ABRASIVE MATERIALS.

DIATOMACEOUS DEPOSITS OF NORTHERN SANTA BARBARA COUNTY, CAL.

By Ralph Arnold and Robert Anderson.

INTRODUCTION.

During the summer of 1906 the writers, with the assistance of H. R. Johnson, made a more or less detailed survey of the Lompoc and Guadalupe quadrangles, California, embracing the Santa Maria oil field of northern Santa Barbara County, to determine the areal distribution and structure of the oil-bearing formations within their boundaries.[a] The diatomaceous deposits that were examined during the course of the investigations occur in such practically inexhaustible quantities in proximity to railroad and ocean transportation facilities that they were deemed worthy of description in this bulletin.

Although these deposits have been known locally for a long time and have received brief notice in such publications as Mineral Resources of the United States and in the reports of the California State Mining Bureau,[b] yet there is a general lack of knowledge in regard to their importance, as is shown by the absence of any mention of them in the standard text-books, where much smaller deposits are emphasized.

Infusorial earth, tripoli, or diatomaceous earth, as the same material is variously called, is of widespread occurrence in the California coast ranges and is found unaltered in great abundance in northern Santa Barbara County, where it is usually known by the name of diatomaceous earth or "chalk rock." The former designation is a very proper one to apply, as the formation is almost entirely made up of the skeletons of minute organisms called diatoms. These are

[a] A preliminary report by the writers on the geology and oil occurrence in this region is being published by the United States Geological Survey as Bulletin No. 317.

[b] For a brief account of the various diatomaceous deposits of California see The structural and industrial materials of California: Bull. California State Min. Bur. No. 38, 1906, pp. 289-296.

one-celled plants that adapt themselves to a wide range of conditions of depth and temperature in fresh and salt water and secrete siliceous casings or frustules around their organic material. They must have lived in extreme abundance in the ancient sea, for it is evident that the deposit was built up by the little shells of these plants which dropped to the sea bottom. The name "chalk rock" is inappropriate, for although the deposits closely resemble soft chalk in appearance they are made of silica instead of calcareous material. Examination with a hand lens almost always reveals a large number of the round forms of the diatom shells thickly embedded in the shale, many of them in a very good state of preservation. In some of the material they can be plainly made out with the naked eye. Here and there in petroliferous portions of the diatomaceous shale, individual diatoms will be seen completely filled with petroleum.

GEOLOGIC RELATIONS OF THE DEPOSITS.

By far the greater part of the diatomaceous material occurring in the territory under discussion is found in the Monterey (middle Miocene) formation. Such is the age of the deposits in the hills south and north of the Santa Ynez River, in the Burton Mesa, Casmalia and Santa Maria oil field areas, and in the region northeast of Santa Maria Valley and Sisquoc River.

Fairbanks[a] also reports diatomaceous earth in the Monterey formation south of Morro Bay, northeast of Port Harford, north of Pismo, and southeast of Edna, in San Luis Obispo County. The principal deposits are found toward the top of the Monterey, those in the lower portion being local in extent. The soft material is usually found in series of beds of considerable thickness, in which are a few beds of impure shale and some limy layers, the latter being common toward the bottom of the Monterey. All gradations from the soft earthy diatomaceous material to the hardest of black flints may be found, in some places within very short distances, thus indicating the extreme localization of the conditions that produced the harder varieties from the unaltered deposits.

Diatomaceous shale is found in the lower part of the Fernando formation, which overlies the Monterey unconformably, in the region between the head of Howard Canyon and Sisquoc and at one or two places along the north side of the Casmalia Hills. This portion of the Fernando is doubtless of upper Miocene age and is the equivalent of the Pismo and Santa Margarita formations described by Fairbanks, which contain diatomaceous earth in the region north of Arroyo Grande, southeast of Edna, and along Salinas River as far up as Rinconada Creek, all in the San Luis quadrangle.

[a] Fairbanks, H. W., Description of the San Luis quadrangle: Geologic Atlas U. S., folio 101, U. S. Geol. Survey, 1904, p. 14.

LOCALITIES OF DIATOMACEOUS DEPOSITS.

REGION SOUTH OF SANTA YNEZ RIVER.

South of Lompoc.—The only deposits of diatomaceous earth in northern Santa Barbara County that have been put to use occur just south of Lompoc, in the foothills of the Santa Ynez Range, east of the canyon of San Miguelito Creek. From the edge of the hills at Lompoc for a distance of 2 miles or more to the south the hills are formed of soft white diatomaceous earth in a very pure state. It is directly at the surface, can be quarried with the utmost ease, and is ready for shipment on removal from the quarry. In some places the material is in great soft masses, in which the bedding can not be recognized except by the characteristic weathering into flaky layers parallel with the original bedding planes. Elsewhere it is more compact and in thin beds varying from half an inch to 2 or 3 inches in thickness or in massive beds. The beds are tilted and in conformity with the much-disturbed hard beds of flinty shale of the lower portion of the Monterey formation, of which the whole series is a part. In places the diatomaceous, earthy horizon is traversed by thin laminæ of hard brown brittle shale. There must be at least 3 square miles over which the diatomaceous shale is exposed, and the thickness in some places reaches several hundred feet.

It may be mentioned in passing that some thin deposits of volcanic ash, comprising over the whole area a large amount of material, are interbedded with the diatomaceous earth in this region. The ash is of a siliceous variety, probably corresponding in composition to an acidic lavalike rhyolite. It is soft, pulverulent, of a lustrous grayish color, slightly more gritty than the tripoli, and very homogeneous. Its somewhat coarser nature might make it valuable for uses to which the diatomaceous earth is unsuited. It is worthy of note that large quantities of volcanic ash under the designation of pumice are imported annually from the Lipari Islands, in Italy, for use as abrasive material.

Two quarries are in active operation at Lompoc, that of Balaam Brothers and that of the Magne-Silica Company, of Los Angeles, and considerable quantities of the diatomaceous earth are shipped to Los Angeles and elsewhere. Active preparations are being made for the installation of a plant at Lompoc for the treatment of the earth.

Southwest and west of Lompoc.—The outer portion of the hills southwest of Lompoc, along the southern border of the Lompoc Valley, is composed of soft white diatomaceous shale that is the westward continuation of the deposit just noted. It is of great purity and of such extent and thickness that it will afford an almost unlimited field for development. It would be difficult to estimate the area covered, but it is many square miles. It forms a fringe to the hills, structurally overlying the hard, contorted lower Monterey shale that forms the greater portion of the hills for several miles back from the valley. On the sides of the canyon followed by a road into the hills 4 miles west of Lompoc about 1,000 feet of these beds are exposed with a steep northward dip toward the valley. It is probable that a considerable portion of the sand-covered hills west of this road as far as Surf, on the shore of the Pacific, is occupied by the soft shale of this series. The covering of sand is thin.

San Julian Rancho.—Diatomaceous shale, white and fairly pure, occurs interbedded with hard limestone and flinty shale at the base of the Monterey formation just north of El Jaro Creek at the point where it joins Salsipuedes Creek, on the northern border of the San Julian Rancho, in the foothills of the Santa Ynez Range. The amount present is small compared with the deposits higher up in the formation, as near Lompoc. In general, the lower half of the Monterey is barren of soft unaltered diatomaceous beds and the upper half is almost entirely composed of them. At least one area of pure flaky diatomaceous earth occurs near the head of Ytias Creek, but the region has not been carefully traversed. It is not probable that any very extensive area of it occurs here.

Other deposits.—Diatomaceous deposits are exposed along the road that follows Santa Ynez River east of Lompoc, on the point of the hills a mile southeast of the mouth of Salsipuedes Creek, and on the point near the western edge of the Santa Rosa grant. At these places the material forms a cap overlying the hard shales, but there is no great area of it.

BURTON MESA.

Burton Mesa is a wide, flat terrace of Monterey shale capped with a horizontal covering (about 25 feet deep) of recent sand and gravel. Along the northern border of the mesa and up the canyons running into it from the northwest and from the southeast are exposed white diatomaceous deposits, and this material constitutes the bulk of the northeastern portion of the mesa. Earth of a very fine quality forms the eastern side of the big canyon next east of Pine Canyon, from 5 to 8 miles northeast of Lompoc, and thence eastward to the point where the mesa merges into the hilly region south of Harris the valleys dissecting the terrace show that the whole region is composed of this material. The earth continues into the hills farther east, as described under the next heading. Good exposures in which the deposits may be examined occur along Santa Lucia Canyon and the valleys running into it. The material is of very light weight and soft, but yet compact. The bedding is thin, but as the earth is very homogeneous the bedding planes or changes from one bed to another are not marked. A block may be split into flat plates of almost any degree of thinness. Santa Lucia Canyon cuts across the strike of the beds, which dip at a very low angle, about 12° on the average, toward the northeast. The thickness of the series within the limits in which it consists of pure diatomaceous earth is at least 2,000 feet.

The beds exposed along the northern edge of the mesa east of a point 2 miles from the ocean are similar, and it is probable that the region between this point and Santa Lucia Canyon, comprising the whole northeastern corner of the mesa, is composed of the same material. The area so included is at least 12 or 15 square miles in extent.

HILLS BETWEEN SANTA YNEZ AND LOS ALAMOS VALLEYS.

South of Harris.—The ridge of hills between the Mission La Purisima grant and Harris is composed of the upper part of the Monterey formation, which is overlain by more recent sand deposits on the flanks of the ridge. The new road from Lompoc to Harris exposes a thickness of at least 2,400 feet, which is almost entirely soft white shale composed of diatom remains. The beds dip northward at angles of 20° to 40°. Some of the material is of less pure quality than the best, and there are a few layers of brown brittle shale or yellowish-white porcelainlike shale, but the great bulk of it would be very suitable for economic use. It is extremely soft, and blocks of any size or shape can be cut out. A knife or saw or other cutting instrument will go through it just as through soft chalk. The same is true of the shale of the other occurrences mentioned in this paper.

Similar diatomaceous earth composes the whole ridge west of the new road as far as Burton Mesa. Locally it is covered by terrace sand, but this is only a thin capping a few feet in depth. There is an available area of at least 7 or 8 square miles of the earth, and when the thickness of the series is considered it becomes evident that a vast amount of the material is present.

Between Cebada Canyon and La Zaca Creek.—In most of the hilly region between Cebada Canyon and La Zaca Creek, for an extent of over 30 square miles, the diatomaceous shale predominates as the surface formation. Much of it is somewhat altered to impure varieties that would not be the best for economic purposes, but areas of many square miles are covered by deposits hundreds of feet thick that are of excellent quality. Areas of especially good material lie just north of Santa Rita all along the ridge for many miles west of Redrock Mountain and over the hills north, northeast, and southeast of that mountain. The thickness of the series that is exposed, all of which seems to be with little doubt of diatomaceous origin, whether now remaining in the original soft state in which it is fit for commercial uses or altered to harder varieties, is at least 4,500 feet.

Hills south of Santa Rita.—Diatomaceous deposits covering several square miles lie on the southern flanks of the hills south of Santa Rita, the series attaining a thickness of several hundred feet and being finely exposed in some of the cliffs on the north side of Santa Ynez River. These deposits are underlain by hard shales, and it is difficult to outline areas in which the one occurs without the other.

VICINITY OF SANTA YNEZ.

Hills of diatomaceous earth are exposed locally about 1½ miles northwest of the Santa Ynez Mission and are readily seen from the valley where the mission stands. The shale is probably of considerable extent here, but is covered for the most part by thin, geologically recent sand deposits.

Soft shale occurs locally 3 miles and again 4 miles southeast of Santa Ynez, about a mile north of the river.

VICINITY OF CASMALIA.

The hills south of Casmalia are composed of white diatomaceous shale interbedded with slightly brittle layers in smaller amount. The canyon, followed by the road due south of Casmalia over to Burton Mesa, exposes a great amount of pure soft earth of a very good quality. This extends eastward under the terrace sands and is exposed again in the next canyons to the east. The sand deposit is not deep, and the tripoli earth is very near the surface over an area of 5 to 10 square miles.

East of Casmalia the deposits above noted continue over an equal area, being covered in some places by the terrace sand, but outcropping in all the canyons and forming the surface over the greater portion of the region. A good quality of shale is exposed along the road from Casmalia to Harris Canyon and on the ridge north of it. Some stretches are occupied by hard or impure shale that is unsuitable for quarrying, but these are only patches. Material of an especially good quality is exposed in large amounts on the southwestern flanks of the ridge running southeastward from Schumann toward Divide. The beds in general are only gently upturned and have a thickness amounting to many hundred feet.

On the northeast side of Schumann Canyon the deposits above mentioned have their continuation. In the low hills just north of Casmalia diatomaceous shale of rather poor quality occurs, but beginning at Schumann and running northwestward is a belt of excellent earth on the southwest side of the high ridge bordering the

Santa Maria Valley. The quality is especially good 2 miles northwest of Schumann, on the south side of this ridge. This deposit is at the summit of the Monterey formation, and just above it on the ridge the overlying Fernando beds have a similar diatomaceous character, although of less purity. The total area of fine diatomaceous material in this region would not exceed 2 square miles.

REGION OF THE SANTA MARIA OIL FIELD.

Something over 1 square of mile of Monterey diatomaceous shale is exposed in the region of the Santa Maria oil field southeast of Orcutt. These deposits were all covered at a not very remote period of geologic time by Fernando or later sediments which have been removed by erosion in the canyons, exposing the shale beneath. The beds are considerably tilted and jointed over most of the area, but in the region of the Pinal wells west of Pine Canyon deposits of fairly pure material of considerable thickness are exposed in the road cuts.

CANADA DEL GATO AND SISQUOC AREA.

Diatomaceous shale is found in the Fernando formation (of upper Miocene age in this part of the formation) in the region between the head of Howard Canyon and a point on the plateau south of Foxen Canyon about 2 miles southeast of Sisquoc post-office. The area over which the diatomaceous shale is exposed is about 5 miles long, with an average width of about 1½ miles, thus comprising 7½ square miles. The deposits vary in thickness from 60 to about 300 feet, and over a considerable portion of the territory lie almost horizontal. Along the southern border of the area the beds dip at angles as high as 35°. The material in this area is not so pure as the diatom shale found in the Monterey (middle Miocene), a fact that, coupled with its remoteness from the railroad, renders it unlikely that this deposit will be of economic importance for a long time, at best.

MOUNTAINS NORTHEAST OF THE SANTA MARIA VALLEY.

Soft, flaky diatomaceous shale occurs on Tepusquet Creek about 2 miles up from the Santa Maria Valley. Soft white shale is also found near the head of Rattlesnake Canyon about 2 miles south of Tepusquet Peak, and again south of Labrea Creek 2 miles northeast of its junction with Sisquoc River. But this shale is of inferior quality to that at previously mentioned places, nor is it comparable in thickness or extent. The major portion of these mountains is composed of strata older than the upper part of the Monterey formation—than that part, in other words, in which the soft shale occurs most abundantly.

SAN LUIS QUADRANGLE.

Diatomaceous deposits occur in the Monterey, Pismo, and Santa Margarita formations (the last two the equivalent of the lower Fernando in the Lompoc quadrangle) in the San Luis quadrangle,[a] immediately north of the Guadalupe quadrangle. The principal localities, according to Fairbanks, are on the mountains back of Pismo, in the region of Arroyo Grande, and along the hills bordering the south side of the San Luis Valley. Another bed of considerable thickness occurs on the slope of the San Luis Range south of Morro Bay, and similar deposits appear at various points along Salinas Valley, extending as far up as Rinconada Valley. These diatomaceous deposits are white and of chalky texture, as at the typical localities in the Lompoc quadrangle.

PHYSICAL AND CHEMICAL PROPERTIES

Diatomaceous earth when pure is white or gray in color, light in weight, and easily pulverized to a fine powder. Owing to the angular nature and hardness of its component particles it has valuable abrasive properties. It also has great absorptive powers, but is very resistant to weathering. Chemically it is composed essentially of opaline or colloidal silica and water, in general associated with minor quantities of alumina, iron oxide, lime, and magnesia as impurities. Diatomaceous earth is not soluble in acids under ordinary conditions, but is easily dissolved in the stronger alkalies. As chalk, with which diatomaceous earth is sometimes confused, is soluble in acid, the two may be distinguished by the acid test.

The following table gives 3 analyses of samples of the shale (slightly hardened diatomaceous earth) from the Lompoc quadrangle, together with analyses of similar diatomaceous material from other localities:

Analyses of diatomaceous earths or shales.

	1.	2.	3.	4.	5.	6.	7.	8.	9.
Silica (SiO_2)	65.62	86.92	72.50	86.89	86.90	80.53	80.66	81.53	84.15
Alumina (Al_2O_3)	....	4.27	11.71	2.32	4.09	5.89	3.84	3.43	1.40
Iron oxide (Fe_2O_3)	....	....	2.35	1.28	1.26	1.03	....	3.34	.70
Lime (CaO)	....	1.60	.32	0.43	.14	.35	.58	2.61	1.75
Magnesia (MgO)	....	Trace.	.83	Trace.	.51	....	....	....	1.10
Alkalies (K_2O+Na_2O)	....	2.48	1.88	3.58	1.18	....	....	2.59	....
Water (H_2O)	11.00	5.13	9.54	4.89	5.99	12.03	14.04	6.04	10.40
	....	100.40	99.13	99.39	100.07	99.83	99.12	99.54	99.50

1. Soft shale, Harris, Santa Barbara County, Cal. Analyst, W. T. Schaller, 1907.
2. Porcelain diatomaceous shale, Point Sal, Santa Barbara County, Cal. Fairbanks, H. W., Bull. Dept. Geol., Univ. California, vol. 2, 1896, p. 12. Specific gravity 2.12.
3. Soft shale, Orcutt, Santa Barbara County, Cal. Analyst, W. T. Schaller, 1907.
4. Monterey, Monterey County, Cal. Lawson, A. C., and Posada, J. de la C., Bull. Dept. Geol., Univ. California, vol. 1, p. 25. Specific gravity 1.8–2.1.
5. Fossil Hill, Nevada. Bull. California State Min. Bur. No. 38, 1906, p. 28.
6. Lake Umbagog, New Hampshire. 7. Morris County, New Jersey. 8. Popes Creek, Maryland. Merrill, G. P., Rept. U. S. Nat. Mus. for 1899, p. 220.
9. Hanover, Germany. Bull. California State Min. Bur. No. 38, 1906, p. 28.

[a] Geologic Atlas U. S., San Luis folio, No. 101, U. S. Geol. Survey, 1904, p. 14 and economic geology sheet.

USES.

The uses to which infusorial earth can be put are constantly being found to be more numerous, and the methods for its application are developing. Formerly it was employed solely for abrasive purposes, and this use has been extended in the manufacture of polishing powders, scouring soaps, etc. But its principal uses are now others. It is of value in the manufacture of dynamite from nitroglycerine, owing to its porosity, which makes it a good absorbent. Being a poor conductor of heat and very light, it is valuable for use in the manufacture of packing for safes, steam pipes, and boilers and of fireproof building materials such as hollow bricks for partition walls, floors, etc., solid bricks, furnace bricks, and tiles; also as a base in the manufacture of cements suitable for withstanding fire and heat. On account of its porous yet compact character it makes a good filtering substance, and is so used commercially. This use is facilitated when the tripoli can be obtained in compact blocks of the required size. The California product is very easily cut into any shape desired. Tripoli powder is also used in the manufacture of plaster. Some of the earth from the Lompoc region, it is said, is sent to a large neighboring refinery for use in the refining of beet sugar. An interesting use to which the raw material is put in the Lompoc region and also at Monterey, farther north on the California coast, is in the construction of buildings. The shale is easily quarried into smooth blocks, which, owing to their light weight, can be readily placed in position. A number of buildings have been very successfully constructed in this way. The shale blocks are compact and yet elastic under changes of temperature, seem to possess sufficient strength, and owing to the siliceous composition of the material are very resistant to weathering. Such building material would be finely adapted to regions subject to earthquakes, owing to the probable lesser effects of shocks on so light a substance and the smaller amount of damage that would result from falling materials.

PRODUCTION IN THE UNITED STATES.

Infusorial deposits occur in many States. Those producing it for economic use in 1903 were, in the order of importance, together with the number of concerns engaged in its exploitation, Missouri (3 producers), Virginia (2), New York (2), California (3), Maryland (1), Georgia (1), Massachusetts (1), New Hampshire (1), Florida (1). In 1904 the order changed somewhat, as follows: Missouri (2 producers), Maryland (1), California (2), Virginia (1), Florida (1), New Hampshire (1), New York (1), Massachusetts (1), and Georgia (1). The amount and quality of the material in California warrants the prophecy that it will lead in the production before long and supply enough to make it unnecessary to import any such products from abroad.

The following table is taken from the Mineral Resources of the United States for 1905, published by the United States Geological Survey:

Production of infusorial earth in the United States from 1880 to 1905.

Year.	Quantity in short tons.	Value.	Year.	Quantity in short tons.	Value.
1880	1,833	$45,660	1893	....	$22,582
1881	1,000	10,000	1894	2,584	11,718
1882	1,000	8,000	1895	4,954	20,514
1883	1,000	5,000	1896	3,846	26,792
1884	1,000	5,000	1897	3,833	22,385
1885	1,000	5,000	1898	2,733	16,691
1886	1,200	6,000	1899	3,302	25,302
1887	3,000	15,000	1900	3,615	24,207
1888	1,500	7,500	1901	4,020	52,950
1889	3,466	23,372	1902	5,665	53,244
1890	2,532	50,240	1903	9,219	76,273
1891	....	21,988	1904	6,274	44,164
1892	....	43,655	1905	10,977	64,637

COMPARISON WITH OCCURRENCES ELSEWHERE.

Infusorial earth occurs at widely separated points in other parts of the world. One of the largest and commercially best developed deposits is in northern Germany, where there are beds of this material varying from 20 to 50 feet in thickness from which the earth is quarried extensively, dried and prepared for market, and shipped to all parts of the world. There is a famous deposit at Richmond, Va., but considerable clayey material is mixed in with the deposit of diatoms, the analysis showing 70 per cent of silica, a considerable quantity of alumina, and some iron oxide. The bed attains a thickness of 40 feet in places and extends many miles. Other deposits over 30 feet thick occur at Bilin, Bohemia, and in Aberdeenshire, England. It can be readily seen that the quantity of infusorial earth at these places can not compare with the vast amount to be found in California.

IMPORTS.

Some infusorial earth is imported into the United States every year, being classed with the so-called rotten stone widely used in the manufacture of polishing substances. In past years the value of the imports of tripoli and rotten stone has approximated closely the value of the tripoli produced in this country, but the amount of the imports is declining with the increase in home production. The value of the imports in 1902 was $39,926; in 1903, $34,977; in 1904, $23,022, and in 1905, $18,986, as given in the Mineral Resources reports of the United States Geological Survey.

SURVEY PUBLICATIONS ON ABRASIVE MATERIALS.

The following list includes a number of papers, published by the United States Geological Survey or by members of its staff, dealing with various abrasive materials:

CHATARD, T. M. Corundum and emery. In Mineral Resources U. S. for 1883–84, pp. 714–720. 1885.

ECKEL, E. C. The emery deposits of Westchester County, N. Y. In Mineral Industry, vol. 9, pp. 15–17. 1901.

FULLER, M. L. Crushed quartz and its source. In Stone, vol. 18, pp. 1–4. 1898.

HIDDEN, W. E. The discovery of emeralds and hiddenite in North Carolina. In Mineral Resources U. S. for 1882, pp. 500–503. 1883.

HOLMES, J. A. Corundum deposits of the southern Appalachian region. In Seventeenth Ann. Rept., pt. 3, pp. 935–943. 1896.

JENKS, C. N. The manufacture and use of corundum. In Seventeenth Ann. Rept., pt. 3, pp. 943–947. 1896.

PARKER, E. W. Abrasive materials. In Nineteenth Ann. Rept., pt. 6, pp. 515–533. 1898.

PRATT, J. H. The occurrence and distribution of corundum in the United States. Bulletin No. 180. 98 pp. 1901.

——— Corundum and its occurrence and distribution in the United States. Bulletin No. 269. 175 pp. 1905.

RABORG, W. A. Buhrstones. In Mineral Resources U. S. for 1886, pp. 581–582. 1887.

——— Grindstones. In Mineral Resources U. S. for 1886, pp. 582–585. 1887.

——— Corundum. In Mineral Resources U. S. for 1886, pp. 585–586. 1887.

READ, M. C. Berea grit. In Mineral Resources U. S. for 1882, pp. 478–479. 1883.

TURNER, G. M. Novaculite. In Mineral Resources U. S. for 1885, pp. 433–436. 1886.

——— Novaculites and other whetstones. In Mineral Resources U. S. for 1886, pp. 589–594. 1887.

WOOLSEY, L. H. Volcanic ash near Durango, Colo. In Bulletin No. 285, pp. 476–479. 1906.