

ON THE ORIGIN OF MONTMORILLONITE

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The rock bentonite, the principal source of montmorillonite for experimental purposes, was shown by D. F. Hewett¹ and by E. T. Wherry² to be a leached and hydrated volcanic ash. Montmorillonite has also been described as having been derived from the decomposition of pegmatite³ and from spodumene.⁴ Ewell and Insley⁵ prepared montmorillonite synthetically in 1935. Recently W. Noll⁶ described an elaborate series of experiments made at Hanover, in which he prepared montmorillonite synthetically from mixtures of alumina, silica, water and various bases, of which magnesium hydrate proved to be the most effective. Noll believed that the conditions under which his experiments were performed would be equivalent to conditions of surface weathering extended over a longer period of time.

The authors have come upon a clay mineral at Glen Riddle, Delaware County, Pennsylvania, which has proved to be montmorillonite and which is evidently in process of formation in position, where found. The natural processes of surface alteration in operation at this locality, are easily determined. Solid rock can be found blending into clay. The alteration of plagioclase can be traced in all stages, from fresh unaltered albite oligoclase to montmorillonite replacement and to montmorillonite in veins.

This montmorillonite is found in roughly horizontal joint-seams across a thin tongue of gabbroid material, and as an alteration product of plagioclase in the wall rock adjacent to these seams. The tongue of gabbroid material as exposed makes contact with a meta-pyroxenite. It is granular in texture, medium in grain size and has a gneissic structure which parallels its irregular contacts. Its mineral composition varies. Where the montmorillonite is found, albite-oligoclase is the chief feldspar and biotite the chief ferro-magnesian mineral. Barium feldspar is present and also cassinite, an intergrowth of albite-oligoclase and a barium-potash feldspar.

When freshly dug this clay breaks into translucent lumps with a pale greenish color. Upon drying it becomes white and of granular appearance. When dropped into water, the partially dried clay expands rather vio-

¹ *Jour. Wash. Acad. Sci.*, vol. 7, p. 196, 1917.

² *Jour. Wash. Acad. Sci.*, vol. 7, p. 576, 1917.

³ Analysis given in "Clays" (3rd ed.), H. Ries, p. 72.

⁴ *Am. Jour. Sci.*, vol. 20, p. 283, 1880.

⁵ *Jour. Research Nat. Bur. Standards*, **RP 819**, vol. 15, Aug. 1935.

⁶ *Min. u. Pet. Mitt.*, Band 48, Heft 3-4, 1936.

lently. Examined optically much of this clay shows low birefringence, being practically amorphous with an index sharply lower than balsam. Where the clay shows crystallization both indices are sharply below the balsam and the birefringence is sufficient to give a first order red in the thicker flakes. We have not found material sufficiently coarse for a satisfactory study of the indices. The 1.47 liquid comes nearest the fine grained material.

A chemical analysis of a sample made without preliminary drying shows a composition as indicated in column "A" of Table 1. When calculated to a water free basis, after 15.5 per cent water had been driven off at 110°C, the analysis is shown in column "B".

TABLE 1. CHEMICAL ANALYSIS OF GLEN RIDDLE MONTMORILLONITE

	A	B	Molecular Proportions	Molecular Ratios	Molecular Ratios in Whole Numbers
SiO ₂	48.79	57.74	.961	4 × .240	12
Al ₂ O ₃	20.73	24.53	.240	1 × .240	3
MgO	5.40	6.39	.159	$\frac{2}{3}$ × .240	2
CaO	0.38	0.45	.008	—	—
Alkalies*	0.80	0.94	.015	—	—
Total H ₂ O	23.74	—	—	—	—
H ₂ O+110°C	—	10.24	.569	2½ × .240	7
H ₂ O-110°C	(15.50)	—	—	—	—
Total	99.84				

* Alkalies reported as Na₂O. Total alkalies only were determined.

A. Analysis of sample without previous drying at 110°C.

B. Calculated to moisture free basis at 110°C.

The water-free composition as expressed in column "B" leads to the formula 2MgO·3Al₂O₃·12SiO₂·7H₂O·Aq. Dana quoting LeChatelier gives the formula for montmorillonite, H₂Al₂Si₄O₁₂·nH₂O.⁷ Ross and Shannon⁸ gave the formula as (Mg,Ca)O·Al₂O₃·5SiO₂·nH₂O, but decided later that there should be only 4 silica molecules. Noll⁶ in his experimental work used an alumina to silica ratio of 1:4.

This montmorillonite showed the following water loss on heating:

At 110°C. for 12 hrs.	15.5 %
At 140° for 17 hrs.	16.5
At 190° for 4 hrs.	17.8
At 240° for 3 hrs.	18.3
At red heat	23.74

⁷ *System of Mineralogy*. (6th ed.)

⁸ *Jour. Am. Cer. Soc.*, vol. 9, p. 77, 1926.

The hill on the flank of which this montmorillonite is found, is made up largely of a thoroughly serpentinized meta-pyroxenite. At the surface and to a considerable depth, this is in an advanced stage of decomposition. Any meteoric waters reaching the joint seams in which the montmorillonite occurs, must first pass over or through this decomposing meta-pyroxenite. That such waters would pick up magnesium salts is a reasonable supposition. That these waters actually have picked up and transported magnesium salts is indicated by the abundant presence of hydrous magnesium silicate minerals with the montmorillonite (Fig. 1).

If we examine sections across one of these veins and into the solid wall rock, we find that the solutions traversing the seam have made a strong attack on the albite-oligoclase along the wall, altering it to montmorillonite. This alteration may extend for several inches into the wall rock. The most interesting feature of this reaction is the fact that the magnesium solutions attack the plagioclase readily without appreciably affecting the other feldspars in the rock. We have prepared a photomicrograph (Fig. 2) to illustrate this selective action. In this photograph differences in relief have been accentuated by a photographic deception so that the montmorillonite appears a deep grey and the unaltered feldspars white. The large grains with platy structure represent cassinite. So selective is this alteration that the albite-oligoclase plates have been thoroughly altered to montmorillonite, the alternate plates of barium-potash feldspar remaining unattacked. This selective action was observed in all sections prepared from material taken adjacent to one of the montmorillonite veins.

At this locality the authors find montmorillonite to be forming from an attack of magnesium solutions on a plagioclase of about the composition Ab_6An_1 . We believe this locality gives field evidence for the genesis of montmorillonite, confirming the conclusions reached by Noll from his laboratory experiments.

The reaction expressing this change as based on field evidence seems to be as follows: Plagioclase (appr. Ab_6An_1), plus basic magnesium carbonate, plus water, equals montmorillonite, plus calcium carbonate, plus sodium carbonate (the last two salts removed in solution).

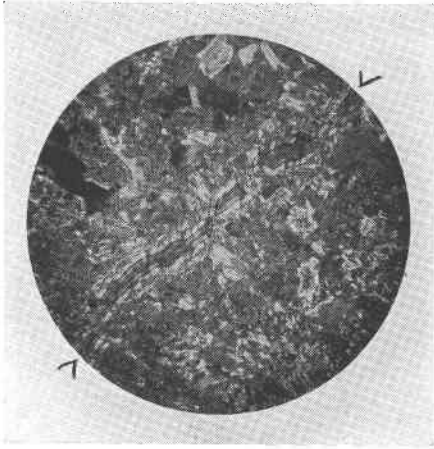


FIG. 1. Hydrous magnesium silicate minerals cutting through montmorillonized rock.
Cr. nicols. $\times 30$.

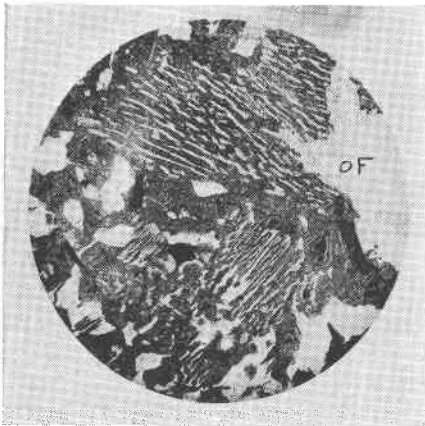


FIG. 2. Albite-oligoclase altered to montmorillonite (grey). Other feldspars unattacked (white). $\times 30$. One nicol. OF=open field.