is a weakly consolidated aggregate of individual microcrystals of quartz. Known U.S. deposits occur in Paleozoic (about 240 million years) or older limestones that contain chert layers obviously related to the tripoli (Berg and Steuart, 1994, p. 1091-1093) and possibly originally diatomite deposits (Thurston, 1978, p. 122-123).

Diatomite, or diatomaceous earth, was apparently used by the ancient Greeks as an abrasive and in making lightweight building brick and blocks. In 535 A.D., blocks of diatomite were used for the 30-meter-diameter dome of the Church of St. Sophia in Istanbul, Turkey (Maurrasse, 1978, p. 263). However, it only became of industrial interest in Europe in the mid-1800's. One of the first uses at that time was as insulating brick. In the 1860's it became the preferred absorbent and stabilizer of nitroglycerine used by Alfred Noble to make dynamite. Maryland was the site of the first U.S. production of diatomite in 1884. By the late 1880's, the very pure, huge deposit near Lompoc, Santa Barbara County, CA, became the focus of interest and has continued to dominate the world's markets. Diatomite is now used principally as a filter aid but has other applications, such as a filler in many products (e.g., paints and plastics), as an absorbent for industrial spills and pet litter, as a mild abrasive in polishes, and as an insulation material.

Overall, at many commercial operations, the analysis of oven-dried crude ore blocks typically shows 80% to 90% (sometimes 95%) silica ( $\text{SiO}_2$ ) plus alumina (2% to 4% attributed mostly to clay minerals) and hematite (0.5% to 2%), with an analytical ignition loss of 4% to 6%. Apparent block density is 320 to 640 grams per liter (compared to water at 1,000 grams per liter) with 80% to 90% voids. In-place ore contains from 10% to as much as 65% water (2% to 10% in the opaline structure). Dry crude rock can absorb 1.5 to more than 3 times its weight of water. Dry powdered natural rock has an apparent density of 80 to 250 grams per liter. The melting point of diatomite ranges from 1,000° C to 1,750° C (Durham, 1973, p. 192; Breese, 1994, p. 398).

Commercial diatomite products provide fine-sized, irregular-shaped, porous particles having a large surface area and high liquid absorptive capacity that are very inert chemically (especially when iron is naturally low or altered in calcining), are mildly abrasive, have low thermal conductivity with a reasonably high fusion point, and can be produced and delivered at a cost consistent with customers' applications. Dimensioned bricks and blocks have been used for thermal and acoustic insulation, especially in the high-clay-containing Danish moler, but particulate products are more widely used and can be tailored to fit desired uses by blending various calcined and natural material. These properties result in industrial applications as a filtration media for sugar and sweetener liquors, oils and fats, beverages (especially beer and wine), water, chemicals (including dry-cleaning fluids), and pharmaceuticals; a filler (both as a functional pigment-like component and/or nonfunctional bulking or extending component) in paints and coatings, plastics, and portland cement, and in products that need an absorptive carrier (e.g., certain chemicals, especially catalysts, pesticides, and

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pharmaceuticals); an absorbent for industrial spills (e.g., oil and toxic liquids) and pet litter; a mild abrasive in polishes (sometimes considered a filler application); and as insulation, thermal and acoustic, in block or brick form, loose, or as a component in concrete and brick. Worldwide use, including moler, was estimated in 1993 as almost one-half for filtration, more than one-quarter for fillers, one-sixth for insulation, and about one-tenth for absorption and other applications (Roskill, 1994, p. 3).

Commercial diatomite product grades are affected by the size, shape, overall arrangement and proportions of the various types of frustules (particularly the effect on filtration rate and clarity, and absorptive capacity), and content of silica and various impurities, such as, certain minerals and chemicals (especially the form of iron, the major impurity), clay, sand, and organics. There are additional specialized application specifications, e.g., brightness/whiteness, absorptive capacity, and abrasiveness. Free crystalline silica content, although normally low, is also a specification required by some environmental regulations, particularly for calcined products. A major influence on the grade is the extent of processing, i.e., naturally milled and dried, simple calcined (to 1,000° C), or flux-calcined (to 1,200° C with the addition of up to 10% of sodium compounds, such as, soda ash, salt, or sodium hydroxide). When advantageous, calcining removes organics, reduces surface area (fuses fine structure) of particles and sinters them into small clusters, increases particle hardness, and oxidizes iron (changing the color of crude feed to pink); but also disadvantageously produces free silica. Flux-calcining further affects the physical and chemical properties and makes a white product. Many filter grades are calcined.

Deposits of various purity occur in many parts of the world and are occasionally mined only for limited local or special markets. Estimated world reserves are 800 million metric tons (250 million tons in the United States) which is equivalent to more than 400 times current estimated annual world production of almost 2 million tons (Antonides, 1998, p. 57). The world reserve base was estimated by the U.S. Bureau of Mines in 1985 to be almost 2 billion tons (Meisinger, 1985, p. 250). A resource estimate based just on the dimensions of the deposit near Lompoc suggests it alone could meet the world's current needs for centuries. However, data on reserves, defined as currently economic using proven practices, among other qualifications (U.S. Bureau of Mines and U.S. Geological Survey, 1980, p. 2), are not readily available and are difficult to calculate because, beyond considerable variation in physical and chemical properties between and even within deposits, the particular potential use and proximity to market are major considerations.

Commercial deposits worldwide are reported as mostly freshwater lake (lacustrine) deposits of Miocene to Pleistocene age (i.e., formed 24 million to 100 thousand years ago), although the less-common ocean (marine) deposits tend to be larger. The world's leading producing deposit (mined by two companies) that outcrops near Lompoc, is a huge, marine deposit of Miocene age. Some marine occurrences are more than twice as old (Cretaceous), but, usually, older occurrences have presumably been changed into other forms of silica. There are younger deposits, some developing even today. Worldwide, many deposits, especially the older marine type, have been found in uplifted

coastal areas exposed to some volcanic effects (e.g., Pacific Rim from Chile to Japan). Lake deposits, especially in mountainous localities, also often show some association with volcanic activity (e.g., Pacific Northwest). However, there are lake deposits presently forming in lowlands far removed from volcanic activity (e.g., Florida). In the United States, California also has other coastal marine deposits (undeveloped) with interior lake deposits (few developed); Nevada has several lake deposits (several developed); Arizona, Idaho, Oregon, and Washington each have several lake deposits (at least one developed in each State); Kansas has a deposit (last mined in the 1970's); Maryland and Virginia have low-purity marine deposits (no longer developed); Florida, New Hampshire, and New York have diatomaceous sediments in existing lake bogs (undeveloped). Several other States possibly have some deposits about which information is not readily available. Outside the United States, there are many known deposits on the Pacific Rim from Chile to British Columbia and from Japan, Korea, and Eastern China to Southeast Asia and Australia; and others are in Western Europe and Eastern Europe, the Middle East, and Eastern Africa. Most deposits are estimated as less than 5 million tons and only a very few are greater than 50 million tons, although most have limited production or prospects for development.

Exploration involves a normal sequence of first locating areas having appropriate stratigraphic horizons by using existing and/or new field mapping, aerial photography, and other remote imaging, as applicable; next, field searching for outcrops; and then sampling (chip, drill, or pit) as appropriate for analysis to decide if the potential quality and size are sufficient to do preliminary economic studies. If results are promising, several campaigns of successively more detailed sampling, eventually by trenching or other bulk sampling methods are normally conducted. Such samples are needed for analysis to estimate the size and content of the deposit and for conducting processing and economic studies that are progressively more accurate and give greater certainty. Potential customers are frequently provided samples for testing and to obtain comments on commercial acceptability.

## **Production**

Recovery of diatomite from most deposits is by low-cost open pit mining because many occurrences are at or near the surface and the topography is suitable. To remove overburden and excavate ore, different combinations of rippers, dozers, scrapers, front-end loaders, power shovels and dump trucks are used. However, outside the United States (e.g., in France and Chile) underground mining is common owing to deposit form and depth, and topographic and other restraints. Usually, room and pillar methods, often with equipment similar to that in open pits, are used, but the smallest mines use hand tools. Explosives are not normally needed at surface or underground mines because of the rock's soft, friable nature. In Iceland, dredging is used to recover diatomaceous mud from the bottom of a lake. As permitted by climate, at many mines the ore is stockpiled in the open to segregate it by grade and to reduce the normally high moisture content before delivering it to the processing facility.

Diatomite processing is usually done near the mine to reduce

the cost of hauling up to 65% water, but the cost of delivering energy (electric power and fuel) to the site is an offsetting consideration. Processing typically involves a series of crushing, drying, multiple steps of further size reduction, and calcining operations, using heated air for conveying and classifying within the plant. Commonly, spiked rolls and hammer mills are used for primary crushing to minus 1.25 centimeters (0.5 inches), while limiting damage to the diatomite structure. With the heated air and multiple passes through special “milling” fans and air cyclones, further drying, size reduction, and classifying are accomplished. The cyclones not only classify for size but also remove undesirable components in the raw feed based on weight differences. Size reduction aims at separating individual frustules without destroying their delicate structure. Fines, especially from baghouses used to remove particulates from the cyclone discharge waste or recycle air, are used mostly for filler grade products; and the coarser bottom discharge particles are used for filter grades. Calcining is normally done in rotary kilns to effect the physical and chemical changes previously mentioned. Plant operators take special precautions to overcome any free crystalline silica health hazards, particularly to the lungs, by containing dust within enclosures and requiring employees to use respirators. Although the generally high moisture in the ore reduces the free crystalline silica health hazards in mining areas, precautions are still taken.

Production cost allocations were reported for the United States in 1983 as 10% mining, 60% processing, and 30% packing and shipping; and a 1990 report stated energy costs were 25% to 30% of direct costs (Breese, 1994, p. 405). The proportion of the product that is calcined directly affects energy consumption.

For the United States, the diatomite production data used to prepare table 1 were collected by a voluntary survey of known producers who gave a 100% response. These surveys cover 7 diatomite-producing companies with 13 individual mining areas and 12 processing facilities in California, Nevada, Oregon, and Washington. Major producers were Celite Corp. (Lompoc, CA, and Quincy, WA); Eagle-Picher Industries Inc. (Lovelock and Fernley NV, and Vale, OR); and Grefco Minerals, Inc. (Burney and Lompoc, CA, and Mina, NV). Smaller producers were Calveras Cement Co. (Burney, CA); CR Minerals Corp. (Fernley, NV); Moltan Co. (Fernley, NV); and Oil-Dry Production Co. (Christmas Valley, OR). California continued to be the lead producing State, followed by Nevada. Together their production accounted for more than 80% of the U.S. production. Except for the major marine deposit at Lompoc, lake deposits are currently the source of U.S. production.

The United States is the world’s largest producer and consumer of diatomite. U.S. production sold or used in 1997 increased about 6% to 773,000 tons valued at \$189 million f.o.b. plant, comparable with 1996 production sold or used of 729,000 tons valued at \$177 million f.o.b. plant. (See table 1.) These figures are revisions that include data received late this year from a producer not previously submitting a report and from another that revised previously submitted figures. Although the new data affects our figures for many years, the adjustments still show a gradual increase in production sold or used for the past 6 years (1992 through 1997) totaling about 20% in tonnage and 33% in total value.

## Consumption

Apparent domestic consumption (production sold or used plus imports minus exports; stock data are not available) of diatomite, using revised data, in 1997 was 635,000 tons, an 8% increase over 1996’s 588,000 tons. The major products were various grades of calcined powders, principally for filtration. (See table 2.)

In 1997, sales (total domestic and export value of production sold or used) of filter-grade diatomite by U.S. producers were 492,000 tons, 5% more than in 1996. Sales for diatomite for absorbents, the second largest use, were 107,000 tons, 11% more than in 1996. Filler use accounted for 93,000 tons, 3% more than in 1996. Comparing 1997 with 1996, sales for insulation were down 12% to 21,000 tons. “Other” uses were up 30% to 61,000 tons, including a significant portion used in cement manufacturing. During the last 6 years, comparing 1997 with revised 1992 data for percentage of total use, filter and filler use have decreased to 63% from 66%, and to 14% from 16%, respectively, while insulation remained unchanged at about 3%. The “Other” category, including absorbent and cement manufacture, has increased to 22% from 15%.

## Prices

The estimated average unit value of U.S. diatomite in 1997 was \$244 per metric ton f.o.b. plant compared with \$242 per ton, in 1996. (See table 3.) The average values per ton for the major end uses in 1997 were \$279 for filtration, \$164 for absorbents, and \$298 for fillers. Comparing 1997 unit values with those for 1992 (revised), in then current dollars, the total average has increased \$24 per ton from \$220, filter and filler grades have each increased about \$30, insulation grades have decreased about \$20, and the “Other” category (including absorbent grades for 1997 as in 1992) has increased almost \$60, principally owing to the value of absorbents.

## Foreign Trade

Exports of diatomite from the United States in 1997 were 140,000 tons, less than 20% of domestic production and 2% less than 1996 exports. (See table 4.) Products went to 68 countries. Main export markets were Canada (25,000 tons), Belgium (24,000 tons), and Germany (14,000 tons). Other major markets included Japan (10,000 tons), the United Kingdom (8,000 tons), and Australia (7,000 tons). The average unit value of exported diatomite was \$305 per ton f.a.s., comparable with values of \$294 in 1996 and \$311 in 1992.

Imports of diatomite were 2,040 metric tons, almost 93% from France and about 7% from Italy.

## World Review

World production, not including not yet quantified production in China and Japan (conceivably totaling 200,000 to 300,000 tons), continued to gradually increase for the fifth year with 1997 output slightly more than 1.5 million tons, 2% more than 1996. (See table 5.) Based on the 1.5 million tons, major producers were

the United States at more than 50%, followed by Denmark with more than 6% (99% molar), and France and the Republic of Korea at 5% each. Mexico, Spain, and Germany each produced a smaller proportion. The former Soviet Union countries together accounted for 6% of world production. However, China and Japan could each have an output greater than Denmark thus changing the percentages significantly. The output of each of the three leading U.S. producers was greater than that of any other country for which production has been quantified.

## Outlook

The diatomite market is mature and generally stable with industry representatives expecting the next 5 years to be similar to the past 5 years. The recent encroachments into filter applications by more advanced technology (ceramic, polymeric, and carbon membranes) seem to be moderating because of cost factors even though disposal of diatomite waste has become a problem not fully solved by recycling. New niche uses for filler grades continue to appear, and absorbent use reportedly is growing. A concern over free crystalline silica associated with diatomite seems to persist despite efforts to resolve it.

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## SOURCES OF INFORMATION

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### Other

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<sup>2</sup>Prior to January 1996, published by the U.S. Bureau of Mines

TABLE 1  
DIATOMITE SOLD OR USED, BY PRODUCERS IN THE UNITED STATES 1/

(Thousand metric tons and thousand dollars)

	1996 r/	1997
Domestic production (sales)	729	773
Value	\$177,000	\$189,000

r/ Revised.

1/ Data are rounded to three significant digits.

TABLE 2  
DIATOMITE SOLD OR USED, BY MAJOR USE 1/

(Percent of U.S. production by tons)

	1996	1997
Absorbents	14	14
Fillers	12 r/	12
Filtration	65 r/	63
Insulation	3	3
Other 2/	6 r/	8

r/ Revised.

1/ Includes exports.

2/ Includes silicate admixtures, especially for cement.

TABLE 3  
AVERAGE ANNUAL VALUE PER METRIC TON OF DIATOMITE, BY MAJOR USE 1/

	1996	1997
Fillers	\$292.56	\$297.56
Filtration	268.42	278.52
Insulation	115.72	127.38
Other 2/	147.35 r/	127.70
Weighted average	242.42 r/	243.99

r/ Revised.

1/ Based on unrounded data.

2/ Includes absorbents and silicate admixtures.

TABLE 4  
U.S. EXPORTS OF DIATOMITE 1/

(Thousand metric tons and thousand dollars)

Year	Quantity	Value 2/
1996	143	42,000
1997	140	42,600

1/ Data are rounded to three significant digits.

2/ Free alongside ship (f.a.s.) U.S. customs value.

Source: Bureau of the Census.

TABLE 5  
DIATOMITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons)

Country	1993	1994	1995	1996	1997 e/
Algeria e/	3 3/	4	4	4	4
Argentina	3	6	5	9 r/	5
Australia e/	11	11	11	11	11
Brazil (marketable)	16	17	14	14 e/	14
Canada e/ 4/	10	10	10	10	10
Chile	6	10	11 r/	10 e/	10
Colombia e/	4	4	4	4	4
Costa Rica e/	7 r/	7 r/	7 r/	8 r/	8
Czech Republic	39	40	29	35	30
Denmark: e/ 5/					
Diatomite	1	1	1	1	1
Moler	95	95	95	95	95
France e/	85	90	80	85	80
Germany e/	52 3/	52	50	50	50
Iceland e/	19	25 3/	24	20	20
Iran e/ 6/	(7/) 3/	(7/)	(7/)	(7/)	(7/)
Italy e/	25	25	25	25	25
Kenya	1	1	(7/) r/	(7/) r/	(7/)
Korea, Republic of	67	83	81	70 r/	70
Macedonia e/	5	5	5	5	5
Mexico	46	52	50 r/	52 r/	54
Peru e/	35	35	35	35	35
Poland	2	3	2	2 e/	2
Portugal	2	2	2 e/	2 e/	2
Romania	10	35	50 r/	60 r/	60
Spain e/	38	36	36	40	40
Thailand	8	6	6	6 e/	6
U.S.S.R., former e/ 8/	150	120	110	100	90
United Kingdom e/	(7/) 3/	(7/)	--	--	--
United States 9/	649 r/	646 r/	722 -/ e/	729 r/	773 3/
Total	1,390 r/	1,420 r/	1,470 r/	1,480 r/	1,500

e/ Estimated. r/ Revised.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through April 7, 1998, except for not yet quantified production in China and Japan.

3/ Reported figure.

4/ Includes an unknown quantity of fuller's earth.

5/ Data represent sales.

6/ Data are for Iranian years beginning March 21 of that stated.

7/ Less than 1/2 unit.

8/ U.S.S.R. dissolved in December 1991; however, information is inadequate to formulate reliable estimates for individual countries.

9/ Sold or used by producers.