SECONDARY MONTMORILLONITE IN A CALIFORNIA PEGMATITE

J. D. Laudermilk and A. O. Woodford, *Pomona College, Claremont, California.*

Abstract

Portions of a southern California pegmatite have been replaced by a clay mineral. The original material appears to have been chiefly feldspar, and the clay mineral has the chemical composition and the optical and x-ray properties of montmorillonite.

Occurrence

There is an abandoned quarry about 2 miles north of Claremont, Los Angeles County, California, at the head of Indian Hill Boulevard and 0.6 mile north of the San Bernardino base line. The quarry is in weathered bedrock at the very base of the south slope of the San Gabriel Mountains. The rocks exposed in the quarry are rotten quartz-biotite schist dipping gently southwest, and rather fine-grained pegmatite in bands a foot or two thick and roughly parallel to the schistosity of the country rock. The pegmatite is composed of abundant quartz, orthoclase and albite, with rare biotite. Most of the feldspar is dull and cloudy. The feldspar crystals range from ½ to 10 mm. in diameter; small feldspars may occur together, making somewhat larger masses. At the northeast end of the quarry in its present (1933) condition part of a pegmatite band, shown in fig. 1, is entirely made up of white to very pale buff clay, containing scattered quartz grains. This part of the quarry is about 20 feet below the original, sloping surface of the ground. That surface was covered by dense chaparral, and roots extend to a measured distance of 22 feet below the surface and probably farther, penetrating here and there the clay zone shown in fig. 1, but not notably abundant in it.

The irregular, branching clay zone occupies the upper part of a pegmatite band, just beneath rotten schist, and averages 1 or 2 inches in thickness. It shows little or no evidence of fault slip or vein filling, but is merely a completely altered portion of the pegmatite. Toward the margin of the zone there is more and more pink feldspar embedded in the clay. The fairly firm pegmatite adjacent to the clay zone contains small, irregular areas of the clay mineral. Thin sections were prepared from partially weathered pegmatite collected at the edge of a downward extension of the clay zone. With a magnification of 1800 diameters it was seen that the cloudiness of the orthoclase and albite is chiefly due to elongated cavities 1 to 12 microns in length. In some cases the cavities are parallel to the cleavages. Some inclusions of mica and other minerals were seen, but no clay mineral. It is concluded that the clay mineral (montmorillonite) is not the result of particle by particle alteration of feldspar in place, though it may be that new crystals of montmorillonite have grown in space vacated by the wasting of the feldspars. Perhaps the absence of vein or geode or other regular structures in the clay is entirely due to its softness, but in this connection it should be noted that no veinlets of montmorillonite were seen, even in crumbly, porous feldspar.

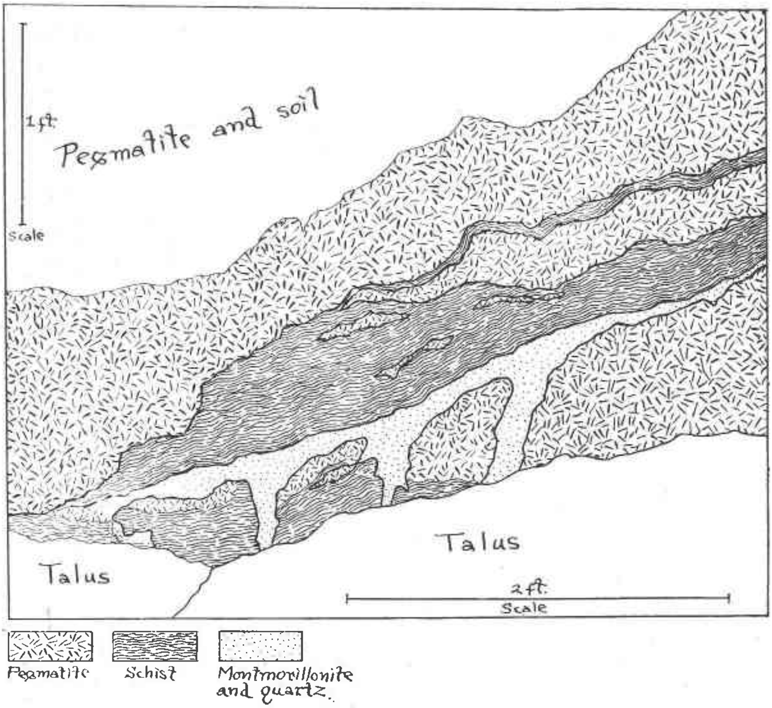

FIG. 1. Sketch showing occurrence of montmorillonite, Claremont, California.

The purest clay was found to have a waxy appearance. Waxy material to the amount of 2 or 3 grams was picked out by hand for further study.

OPTICAL PROPERTIES

The selected material was judged from microscopic examination (by Woodford) to be almost entirely one mineral, even though the indices were not absolutely uniform throughout. The only impurities recognized were 3 or 4 small bits of altered feldspar and biotite, and the total impurities exclusive of iron stain were estimated to be less than 1%.

The clay mineral occurs as a tangled mass of very small, flexible plates, which are 5 or 10 or at most 40 or 50 microns across. There is probably basal micaceous cleavage. Plates lying flat are practically isotropic. Plates on edge show interference tints up to second order blue-green, indicating a birefringence of .015. Extinction is usually parallel or nearly so, with positive elongation, but several plates with slightly inclined extinction were seen, and one with 20° extinction angle and negative elongation. This last grain is presumably an impurity. It is thought that in most cases X is nearly perpendicular to the cleavage.

The indices of refraction of the air-dried material used for analysis were determined in oils with white light, and the oils calibrated with a Spencer Abbe refractometer, wnich was in turn checked by test plates. Beta and gamma are commonly 1.491±.002, exceptionally as high as 1.496±.002, very rarely as high as 1.510±.003. Alpha is some .015 lower, commonly 1.475–1.480±.002. After standing 5 days over 52% H_2SO_4 to give a definite water vapor pressure, the indices became more uniform, beta and gamma 1.490±.002; alpha 1.475±.002. A comparison of these indices with those of other examples of montmorillonite is shown in Table I.

TABLE I. OPTICAL PROPERTIES OF MONTMORILLONITES

	alpha	beta and gamma	$\gamma-\alpha$	2V
Claremont, Calif. (Woodford)	1.475 up	1.490–1.510	.015	—
Otay, Calif. (otaylite) (Woodford)	1.468–1.485	1.487–1.500	.019	very small
Otay, Calif. (otaylite) (Ross & Shannon, 1926, p. 95)	1.492	1.513	.021	16°–24°
Montmorillon, France (Ross & Shannon, 1926, p. 96)	1.503	1.527	.024	—
France (Montmorillon?) (Kerr, 1932, p. 197)	1.485	1.506	.021	—

The white otaylite, after standing 48 hours over 52% H_2SO_4, gave values of 1.468 for alpha, and 1.487 for beta and gamma. We do not understand the causes for the variations in montmorillonite indices shown by Table I. The differences may be connected with the amount of water present. Kerr (1931, p. 161) reports that the values for moist bentonite from Ventura, California, were alpha 1.470, gamma 1.481, and after air-drying, alpha 1.510, gamma 1.532. However, the Claremont montmorillonite is not unusually high in H_2O.

CHEMICAL COMPOSITION

Spectrographic analysis (by Dr. T. G. Kennard of Claremont Colleges) showed the presence of abundant Al and Si, some Mg, little Na and Fe, and traces of Cu, Ca and Ti.

A single chemical analysis was made (by Laudermilk) with results shown in Table II, C.

TABLE II. CHEMICAL ANALYSES OF MONTMORILLONITES

	A	B	C	D
SiO_2	48.60%	50.30%	49.70%	.8275
TiO_2	—	—	0.28	.0035
Al_2O_3	20.03	15.96	22.10	.2168
Fe_2O_3	1.25	0.86	2.12	.0133
MnO	0.16	—	Trace	—
CaO	1.72	1.24	1.08	.0193
MgO	5.24	6.53	2.85	.0707
K_2O	—	0.45	None	—
Na_2O	—	1.19	1.17	.0189
P_2O_5	—	—	None	—
H_2O	21.52	23.61	21.14	1.1734
Total	98.52%	100.24%	100.44%	

A. Montmorillonite, Montmorillon, France. Earl V. Shannon, analyst (Ross & Shannon, 1926, p. 90).

B. Bentonite (otaylite), crude selected white material near Otay, San Diego Co., Calif. J. E. Whitfield, analyst (Ross & Shannon, 1926, p. 88). Slightly in error as given, for constituents add up to 100.14%.

C. Montmorillonite, Claremont, Calif. J. D. Laudermilk, analyst.

D. Molecular ratios of C.

Comparison with the other analyses of Table II shows that the Claremont montmorillonite is somewhat high in alumina and low in magnesia. The molecular ratio of SiO_2 to Al_2O_3 is 3.8 as compared to the typical ratio of 5 suggested by Ross and Shannon (1926, pp. 87, 89). The formula of the Claremont mineral might be written $(Mg,Ca)O.2Al_2O_3 \cdot 8SiO_2 \cdot 12H_2O$, as compared with the formula $(H_2,Mg,Ca)O \cdot Al_2O_3 \cdot 5SiO_2 \cdot 5\text{–}7H_2O$ suggested for montmorillonite by Ross and Shannon (1926, p. 89).

X-RAY EXAMINATION

Through the kindness of Dr. W. P. Kelley and Mr. W. H. Dore of the University of California we are able to give the results of an *x*-ray examination of the Claremont clay. Mr. Dore determined the *x*-ray powder spectrum, and obtained its intensity curve, as given by a Zeiss Photo-electric Recording Photometer, from the University Department of Physics. Otay bentonite (otaylite) was used for comparison, with results shown in Table III and Fig. 2.

TABLE III. *X*-RAY COMPARISON OF CLAREMONT CLAY AND OTAYLITE

Claremont						Otay		
Light exposure (No. 1334)			Over-exposed (No. 1376)			Over-exposed (No. 1375)		
Dist. to zero line, cm.	Corr. spacing Å	Intensity peaks	Dist. to zero line, cm.	Corr. spacing Å	Intensity peaks	Dist. to zero line, cm.	Corr. spacing Å	Intensity peaks
2.85	5.0	54.5	2.85	5.0	48	2.85	5.0	50
3.23	4.4	59.5	3.23	4.4	50	3.23	4.4	52.5
4.75	3.03	51	4.80	3.0	46	4.8	3.03	48
5.15	2.80	45						
5.65	2.56	52	5.65	2.56	47	5.65	2.56	48.5
6.4	2.26	44	6.4	2.26	42	6.5	2.23	43
6.7	2.17	43	6.6	2.20	42			
7.55	1.92	37.5						
8.05	1.80	35						
8.2	1.77	35						
8.6	1.69	40.5	8.65	1.68	39.5	8.6	1.69	41
9.7	1.50	46	9.75	1.495	43	9.75	1.495	44.5
11.3	1.295	36	11.35	1.29	38	11.3	1.295	39
11.7	1.25	33	11.8	1.24	36	11.7	1.25	36

Notes: The columns headed "corresponding spacings Å.," represent only approximate values for the interplanar spacings, but are nevertheless in satisfactory agreement with more accurate measurements made upon original x-ray films and with data which are already in the literature. The heights of the intensity peaks, given under that heading in the table, have only comparative value, e.g., as between Nos. 1375 and 1376, which were on the same original film. No. 1334 is added because over-exposure snubbed the first peak intensities for 1375 and 1376 and obscured other lines.

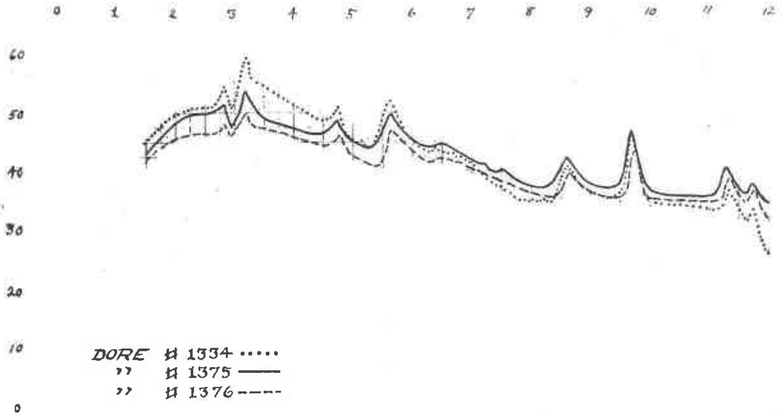

FIG. 2. X-ray intensity curves for Claremont (1334, 1376) and Otay (1375) montmorillonites. Abscissas: cms. to zero line; ordinates: relative intensities.

Mr. Dore furnishes the following notes: "Spacings 1.115, 1.02 and 0.97 Å., observed on the original x-ray films, were represented on the intensity curves by broad or irregular humps, and the exact positions of the peak intensities cannot be given. On the other hand, a small intensity peak occurs at about 6.5 cms., corresponding to 2.26 to 2.17 Å. This spacing was not observed on the original x-ray films 1334, 1375 and 1376, but similar spacings have been observed in other montmorillonite patterns, both in the original x-ray films and as peaks on their intensity curves, leaving little doubt that this spacing should be included in the characteristic list for montmorillonite. The sharp intensity peak at 5.65 cms., corresponding to 2.56 Å., makes definite a spacing value previously reported as a broad band on the original x-ray films, corresponding to a spacing between 2.60 and 2.48 Å. The photometric work confirms our original conclusion as to the identity of your material with montmorillonite."

DISCUSSION

If one may judge from Lacroix's description (1895, p. 482) the montmorillonite at the type locality occurs in sedimentary rocks. The numerous well-established occurrences of montmorillonite described in recent years (e.g., by Ross and Shannon, 1926) are practically all in bentonite. The mineral may also be formed by solfataric action (Ross and Kerr, 1931, p. 62). Ross and Shannon (1926) mention 3 possible pegmatite occurrences, one at the type locality, a second in New Mexico and a third in Connecticut. As to the first mentioned case, a communication from Dr. Ross states that Ross and Shannon wished to emphasize the fact that in all observable properties the material from the type locality is identical with the montmorillonite from pegmatites. They did not intend to state that it came from an altered pegmatite. The New Mexico example was not discussed by Ross and Shannon in any detail. The Connecticut locality was fully described long ago by Brush and Dana (1880). They found spodumene altered to "cymatolite," a mixture of albite and muscovite, and (p. 283) montmorillonite associated with partially altered spodumene and with "cymatolite" and also as independent masses in the pegmatite.

Schaller (1905) analyzed pink halloysite from a Pala, California, pegmatite. After optical study, Ross and Shannon (1926) referred to this material as crystalline "halloysite." It differs chemically from montmorillonite, but is similar optically. It has been suggested (Eakle 1923, p. 223) that some of the Pala pegmatite clay may be montmorillonite. Schaller in a later paper (1925, p. 273) perhaps implies for this clay an origin by weathering rather than by hydrothermal action.

In the fine-grained, uniform Claremont pegmatite there is no reason to suspect the former presence of spodumene or other rare minerals. It is more probable that feldspars furnished the principal part of the substance of the clay, as suggested above. We think that the mode of occurrence and the absence of any evidence of hydrothermal alteration establish our case as one of weathering.

REFERENCES

Brush, George J., and Dana, Edward S., On the Mineral Locality at Branchville, Connecticut: Fourth Paper. Spodumene and the Results of its Alteration: *Am. Jour. Sci.*, (3) **20**, pp. 257–285, 1880, pl. 4.

Eakle, Arthur S., Minerals of California: *Calif. State Mining Bureau, Bull.* **91,** 1923, 328 pp.

Kerr, Paul F., Bentonite from Ventura, California: *Econ. Geol.*, **26,** pp. 153–168, 1931.

Kerr, Paul F., Montmorillonite or Smectite as Constituents of Fuller's Earth and Bentonite: *Am. Mineral.* **17,** pp. 192–198, 1932.

Lacroix, A., Montmorillonite. Mineralogie de la France et de ses Colonies, I, pp. 480–484, 1895.

Ross, Clarence S., and Kerr, Paul F., The Clay Minerals and their Identity: *Jour. of Sedimentary Petrology,* **1,** pp. 55–65, 1931.

Ross, Clarence S., and Shannon, Earl V., The Minerals of Bentonite and Related Clays and their Physical Properties: *Jour. Am. Ceramic Soc.*, **9,** pp. 77–96, 1926.

Schaller, W. T., Mineralogical Notes: *U. S. Geol. Surv., Bull.* **262,** pp. 121–144, 1905.

Schaller, W. T., The Genesis of Lithium Pegmatites: *Am. Jour. Sci.*, (5), **10,** pp. 269–279, 1925.