

# BENTONITIC MAGNESIAN CLAY-MINERAL FROM CALIFORNIA

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## OCCURRENCE

The clay-mineral which is here described was found on the Mojave Desert, in folded sediments of probably Tertiary age. The locality is the "Company No. 1" quarry, three miles south of Hector, in San Bernardino Co., California.

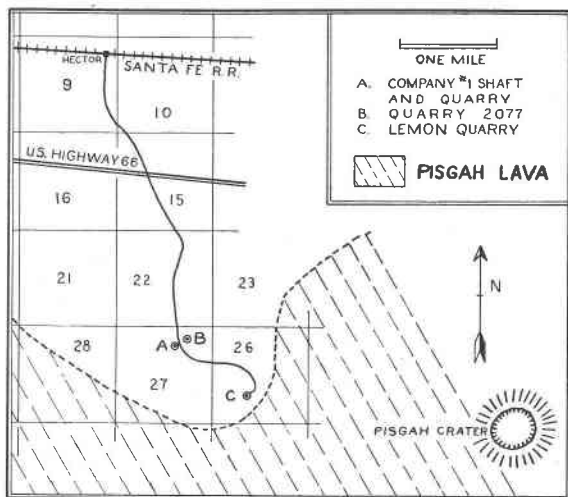


FIG. 1

Company No. 1 quarry is one of three more or less developed prospects on properties of the California Talc Company near Hector. All three prospects have yielded light-colored, swelling bentonitic clays. One lies three to three and one-half miles northwest of Hector station on the Santa Fe Railroad.

The other two prospects are south of Hector station and are less extensively developed. The Lemon quarry in section 26 (C in Fig. 1) discloses a one to three foot, irregular, distorted bed of brown to pale lemon colored clay. This bed is part of a sand-clay-tuff series. The swelling, pale yellow clay contains chalcedony and calcite concretions. Company analyses are said to indicate a magnesium-aluminum clay (normal bentonite).

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The third prospect is Company No. 1 quarry in section 27 (A in Fig. 1). The bentonitic magnesian clay-mineral here described came from this locality. This prospect is apparently on a small anticline in a Tertiary volcanic series, originally almost completely unconformably overlain by the edge of a flow of basaltic lava extending northwestward from Mt. Pisgah.<sup>1</sup> At a little quarry 200 yards northeast of Company No. 1 (B in Fig. 1, Quarry 2077) the dips of the exposed beds suggest another small anticline, and the Lemon outcrops may indicate a third.

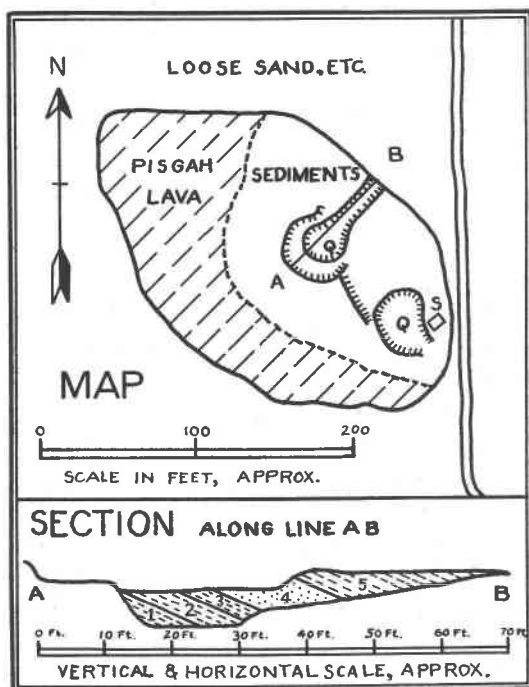


FIG. 2

As shown in Fig. 2, the brown sandy clay at Company No 1 is interbedded in a sand and clay series. The lower part of this series is tuffaceous, the upper part probably eolian. The bentonitic magnesian mineral is a white to cream-colored, swelling clay which appears to develop at the top and in cracks of the tuff (bed No. 2) and is obviously secondary. Hundreds, perhaps thousands, of pounds of it have been removed from the quarries. A sample furnished by the Flintkote Corporation was used for a chemical analysis and *x*-ray study. Other samples, collected by A. O.

<sup>1</sup> *U. S. Geol. Surv., Bull.* 613, pp. 158-159, 1916.

Woodford at the same spot, were used for both optical and chemical study.

A partially timbered shaft (S in Fig. 2) 35 feet deep in 1934, exposes in its lower half complexly cracked and slickensided buff clays and sandy clays (tuffs), which underlie those exposed in the quarries and which contain calcite and a little plastic clay in cracks and seams.

The small and shallow quarry 2077 (Fig. 1) exposes a few feet of clayey and sandy beds somewhat similar to those at Company No. 1. Some calcite nodules found in brown clay from Quarry 2077 are coated with white clay chemically and optically almost identical with that at Company No. 1.

#### PHYSICAL PROPERTIES OF THE MAGNESIAN CLAY

The swelling clay from Company No. 1 quarry is mottled white to pale brown in color, and has an earthy to semi-waxy luster. Scattered through this clay are pale buff calcite crystals two to three millimeters in length. The clay is translucent on the edges of the purer masses and transparent under the microscope. The dried material shows numerous shrinkage cracks and crumbles readily into lumps.

The white clay swells immediately when placed in water and soon becomes a gelatinous mass, which, after 24 hours, is a firm jelly estimated to be five or six times the volume of the original dry clay.

In thin-sections the swelling clay is distinctly crystalline. Between crossed nicols the material shows weak to medium birefringent areas with a speckled or reticulated pattern. The more strongly birefringent (coarser grained) portions are arranged in minute veinlets. The appearance of the clay in thin-section resembles many serpentines in structure. No relic structures were observed in thin-sections of this material.

Studied in oils under the microscope, the white clay is seen to be made up of tangled masses of minute doubly-refracting grains, and somewhat larger plates, with a poor basal cleavage. The indices of refraction are somewhat variable:  $\gamma = 1.500 - 1.520 \pm .005$ , and  $\gamma - \alpha = .020 \pm .005$ . Extinction is roughly parallel to the basal sections of the plates; elongation is usually positive but sometimes negative. No interference figures were obtained. Most plates are probably optically negative. The white clay from Quarry 2077 is optically similar, made up of grains and plates .003-.015 mm. in diameter, but with slightly lower indices.  $\gamma = 1.490 \pm .005$ . The white clays contain a few mineral grains identical with those of the brown tuff, described below.

#### CHEMICAL COMPOSITION OF THE MAGNESIAN CLAY

For analysis the pure white clay-mineral from Company No. 1 quarry, free from carbonate grains, was selected. Under the petrographic mi-

crosscope the mineral appeared essentially pure and had a mean index of refraction of 1.500. The analysis, carried out by standard methods is given in Table 1, No. 1. From this analysis it is evident that this clay is essentially a magnesium silicate with only an insignificant amount of alumina present. Noteworthy is the high soda content (3.00%), and particularly the lithia content (1.12%).

TABLE 1. CHEMICAL COMPOSITION OF HECTOR CLAY

	1	2	3	4	5	6	7	8	9	
SiO <sub>2</sub>	53.68%	.8736	51.26%	.8501	50.89%	.8437	43.00%	23.42%	14.72	
Al <sub>2</sub> O <sub>3</sub>	0.60	.0059	0.36	.0035	9.40	.0920	3.48	} 9.00	1.40	
Fe <sub>2</sub> O <sub>3</sub>			0.09	.0006	2.06	.0129	1.76			
CaO	0.52	.0093	2.60	.0463	0.78	.0139	9.06		0.00	22.32
MgO	25.34	.6285	23.25	.5766	26.52	.6577	17.11	15.26	21.75	
FeO			0.06	.0012						
Sr			tr.	.0011						
Na <sub>2</sub> O	3.00	.0484	3.47	.0560				0.20		
K <sub>2</sub> O	0.07	.0007	0.10					1.25		
Li <sub>2</sub> O	1.12	.0375	0.60	.0204				0.50		
H <sub>2</sub> O+	8.24	.4574	5.14	.2853	} 11.06			4.96		
H <sub>2</sub> O-	7.28	.4041	11.56	.5902						8.34
Cl	0.31	.0087								31.50
CO <sub>2</sub>			1.35	.0307						
F			None							
Insoluble							1.83			
Ignition										
loss							19.60			
Soluble										
salts							2.60			
Totals	100.16%		99.84%		100.71%					

1. Hector clay, California. W. F. Foshag, *analyst*.
2. Molecular ratios of No. 1.
3. Hector clay, California. R. E. Stevens, *analyst*.
4. Molecular ratios of No. 3.
5. Saponite, Svardsjo, Sweden. Svanberg, *analyst*, 1840.
6. Molecular ratios of No. 5.
7. Lucianite from near Mexico City. E. W. Hilgard, A peculiar clay from near the City of Mexico: *Proc. National Acad. Sci.*, vol. 2, pp. 8-12, 1916.
8. Tertiary clay, 16 miles northeast of Amboy, California. J. D. Lauder milk, *analyst*, 1935.
9. Marl, Borax Mine, Callville Wash, Nevada. W. F. Foshag, *analyst*.

A second analysis, (Table 1 No. 3), by R. E. Stevens of the U. S. Geological Survey on material collected by Bernard Moore has been made available to us by Dr. Clarence S. Ross.

Spectrographic examination of another sample from the same quarry, made by Dr. T. G. Kennard of the Claremont Colleges, showed, in addition to the elements listed in Table 1, considerable F, a small amount of Sr, and traces of Ba, B, Fe, Mn, Ti, V.

#### X-RAY EXAMINATION

The material used for our analysis was also used for an  $x$ -ray examination by the powder method. Samples of typical sepiolite from Cerro Mercado, Mexico (analyzed), saponite from Cook's Kitchen, Cornwall, and spadaite from Capo di Bove, Rome, similar magnesium silicates, were also photographed for comparison. The powder photographs of the clay showed distinct diffraction lines, indicating a crystalline nature. Comparison with  $x$ -ray spectra of sepiolite and spadaite showed marked differences. A comparison with saponite, however, showed a similar but not identical spacing of the diffraction lines, the lines of the Hector mineral being slightly displaced with respect to those of saponite. This indicates that the Hector mineral is closely related but not completely similar to true saponite. The relationship of the spectra of the two is indicative of isomorphism between the two compounds.

#### PHYSICAL AND CHEMICAL PROPERTIES OF THE BROWN TUFF

The brown tuff (bed No. 2 of Fig. 2) with which the magnesium clay is associated and from which it presumably is derived, is fairly hard, and has a somewhat waxy appearance on fresh fractures. It does not swell or disintegrate in water, though it may be broken by the swelling of minute white clay veins.

This tuff was studied in thin-sections and in oils. The sections show tangles of clay flakes, in which lie a few isolated grains of plagioclase, quartz, etc., 0.1 to 0.5 mm. long. The clay-mineral has a basal cleavage, with indices  $\beta = \gamma = 1.520 \pm .005$  (determined in oils) and  $\gamma - \alpha = .021 \pm .003$ . Extinction  $0^\circ - 15^\circ$  and perhaps higher; elongation usually positive. Exceptions may be only apparent, as cleavage seems to *cross* areas of negative elongation.

The greater part of the large grains are plagioclase, including both crystals and broken fragments. Indices and extinction angles indicate 28-30% An, or oligoclase-andesine. Some quartz grains are doubly terminated crystals, much corroded. Some quartz shows undulatory extinction. There are also present shiny euhedral plates of biotite, crystals and fragments of pyroxene, probably augite, abundant minute octahe-

drons, complex crystals and irregular bits of magnetite, and a few minute zircon crystals.

A partial bulk chemical analysis of the altered brown tuff (A. O. W. 2082D) and its included crystals, was made by J. D. Lauder milk of Pomona College, with the following results:

SiO <sub>2</sub>	52.20%
Al <sub>2</sub> O <sub>3</sub> and Fe <sub>2</sub> O <sub>3</sub>	8.10
CaO	0.56
MgO	19.86
Loss on ignition	13.71

Spectrographic examination by Dr. T. G. Kennard of the Claremont Colleges showed, in addition, some Na and less Li, with a very little K, and traces of Sr, Ba, Cu, Ti, V, B and Mn. Fluorine indeterminate.

Relic textures are present in abundance in the clay matrix. They include minute collapsed cavities, lined with layers of the clay-mineral, and also curved structures which may be altered pumice shards. It seems probable that this rock is a greatly altered dacite tuff. The clay-mineral, of which the rock is now chiefly composed, is chemically and optically almost identical with the magnesian clay-mineral, but differs from it by not swelling greatly in water. In origin, therefore, this bentonitic magnesian clay is not essentially different from most normal bentonites.

#### EXTENT OF MAGNESIAN CLAYS IN THE MOJAVE DESERT

No general chemical study of the Tertiary bentonites and other clays of the Mojave Desert has been made by us. However, we have incidentally examined a clay for Mr. William Hunger of Los Angeles which came from a point 16 miles northeast of Amboy, and hence 65 miles east of Hector. This clay is hard, and high in calcite. A partial analysis of this clay is given in column 8, Table 1. After subtracting CaCO<sub>3</sub>, this analysis is surprisingly close to that of the Hector clay, even to the minor constituents. The clay-mineral is too fine grained to yield definite optical data. It is probably birefringent.

Similarly in a marl associated with the borax deposits of Callville Wash, Clark County, Nevada, (analysis 9, Table 1) after deducting lime and magnesia, equivalent to the carbonate content, there is left a magnesia-silica residue with ratios very close to those of the Hector mineral. In the bentonitic clays of Ash Meadows, near Shoshone, California, there are numerous lumps of mixed lime, magnesia carbonates and a magnesian silicate close to sepiolite.

The magnesite beds near Bissell, contain silica and an excess of magnesia in ratios similar to those of the Hector clay. Borax-bearing marls from Cave Springs Wash, Nevada, show similar features.

## FORMULA OF HECTOR CLAY AND RELATION TO OTHER MINERALS

The analysis of Hector clay given in Table 1 (No. 1) corresponds fairly closely to the formula  $7\text{MgO} \cdot 10\text{SiO}_2 \cdot 5\text{H}_2\text{O}$ , while that of No. 3 is close to  $2\text{MgO} \cdot 3\text{SiO}_2 \cdot 3\text{H}_2\text{O}$ , if one disregards the alkali content as adsorbed and not essential to the mineral molecule proper.

As can be seen from Table 1, Hector clay is chemically similar to the original saponite from Svardsjo, Sweden (No. 5). It may be close to the magnesian constituent of Hilgard's lucianite (No. 7), and it is probably significant that lucianite was described as a clay which swelled in water to 25 or more times its dry volume. Unfortunately no microscopical examination of lucianite, a surface clay from the Valley of Mexico was reported by Hilgard, and we can find neither Hilgard's locality nor his samples, despite searches at Mexico and the University of California.

## ACKNOWLEDGMENTS

This clay was first studied for the Flintkote Corporation and we are grateful to Mr. L. Kirschbraun and the Flintkote Corporation for permission to publish the results. The base map for Fig. 1 was kindly furnished by the California Talc Company. For the  $x$ -ray diffraction photographs, we are indebted to Mr. Charles J. Ksanda, of the Geophysical Laboratory. We were assisted in the field by Mr. T. F. Harris.

## SUMMARY

A bentonitic clay from deposits three miles south of Hector, San Bernardino County, California, is a hydrous magnesium silicate related to saponite. It is further unusual in its appreciable lithia content (about 1%). Similar magnesian clays are widespread in the Mojave Desert Region of California and Nevada.