

# REGULARLY INTERSTRATIFIED MONTMORILLONITE-CHLORITE IN BASALT

*By*

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## ABSTRACT

The dominant clay mineral in an amygdaloidal basalt from Mozambique is a mixed-layer variety having a highly regular alternation of montmorillonite-like and chlorite-like layers. The montmorillonite-chlorite occurs in the amygdules as green rosettes having a fine fibrous structure.

X-ray examination of this mineral shows a long spacing of about 29 Å in air and a fairly well-developed sequence of basal spacings. The long spacing shows some variation which is dependent on the relative humidity of the air surrounding the sample. The montmorillonite-like layers expand with glycerol and contract with heat treatment similar to montmorillonite, while the chlorite-like layers show modified reflection intensities on heating similar to chlorite. The mineral shows a 31.7 Å spacing when glycerol saturated and a 23.3 Å spacing when fully dehydrated.

## INTRODUCTION

A regularly interstratified clay mineral having montmorillonite-like and chlorite-like layers was identified in the amygdules of a basalt from Mozambique. Core samples were made available for study by the Foreign Production Division of the Gulf Oil Corporation.

Mixed-layer silicates with randomly interstratified layers are commonly found as intermediate stages in the alteration of micas and other silicates to clay minerals. In contrast, regular interstratifications are relatively rare, although examples of various pairs of clay minerals have been described by Bradley (1950), Sudo, Takahashi, and Matsui (1954), Heystek (1954), Lippman (1954), and Earley and others (1956). Because it is the first occurrence of a regularly interstratified montmorillonite-chlorite in an igneous rock, the authors believe this mineral to be worthy of a brief description.

Montmorillonite-chlorite occurs as green amygdule fillings in the basalt, having a fibrous structure with the fibers arranged in rosettes. A very thin, opaque, light-green rim surrounds many of the amygdules. Microscopically, the fibers have low birefringence and show an anomalous blue interference color somewhat similar to penninite. There is some evidence to indicate that montmorillonite-chlorite also occurs in the argillaceous sedimentary material which is interbedded with the basalt.

## X-RAY ANALYSIS

X-ray diffractometer records of the amygdule fillings show well-defined reflections from spacings of 26 to 29 Å and 31.7 Å for the natural and glycerol-

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saturated materials, respectively. These are assumed to be first-order basal reflections. The presence of other sheet-type silicate minerals, such as mica, has precluded presentation of reliably indexed powder data. A strong reflection at 1.538 Å has been interpreted as the 060 reflection and its diffuseness points to the presence of layer displacements commonly found in mixed-layer structures.

On the supposition that montmorillonite-chlorite might have hexagonal symmetry, an attempt was made to index the pattern. Lack of success limited the determination of the unit cell to the  $b$  parameter:

$$b = 6 \times 1.538 = 9.23 \text{ \AA}$$

This value is comparable with the  $b$  parameters of chlorites which lie in the range 9.20 to 9.35 Å, the lower value corresponding to Mg-rich chlorite and the higher value to Fe-rich chlorite. The  $b$  parameter for Mg-montmorillonite (saponite) has been given as 9.16 Å. Thus, the x-ray data suggest that the montmorillonite-chlorite is Mg-rich.

The chloritic character of the mineral was further confirmed by acid dissolution. The mineral is slightly soluble in cold 1:1 HCl but readily soluble in warm acid.

Variations in the  $c$  parameter of the montmorillonite-chlorite with water loss were determined from diffractometer traces of oriented specimens in atmospheres of room air and dry air, respectively, after heating at temperatures up to 500° C. Diffractometer patterns illustrating the characteristic changes are reproduced in Figure 1. Spacings corresponding to the reflection peaks (Table 1) are tentatively associated with integral orders of basal reflection. The mean lattice spacing derived for each temperature is no more than an approximation for a lattice rendered partially inhomogeneous by dehydration. Although the natural material in equilibrium with room air and the fully dehydrated material have substantially regular layer successions there is undoubtedly some random interstratification.

Significant changes in the  $c$  parameter and in the reflected intensities occur on heating (Table 1 and Fig. 1). Between room temperature and 250° C, the basal spacings decrease from about 29 Å to about 24 Å and the first-order reflection disappears provided the sample is kept in dry air after heating. Under normal atmospheric conditions the mineral rehydrates very rapidly to give a first-order basal spacing of about 29 Å similar to that of the unheated material. At 500° C the first-order basal reflection reappears with a spacing of about 20 Å while the higher orders yield a value of about 23.3 Å. Thus, montmorillonite-chlorite behaves in a manner analogous to that of the chlorites in that it shows modified basal intensities after partial dehydration.

The decrease of the basal spacing of the basalt sample from 28.9 Å to 23.3 Å, a difference of 5.6 Å, corresponds to a loss of roughly two water layers per unit cell. If one chlorite layer, 14.2 Å, is subtracted from each of these parameters, the values obtained, 14.7 Å and 9.1 Å, respectively, are in rough agreement with the values for air-dry and dehydrated montmorillonite. Saturated with water vapor, the mineral has a spacing of about 32 Å corresponding to approximately three layers of water.

Further indication of the presence of montmorillonite-like layers was obtained by glycerol solvation which expands the  $c$ -parameter to 31.7 Å. On subtracting 14.2 Å for the chlorite, one obtains 17.5 Å for the glycerol-montmorillonite complex. In addition to the 31.7 Å spacing for montmorillonite-chlorite, the

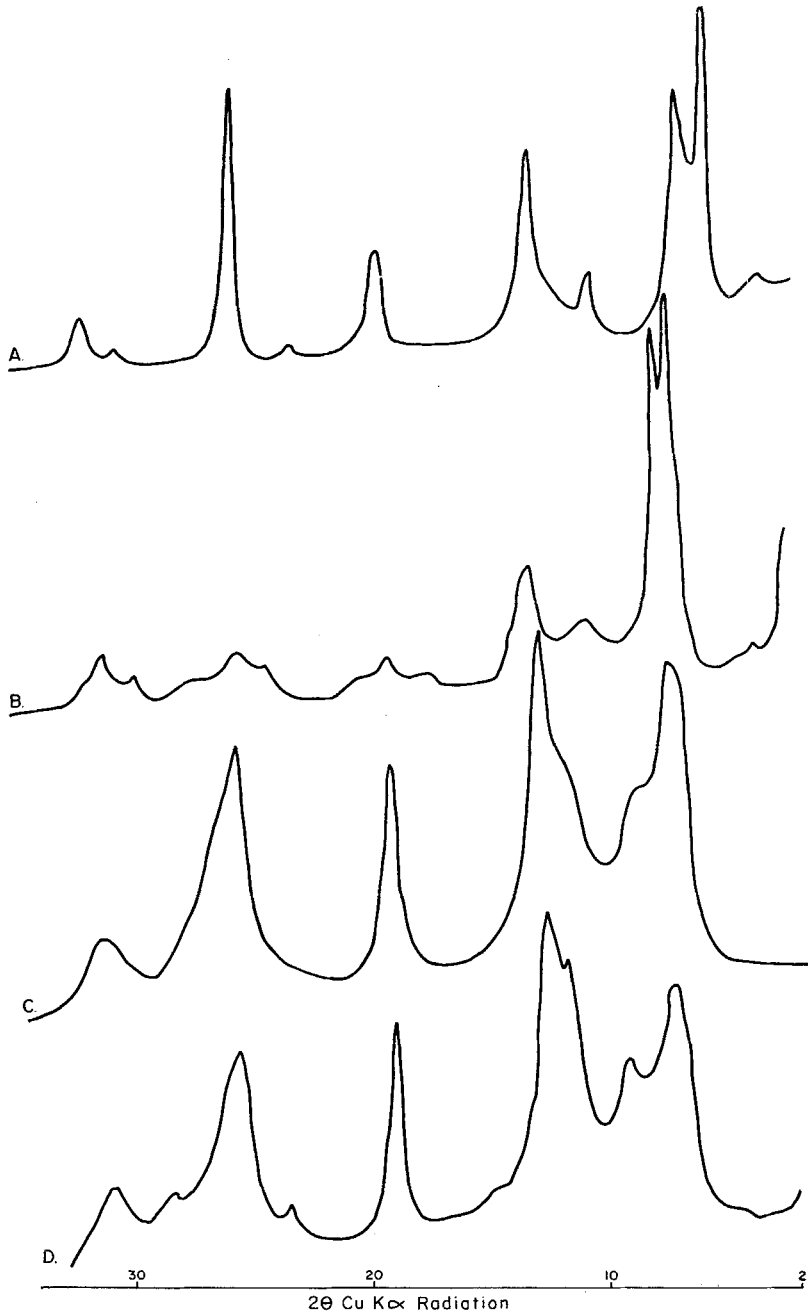


FIGURE 1.—X-ray diffractometer patterns of montmorillonite-chlorite from basalt, Mozambique, prepared by sedimentation on glass slides to yield maximum preferred orientation. A. Glycerol saturated, dry air; B. Unheated, room air; C. 250° C, dry air; D. 500° C, dry air.

TABLE 1.—BASAL REFLECTIONS FROM NATURAL, GLYCEROL-SOLVATED AND HEAT-TREATED SAMPLES IN DRY AIR OF THE MONTMORILLONITE-CHLORITE DERIVED FROM BASALT (FILTERED  $\text{CuK}\alpha$  RADIATION,  $\lambda 1.5418 \text{ \AA}$ )

Natural			250° C		500° C		Glycerol	
<i>n</i>	<i>d/n</i>	<i>d</i> (001)	<i>d/n</i>	<i>d</i> (001)	<i>d/n</i>	<i>d</i> (001)	<i>d/n</i>	<i>d</i> (001)
1	27.6	27.6*			20.5	20.5*	31.6	31.6
2	14.5	29.0	13.0	26.0*	12.6	25.2*	15.8	31.6
3			7.8	23.4	7.7	23.1		
4	7.2	28.8 K					7.83	31.3
5			4.74	23.7	4.74	23.7		
6	4.82	28.9						
7			3.53	24.7 K			4.65	32.5
8	3.61	28.9	2.90	23.2	2.91	23.2		
Mean		28.9		23.8		23.3		31.7
<i>d</i> (001)								

\* reflections excluded in taking mean *d*(001)

K—includes a kaolinite reflection

basalt sample shows a 17.7 Å peak confirming the presence of admixed montmorillonite.

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