

History and Overview of the U.S. Diatomite Mining Industry, with Emphasis on the Western United States

Chapter E of
Contributions to Industrial-Minerals Research

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History and Overview of the U.S. Diatomite Mining Industry, with Emphasis on the Western United States

By Thomas P. Dolley and Phillip R. Moyle

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James D. Bliss, Phillip R. Moyle, and Keith R. Long, Editors

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History and Overview of the U.S. Diatomite Mining Industry, with Emphasis on the Western United States

By Thomas P. Dolley and Phillip R. Moyle

Abstract

The United States is the largest producer and consumer of diatomite in the world. In 2001, the United States produced about a third of the estimated global production of 1.95 million metric tons (Mt) of diatomite (Dolley, 2003). In any given year, the United States accounts for at least 50 percent of all the diatomite exported in the world (Roskill, 1994). Seven diatomite companies operating in the United States produce diatomite in various grades for a range of applications, including filtration, absorbents, fillers, insulation, and cement manufacture. Economic deposits of diatomite within the United States depend on variations in the physical and chemical properties between and within deposits, potential end uses, and proximity to suitable markets. On the basis of historical production figures, estimated U.S. diatomite-production capacity is currently about 800,000 metric tons per year (t/yr).

Introduction

In 2001, the United States was the world's largest producer and consumer of diatomite, producing 644,000 metric tons (t), which accounted for about 33 percent of global production (table 1). The Western United States (California, Nevada, Oregon, and Washington) are the primary source of U.S. production of diatomite; the largest single amount comes from the marine diatomite deposits of Lompoc, Calif. (fig. 1). Within the United States, cumulative production of diatomite from all lacustrine deposits combined exceeds production from the Lompoc marine deposits. Additional information on the characteristics of marine and lacustrine deposits is presented in chapter D of this Bulletin (Moyle and Dolley, 2003). Seven diatomite companies operating in the United States produce diatomite for a range of applications; major diatomite products are sold in various grades of calcined powders. Diatomite continues to be used primarily for filtration (beer, cooking oils, wine); other major uses are as absorbents, filler applications, and insulation and in cement manufacture. With a diatomite production averaging about 350,000 t/yr, China is the United States' main competitor. The statistical data used in this chapter were generated by the U.S. Bureau of Mines and the U.S. Geological Survey, unless otherwise noted.

History and Overview of the Diatomite Industry

References to diatomite date back to the “floating bricks” mentioned by the early Greeks and Romans, although it is difficult to ascertain whether the references

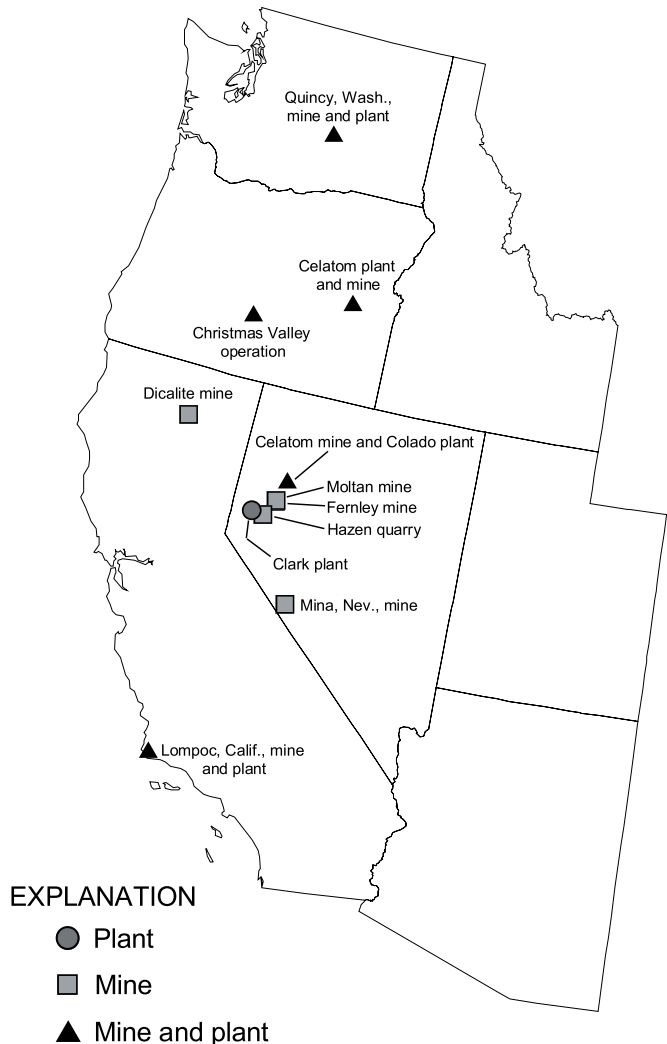


Figure 1. Sketch map of the Western United States, showing locations of principal diatomite operations.

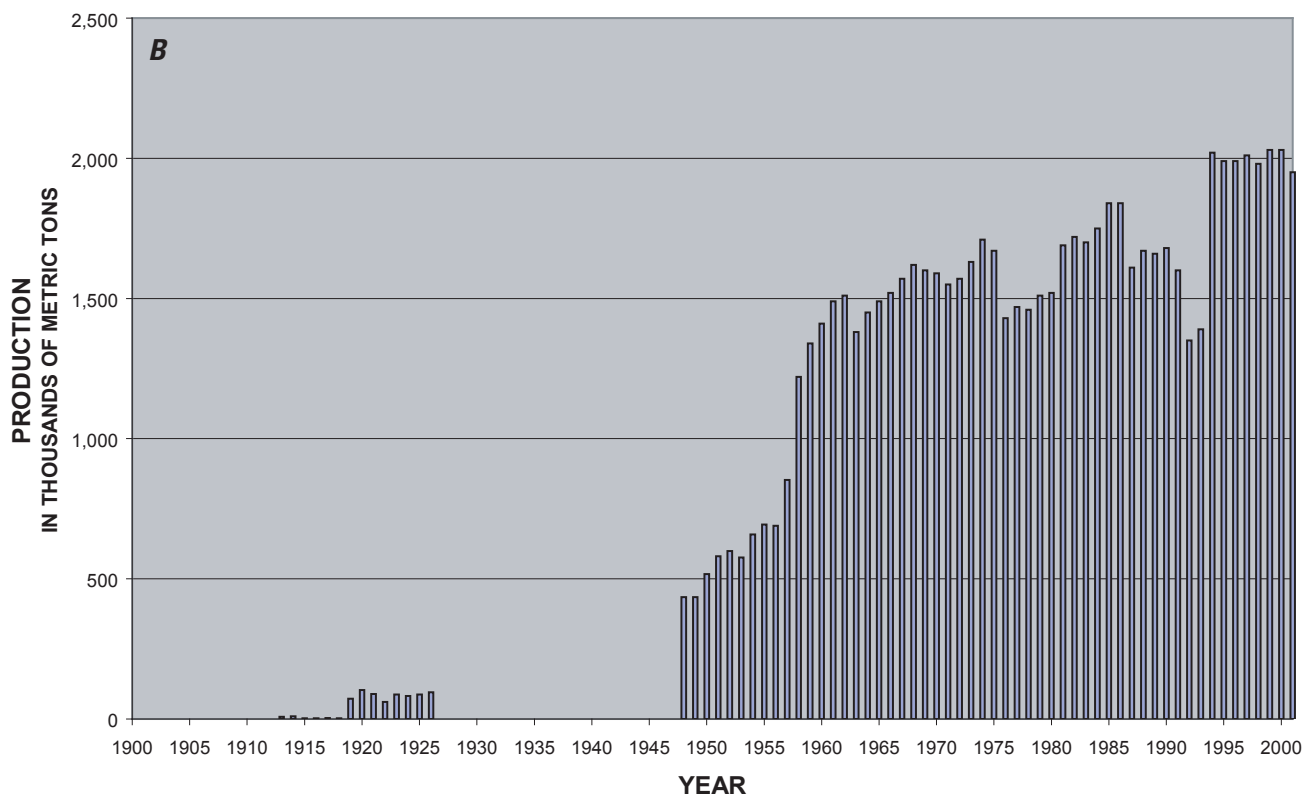
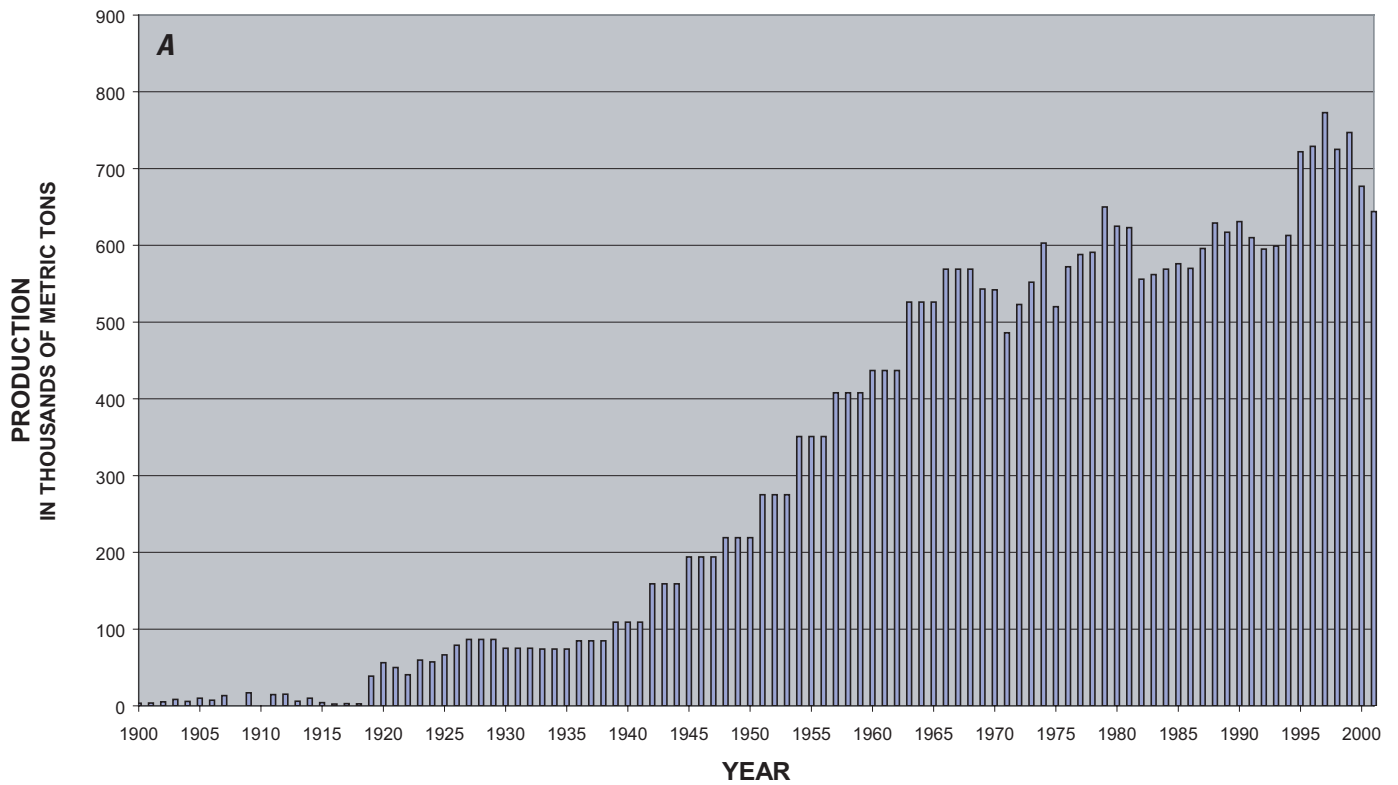


Figure 2. Bar charts showing diatomite production in the United States (A) and worldwide (B) and diatomite consumption by end use over the past 30 years (C).

are to pumice or another siliceous material than diatomite. Although pumice and other similar materials were evidently used in antiquity as lightweight building materials, early descriptions of the “floating bricks,” such as their plasticity and their forming and burning as opposed to cutting from a natural material, indicate diatomite rather than pumice. In A.D. 535, the Roman Emperor Justinian I used diatomite bricks to lighten the construction of a 30-m-diameter dome for the Church of St. Sofia in Constantinople (Maurrasse, 1978).

In the United States, three main types of diatomite deposit are recognized: (1) marine (oceanic) rocks that accumulated near continental margins; (2) lacustrine (fresh-water) or nonmarine rocks that formed in lakes or marshes; and (3) sedimentary rocks in modern lakes, marshes, and bogs. An example of the first type are the diatomite deposits of Lompoc, Calif.; other marine diatomite deposits in Maryland and Virginia are presently uneconomic. Examples of the second type are the diatomite deposits of Idaho (uneconomic), Nevada, Oregon, Washington, and eastern California. Examples of the third type are diatomaceous sedimentary rocks in Florida, New Hampshire, and New York that are currently uneconomic (Durham, 1973). (See

Wallace, 2003, for additional information on the geologic setting of diatomite in the Western United States.)

Historical statistics for U.S. and worldwide diatomite production are plotted in figures 2A and 2B and listed in table 1. U.S. diatomite production peaked in 1997 at 773,000 t, with apparent consumption (defined as production minus exports plus imports) reaching a historical high of 635,000 t. Statistics show that U.S. diatomite production started a slow rise to modern levels in 1919 at 38,700 t, partly because of the buildup to World War II and diatomite’s use by the U.S. military for water filtration during that war.

Early Developments of the U.S. Diatomite Industry

The first discovery of diatomite in North America was by J.W. Bailey in 1839 near West Point, N.Y. Alfred Nobel’s invention of dynamite in 1867 spawned the world’s first significant diatomite industry because dynamite and nitroglycerine explosives required significant amounts of diatomite as an absorbent and stabilizer, and so operations began to flourish. Diatomite was first produced in the United States

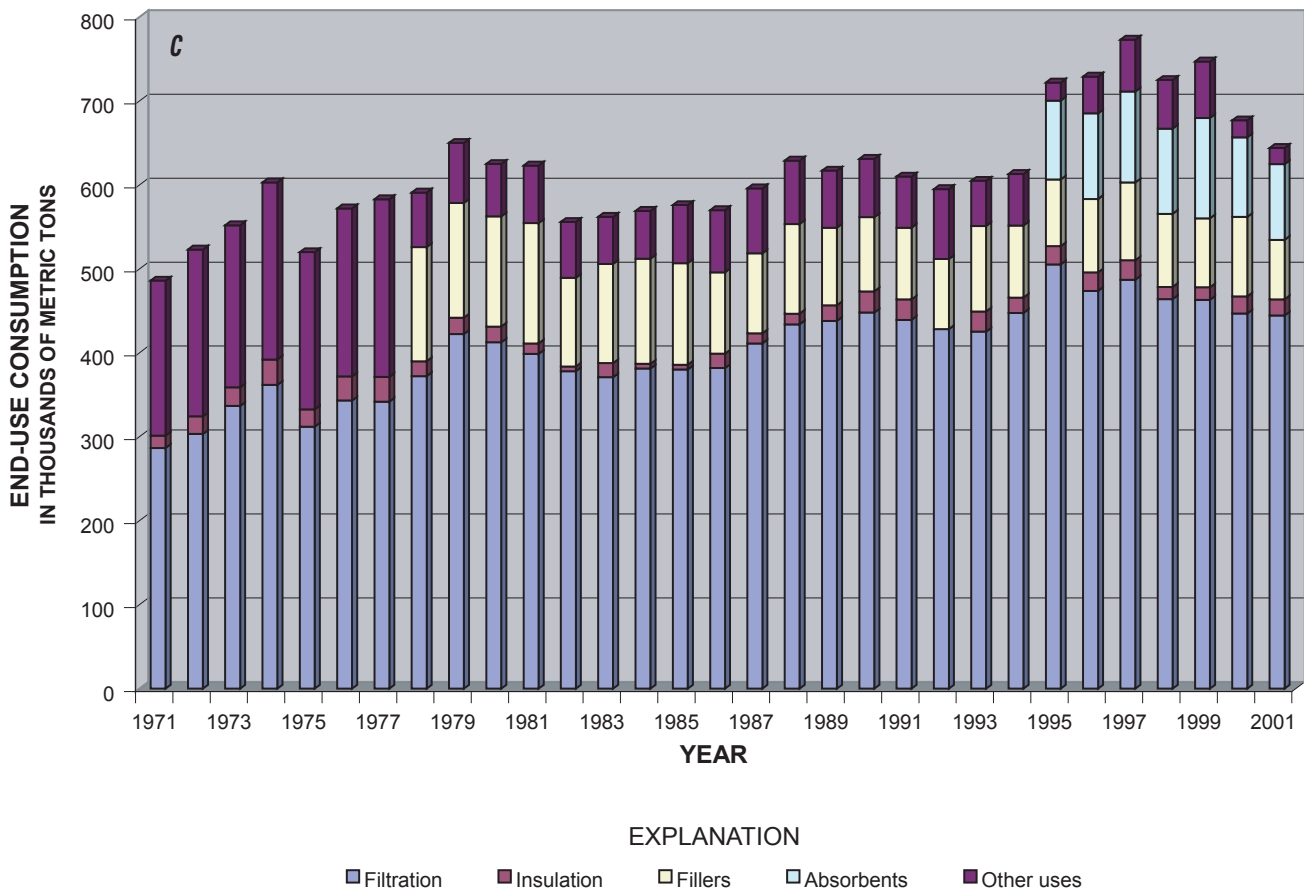


Figure 2. Continued.

Table 1. Historical statistics for U.S. and worldwide diatomite production.

[Data from U.S. Bureau of Mines/U.S. Geological Survey “Minerals Yearbook” (MYB), 1932–94 and 1995–2000, and its predecessor, “Mineral Resources of the United States” (MR), 1900–23 and 1924–31, and “Mineral Commodity Summaries” (MCS), 1978–95, 1996, and 1997–2002; blanks, data unavailable or proprietary. U.S. production data for years 1900–21 from MR and MYB; for years 1900–12, summed weights of infusorial earth (diatomite) and tripoli produced within the United States; for years 1908 and 1912, proprietary; for years 1915–18, incomplete because many data were proprietary. Imports: for years 1946–63, proprietary; for years 1964–2000, from MYB. Exports: for years 1946–57, proprietary; for years 1958–2000, from MYB. Worldwide production data for years 1913–26 and 1948–2000 from MR and MYB]

Year	U.S. production	Imports	Exports	Worldwide production	Year	U.S. production	Imports	Exports	Worldwide production
1900	3,280	--	--	--	1952	275,000	--	--	599,000
1901	3,650	--	--	--	1953	275,000	--	--	576,000
1902	5,140	--	--	--	1954	351,000	--	--	658,000
1903	8,360	--	--	--	1955	351,000	--	--	694,000
1904	5,690	--	--	--	1956	351,000	--	--	689,000
1905	9,960	--	--	--	1957	408,000	--	--	853,000
1906	7,350	--	--	--	1958	408,000	--	54,400	1,220,000
1907	13,400	--	--	--	1959	408,000	--	64,400	1,340,000
1908	--	--	--	--	1960	437,000	--	83,500	1,410,000
1909	16,900	--	--	--	1961	437,000	--	86,200	1,490,000
1910	--	--	--	--	1962	437,000	--	98,900	1,510,000
1911	14,600	--	--	--	1963	526,000	--	102,000	1,380,000
1912	15,200	--	--	--	1964	526,000	519	116,000	1,450,000
1913	5,970	--	--	8,050	1965	526,000	160	103,000	1,490,000
1914	9,990	--	--	10,100	1966	569,000	0	131,000	1,520,000
1915	4,170	--	--	2,810	1967	569,000	140	134,000	1,570,000
1916	2,470	--	--	2,710	1968	569,000	120	149,000	1,620,000
1917	2,750	--	--	3,660	1969	543,000	43	160,000	1,600,000
1918	2,690	--	--	2,850	1970	542,000	439	140,000	1,590,000
1919	38,700	--	--	72,500	1971	486,000	120	129,000	1,550,000
1920	56,200	--	--	103,000	1972	523,000	57	134,000	1,570,000
1921	50,000	--	--	89,100	1973	552,000	149	161,000	1,630,000
1922	40,600	--	--	60,800	1974	603,000	3,350	169,000	1,710,000
1923	59,700	--	--	87,500	1975	520,000	3,480	133,000	1,670,000
1924	57,300	--	--	82,500	1976	572,000	4,680	135,000	1,430,000
1925	66,300	--	--	87,400	1977	588,000	591	138,000	1,470,000
1926	79,000	--	--	95,000	1978	591,000	181	139,000	1,460,000
1927	86,600	--	--	--	1979	650,000	479	154,000	1,510,000
1928	86,600	--	--	--	1980	625,000	268	157,000	1,520,000
1929	86,600	--	--	--	1981	623,000	349	147,000	1,690,000
1930	75,100	--	--	--	1982	556,000	229	128,000	1,720,000
1931	75,100	--	--	--	1983	562,000	314	132,000	1,700,000
1932	75,100	--	--	--	1984	569,000	307	115,000	1,750,000
1933	73,900	--	--	--	1985	576,000	4,490	109,000	1,840,000
1934	73,900	--	--	--	1986	570,000	711	119,000	1,840,000
1935	73,900	--	--	--	1987	596,000	6,030	126,000	1,610,000
1936	84,600	--	--	--	1988	629,000	2,720	147,000	1,670,000
1937	84,600	--	--	--	1989	617,000	838	137,000	1,660,000
1938	84,600	--	--	--	1990	631,000	689	144,000	1,680,000
1939	109,000	--	--	--	1991	610,000	436	152,000	1,600,000
1940	109,000	--	--	--	1992	595,000	--	163,000	1,350,000
1941	109,000	--	--	--	1993	599,000	--	165,000	1,390,000
1942	159,000	--	--	--	1994	613,000	379	157,000	2,020,000
1943	159,000	--	--	--	1995	722,000	259	144,000	1,990,000
1944	159,000	--	--	--	1996	729,000	1,550	143,000	1,990,000
1945	194,000	--	--	--	1997	773,000	2,040	140,000	2,010,000
1946	194,000	--	--	--	1998	725,000	816	138,000	1,980,000
1947	194,000	--	--	--	1999	747,000	387	123,000	2,030,000
1948	219,000	--	--	435,000	2000	677,000	529	131,000	2,030,000
1949	219,000	--	--	435,000	2001	644,000	1,990	148,000	1,950,000
1950	219,000	--	--	517,000					

in 1884 from a deposit in Maryland; small-scale commercial development of diatomite also occurred in California in 1889 (Cummins, 1975; Dolley, 2002).

By 1900, uses for diatomite had expanded to include building materials, polishing compounds, filtration, filler material in rubber, paint, roofing, and paper—a prelude to

its worldwide use in the 20th century. In 1900, the first U.S. patent was issued for the use of diatomite in beer filtration, one of diatomite’s primary applications in modern times. In 1900, U.S. diatomite production was about 3,300 t. During the 1920s, the development of processing techniques (such as calcination, flux calcination, and grade and sizing tech-

nologies) enabled diatomite to be used in various market applications and end uses. The use of diatomite for beer and wine filtration became more widespread after the repeal of Prohibition in 1933; previously, breweries utilized a wood-pulp filtration process (Cummins, 1973).

The growth of the U.S. diatomite industry approximately paralleled the rise of industrialization in the United States. The industry grew gradually during the 1920s; however, significant changes took place during World War II. Just before that war, the industry was dominated by Johns Manville Corp. and Dicalite Corp. at their operations in California and Nevada; both of these companies were planning an expansion of their operations before World War II.

The primary consumers of diatomite during World War II were the U.S. Army (as a lightweight material for water purification) and the U.S. Navy (for water purification, removal of oil from boiler and engine water, and low-light-reflectance paints for ships). Production increased during the war, but shortfalls occurred at Lompoc in spring 1945, owing to a lack of skilled labor and spare parts for machinery. At one point, military personnel provided labor from a nearby U.S. Army base. Additionally, an attempt was made to use German prisoners of war at the minesite, but this plan failed (Gitter, 1945).

Post-World War II economic growth resulted in production-capacity increases to accommodate emerging diatomite markets, a trend that continued into the 1960s and 1970s. This period also featured an increase in corporate consolidation, resulting in a mature and modern diatomite industry (Cummins, 1973).

The economic recession of 1982 severely affected global diatomite consumption, resulting in U.S. production declines in the early 1980s. During this period, U.S. diatomite exports first felt the negative impact of emerging regional diatomite producers and their intrusion into foreign markets, particularly in the circum-Pacific region. Production amounts did not recover to pre-1980 levels until 1990. Additionally, by the mid-1980s, the U.S. diatomite industry had a 25-percent production overcapacity (Miles, 1987). U.S. production-capacity increases in the 1990s fell far short of those that occurred immediately after World War II.

Current State of the U.S. Diatomite Industry

As of 2001, the U.S. diatomite industry is dominated by three major producers: Celite Corp. (Lompoc, Calif., and Quincy, Wash.); Eagle-Picher Industries, Inc. (Lovelock and Fernley, Nev., and Vale, Oreg.); and Grefco Minerals, Inc. (Mina, Nev.). California is the leading diatomite-producing State, followed by Nevada; together, these two States accounted for about 86 percent of total U.S. production in 2001 (Dolley, 2003). On the basis of historical production figures, estimated U.S. diatomite production-capacity is currently about 800,000 t/yr.

The World Diatomite Industry

World diatomite-production data for the years 1913–26 and 1948–2001 are plotted in figure 2B and listed in table 1. The United States is the world's largest diatomite producer, and the growth of the global industry can be said to parallel developments in the United States. Worldwide diatomite production peaked in 1999 and 2000 at slightly more than 2 Mt and in 2001 was about 1.95 Mt. Major diatomite producers in 2001 were the United States, accounting for 33 percent of worldwide production, followed by China (18 percent), Japan (10 percent), Denmark (approx. 9 percent, all moler products, which contain 30 weight percent clay), Mexico (5 percent), and some former Soviet Union countries (approx 4 percent) (Dolley, 2003). In any given year, the United States accounts for at least 50 percent of all diatomite exported in the world (Roskill, 1994). Increasing diatomite-production capacity and industry development in certain Pacific Rim nations could negatively affect U.S. overseas markets in the future.

Production and Processing Methods

Several companies mine and process diatomite by using various techniques at many different locations in the Western United States (fig. 1). The flow diagram shown in figure 3 demonstrates the major steps common to most mining and processing of diatomite. Recovery of diatomite from most U.S. deposits is by low-cost open-pit mining because many occurrences are at or near the surface. To remove overburden and excavate ore, different combinations of rippers, dozers, scrapers, front-end loaders, power shovels, and dump trucks are used. Outside the United States, however, underground mining is fairly common (such as in Chile, China, and France), owing to deposit form, depth, topography, and other physiographic constraints. Room-and-pillar methods generally are used, commonly with equipment similar to that used in open pits, but the smallest mines are excavated with hand tools. Explosives are not normally needed at surface or underground mines because of the softness and friability of the ore. In Iceland, dredging is used to recover diatomaceous mud from the bottom of Lake Myvatn. As weather permits, the ore is stockpiled in the open air to segregate it by grade and to reduce the normally high moisture content before delivering it to the processing facility (Dolley, 2002).

Diatomite processing is commonly done near the mine to reduce the cost of hauling mine-run rock, which may contain as much as 65 weight percent water, but the cost of delivering energy (electric power and fuel) to the site also is a consideration. Processing typically involves a series of crushing, drying, size-reduction, and calcining steps, and heated air is used for conveying and classifying within the plant. Commonly, spiked rolls and hammer mills are used for primary crushing to a size of 1.25 cm (0.5 in.), because they limit damage to the diatom structure. With the heated air and multiple passes through special “milling” fans and

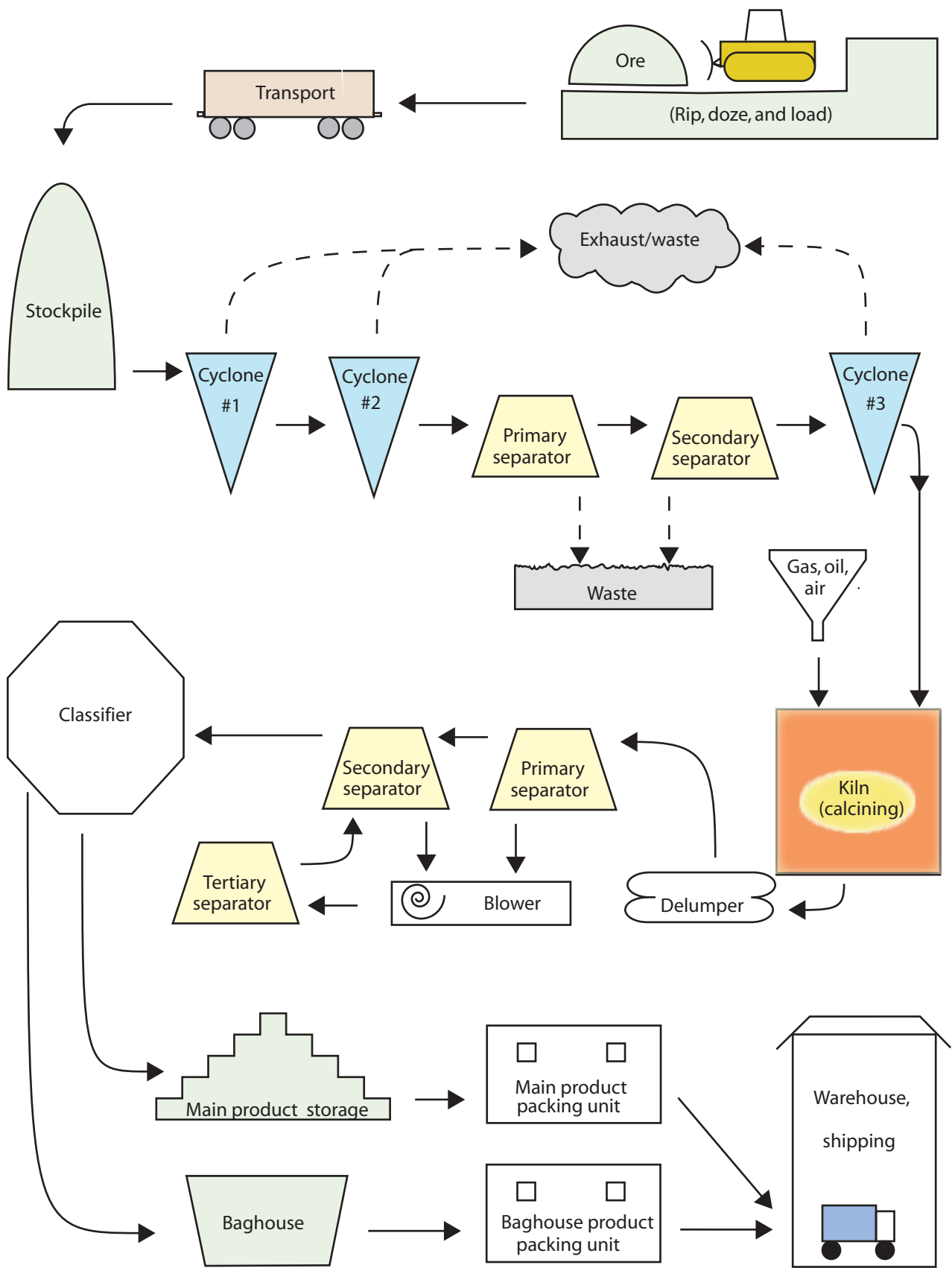


Figure 3. Flow diagram showing major steps in mining and processing of diatomite in the United States.

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 on the basis of density differences. The goal of size reduction is to separate individual frustules (one of a diatom's two valves) without destroying their delicate structure. Diatom structure is the single most important factor in filtration. In the later stages of processing, calcining is normally done in rotary kilns. Plant operators take special precautions to mitigate any health hazards from free crystalline silica in mining areas (Dolley, 2002).

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

Commercial diatomite products are offered in a great variety of grades. Principal factors are the size, shape, overall arrangement and proportions of the various types of frustule (factors that affect filtration rate, product clarity, and absorption capacity), and the contents of silica and impurities, such as certain minerals and chemicals (especially iron, a major impurity), clay, sand, and organic matter. Several additional specifications are made for certain applications, such as brightness/whiteness and abrasive hardness. Reduction in the content of free crystalline silica, though normally low, is also required by some environmental regulations, particularly for calcined products. A major influence on the deposit grade is the extent of processing within three broad classifications: naturally milled and dried; plain ("straight") calcined (to 1,000°C); and flux calcined (to 1,200°C with the addition of as much as 10 weight percent sodium compounds, such as soda ash, salt, or sodium hydroxide). Calcining removes organic matter, increases filtration rate (surface area is reduced by fusing more delicate structures of particles and sintering them into small clusters, resulting in larger particle size and increased pore size), oxidizes iron (changing the buff to gray colors common in crude ore feed to pink or white), increases specific gravity, and increases particle hardness but also produces free silica. The flux-calcining process produces a filter product characterized by faster flow rates. In flux calcining, a fluxing agent, such as soda ash, is added to the kiln feed to increase particle sintering and thus increase particle size. Flux calcining modifies the physical structure of frustules and converts iron oxides to a clear glassy phase to produce a range of white filter-grade product. Most filter grades are calcined (Dolley, 2002).

End Uses

Commercial diatomite products are fine-size, irregular porous noncaking particles with a large surface area and high liquid-absorption capacity. They are relatively inert chemically, have a low refractive index, are mildly abrasive, have a low thermal conductivity with a reasonably high fusion point,

can be slightly pozzolanic (chemically resistant and superior-strength cements), are very high in silica, and can be produced and delivered at a cost consistent with customer applications. Sawn shapes, which have long been used as lightweight building material (especially in China) and for primarily thermal insulation (especially the high-clay-content Danish moler), continue to account for a significant part of worldwide diatomite production. Dried natural products and calcined products are used in the above-mentioned applications. Particulate products are more widely used and can be tailored to fit desired uses by blending various grades of calcined and natural material. 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.

The most important use of diatomite, in a great variety of grades, is as a filtration medium for beverages (especially beer and wine), sugar and sweetener liquors, oils and fats, petroleum and chemical processing (including waste drycleaning fluids), pharmaceuticals, and water (potable, industrial process, waste, and swimming pool). A large and growing application is diatomite's use as an absorbent for industrial spills (oil and toxic liquids) and for pet litter. Another important broad category of use is as a filler, commonly serving a dual purpose, such as an extender and flattening agent in granular materials, a multieffect component in plastics (including the prevention of films from sticking), and an extender/absorbent carrier for dry pesticides, pharmaceuticals, catalysts, and other chemicals. Other significant uses are as an insulation material in bulk (loose) and in molded forms, in other insulation products that include calcium silicate as a component, and as a silica additive in various compounds, including mortar and portland cement, where it is also used for its pozzolanic properties. Emerging markets for diatomite include use in biotechnology and pharmaceuticals and as a nontoxic insecticide (Crossley, 2000, p. 135). In 2001, the percentage of U.S. diatomite production by end use was as follows: filtration, 69 percent; absorbents, 14 percent; fillers, 11 percent; insulation, 3 percent; and other (cement production and unspecified uses), 3 percent. Trends in U.S. diatomite end-use consumption from 1971 to 2001 are plotted in figure 2C (Dolley, 2003).

Conclusions

The U.S. diatomite industry appears to be mature and generally stable at the beginning of the 21st century. Increasing energy costs and possible global production overcapacity may represent impediments to future expansion. The past encroachments into filter applications of diatomite by more advanced technology (ceramic, polymeric, and carbon membranes) apparently are not of major concern to producers, possibly because of cost factors. Disposal of diatomite waste, however, is a problem not fully resolved by recycling. The problem of free crystalline silica associated with diatomite, particularly when calcined, continues to be of concern (Dolley, 2002).

Acknowledgments

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