

the split type-(b) reflections are probably connected with longer-range Si/Al and Ca/Na order with the resultant presence of domains. Reference is made here to the electron-microscope photograph published by Baier and Pense (1957) of a replica of a face ground on labradorite in which evenly spaced linear traces of separation 0.3μ (about 250 unit cells) are seen. The nature of these lamellae and the effect of heat treatment on them is being studied.

REFERENCES

- BAIER, E. AND PENSE, J. (1957), Elektronenmikroskopische Untersuchungen an Labradoriten: *Naturwiss.*, **44**, 110–111.
- BROWN, W. L. (1959), Lattice changes in heat-treated plagioclases—the existence of monalbite at room temperature: *Z. Krist.*, in press.
- CHAO, S. H. AND TAYLOR, W. H. (1940), Isomorphous replacement and superlattice structures in the plagioclase feldspars: *Proc. Roy. Soc. (London)*, **176A**, 76–87.
- CHAYES, F. (1958), A possible explanation of the δ_c separations in intermediate plagioclases: *Acta Cryst.*, **11**, 323–324.
- COLE, W. F., SÖRUM, H. AND TAYLOR, W. H. (1951), The structures of the plagioclase feldspars: *Acta Cryst.*, **4**, 20–29.
- GAY, P. (1953), The structure of the plagioclase feldspars: III An X-ray study of anorthites and bytownites: *Min. Mag.*, **30**, 169–177.
- (1954), The structure of the plagioclase feldspars: V The heat treatment of lime-rich plagioclases: *Min. Mag.*, **30**, 428–438.
- (1956), The structure of the plagioclase feldspars: VI Natural intermediate plagioclases: *Min. Mag.*, **31**, 21–40.
- GAY, P. AND BOWN, M. G. (1956) The structure of the plagioclase feldspars: VII The heat treatment of the intermediate plagioclases: *Min. Mag.*, **31**, 306–313.
- LAVES, F. AND GOLDSMITH, J. R. (1951), Short-range order in anorthite: A.C.A. Meeting, Chicago, October 1951. (Abstract p. 10). Compare *Acta Cryst.*, (1954), **7**, 131–132.
- MEGAW, H. (1957), Structure and disorder in plagioclase feldspars: *Acta Cryst.* **10**, 761.

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DIFFERENCES IN THE MONTMORILLONITE SOLVATING
ABILITY OF POLAR LIQUIDS

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The polar organic liquids which are most commonly employed to demonstrate the expandable nature of montmorillonite units are ethylene glycol and glycerol (Bradley, 1945; MacEwan, 1948). Heretofore, it has been generally assumed that these two organic liquids exhibit nearly the

same ability to solvate materials which have an expandable nature. That this supposition is incorrect has recently been revealed during the course of a study of montmorillonites (Tettenhorst, 1957).

A series of pure, dioctahedral montmorillonite samples have been analyzed in an attempt to explain the nature of the variations in properties from sample to sample. As a part of this study, three separate portions of 8 samples were made homoionic with Li^+ , Zn^{++} , and K^+ . Upon heating to $200^\circ\text{--}300^\circ\text{C}$, some of the montmorillonite layers of each sample collapsed to mica-like or pyrophyllite-like dimensions. It is significant that the extent of the irreversibility of the collapse depends on the solvating agent which was employed to demonstrate the reexpandability.

In order to demonstrate the expandable character of those units not affected by the above treatments, parallel investigations involving solvation with water, glycerol and ethylene glycol were employed. In every instance, ethylene glycol reexpanded more layers than glycerol, and glycerol reexpanded more layers than water, after lithium, zinc, or potassium saturation and heat treatment. This was true whether or not these solvating agents were applied to the oriented clay slides as a liquid at room temperature or by the vapor pressure method (Brunton, 1955). This difference in behavior leads to the conclusion that these polar substances actually differ in their ability to reexpand montmorillonite layers which have been artificially modified. Estimates of the percentage of the reexpandable units following cation saturation, heat treatment, and solvation are tabulated in Table 1 for 8 different montmorillonites.

Prior to cation saturation, all of the montmorillonite layers of each sample expanded with water, glycerol, and ethylene glycol. It is apparent

TABLE 1. REEXPANSION OF MONTMORILLONITES FOLLOWING CATION SATURATION AND HEAT TREATMENT TO $200\text{--}300^\circ\text{C}$.

Sample No.	Li			Zn			K		
	Water	Glycerol	Glycol	Water	Glycerol	Glycol	Water	Glycerol	Glycol
1	0	10	65	0	70	100	0	55	90
2	0	10	70	0	80	100	0	50	85
3	0	5	45	0	70	100	0	50	75
4	0	5	40	0	70	100	0	55	85
5	0	45	75	0	80	100	0	80	100
6	0	25	75	nd	nd	nd	0	35	50
7	0	5	20	nd	nd	nd	0	85	100
8	0	5	25	nd	nd	nd	0	50	65

Numbers represent % units expanded. nd = not determined.

from Table 1 that differences in the effect of lithium, zinc, and potassium treatments on the individual units within a montmorillonite are least apparent after solvation with ethylene glycol. For example, consider montmorillonite number 5 which has been potassium saturated and heated to 300° C. Solvation with water following treatment indicates that the montmorillonite has been modified in some manner, since, unlike the natural material, it does not reexpand in water. On the other hand, ethylene glycol solvation would have suggested that treatment had not affected the expandability, since all of the layers expanded completely like the natural material. Glycerol treatment, however, is more revealing, and indicates the presence of two kinds of layers (with respect to reexpandability) following treatment.

It is not our intention to discuss the manner in which certain montmorillonite layers have been differentially modified. Greene-Kelly (1953) and others have dealt with this matter. We only wish to emphasize that glycerol appears in these instances to be a better agent than ethylene glycol in revealing differences between silicate layers in a montmorillonite. This is particularly important in light of recently adopted practice (Weaver, 1958) in which glycol is used following potassium treatment to reveal differences in expanding characteristics and therefore, to distinguish between stripped micas and montmorillonites. It is likely that other polar organic liquids may be found which are even more selective than glycerol. The interpretation of the significance of the expandability of clays may be meaningless unless the character of the solvating agent is also taken into consideration.

It is apparent that further study of the mechanism of clay-organic complex formation is necessary. The fact that certain solvating agents are preferentially adsorbed by montmorillonite layers must be related to the structure of the organic molecule and its configuration when in contact with the clay surface.

REFERENCES

- BRADLEY, W. F. (1945), Molecular associations between montmorillonite and some poly-functional organic liquids: *Jour. Amer. Chem. Soc.*, **67**, 975-981.
- BRUNTON, G. (1955), Vapor pressure glycolation of oriented clay minerals: *Amer. Mineral.*, **40**, 124-126.
- GREENE-KELLY, R. (1953), Irreversible dehydration in montmorillonite, Part II: *Clay Minerals Bulletin*, **2**, 52-56.
- MACÉWAN, D. M. C. (1948), Complexes of clays with organic compounds, I: *Trans. Faraday Soc.*, **44**, 349-367.
- TETTENHORST, R. (1957), Unpublished M.A. thesis, Washington Univ., St. Louis, Mo.
- WEAVER, C. E. (1958), The effects and geologic significance of K "fixation" by expandable clay minerals derived from muscovite, biotite, chlorite and volcanic material: *Am. Mineral.*, **43**, 839-861.