# A REGULARLY INTERSTRATIFIED CHLORITE-VERMICULITE CLAY MINERAL*§

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## Abstract

*X*-ray diffraction and differential thermal data together with a chemical analysis, base-exchange determination, and a one-dimensional Fourier synthesis indicate that a clay residue of the Upper Mississippian Brazer limestone of Colorado contains a regularly interstratified chlorite-vermiculite clay mineral.

The first example of a clay characterized by a specific regularly alternating epitactic intergrowth was rectorite (1) which consists of alternations of one pyrophyllite unit with one vermiculite unit.

Similarly complex chloritic minerals from several English Keuper marls were described by Honeyborne, (2) and by Stephen and MacEwan, (3); others from Japanese clays by Sudo, Takahashi, and Matsui (4). Lippmann (5) reported on an occurrence from a red Keuper clay from Zaiserweiler which he described as a regular alternation of chlorite and vermiculite layers, and for which he proposed the name corrensite. In each of these studies, diffraction diagrams were complicated by the presence of other layer minerals, mainly illite, as accessories. The present intention is to describe an occurrence sufficiently free of accessory minerals for the analyses to be viewed in more intimate detail.

The best example was obtained from the Brazer of Upper Mississippian age, in Juniper Canyon, Moffat County, Colorado. The clay is disseminated through the limestone and can be concentrated as an insoluble residue. Similar though less well-developed clays have been found in the Ordovician limestones of west Texas, and in the Des Moines shales of western Oklahoma.

The Juniper Canyon sample has no significant amount of other clay present but does contain approximately 20 per cent quartz.

*X*-ray diffraction diagrams of oriented specimens show a regular series

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§ This note was prepared to illustrate that occurrences of corrensite, as named by Lippmann, are not rare, are indeed regularly alternating and justify Lippmann's name. The publication by Earley, Brindley, McVeagh and Vanden Heuvel (*Am. Mineral.*, **41**, 258–267) which arrived with these galleys obviates much of the need for an additional description, but the need still exists to call attention that equivalent geometry characterizes all three cited occurrences. Different choices of descriptive words do not present need for new mineral names.

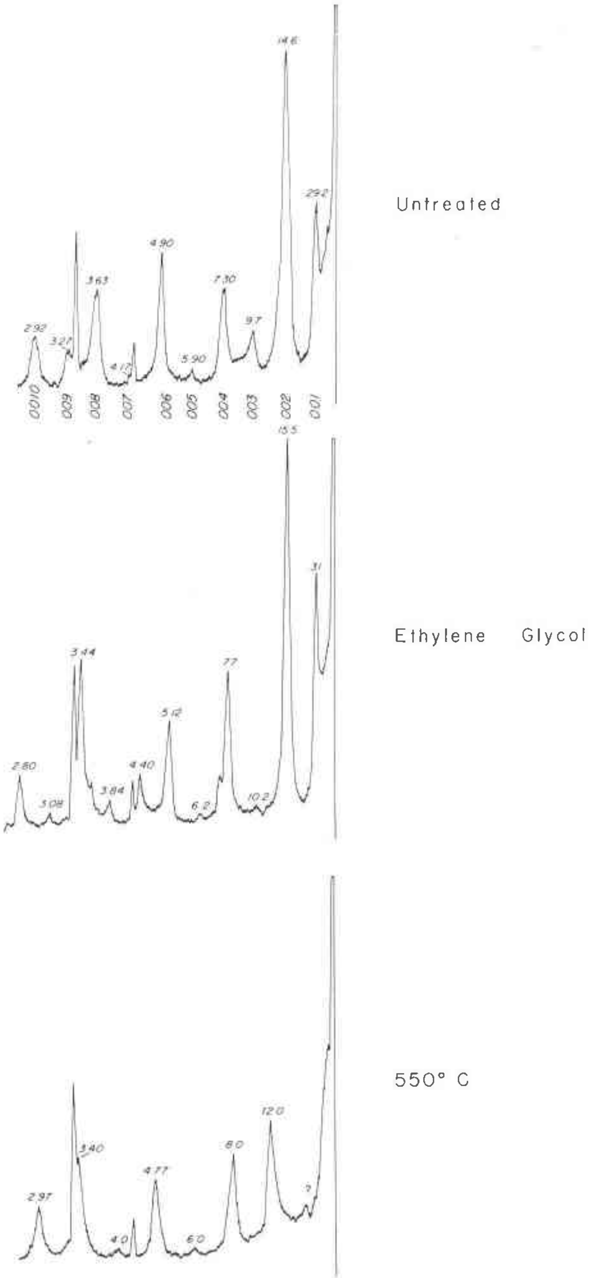

FIG. 1. *X*-ray spectrometer diffraction pattern of oriented slides of Juniper Canyon corrensite. (Peaks proportional to counting rate)

TABLE 1. MEASURED AND CALCULATED 001 SPACINGS OF JUNIPER CANYON SAMPLE

| | Untreated | | Ethylene glycol | | 550° C. | |
|---|---|---|---|---|---|---|
| | Calculated (Å) | Measured (Å) | Calculated (Å) | Measured (Å) | Calculated (Å) | Measured (Å) |
| 001 | 29.2 | 29 | 31.0 | 31 | 24.0 | 23 |
| 002 | 14.6 | 14.6 | 15.5 | 15.5 | 12.0 | 12.0 |
| 003 | 9.73 | 9.7 | 10.3 | 10.2 | 8.0 | 8.0 |
| 004 | 7.30 | 7.30 | 7.75 | 7.7 | 6.0 | 6.0 |
| 005 | 5.84 | 5.90 | 6.20 | 6.2 | 4.8 | 4.77 |
| 006 | 4.87 | 4.90 | 5.16 | 5.12 | 4.0 | 4.0 |
| 007 | 4.17 | 4.17 | 4.43 | 4.40 | 3.43 | 3.40 |
| 008 | 3.65 | 3.63 | 3.88 | 3.84 | 3.0 | 2.97 |
| 009 | 3.24 | 3.27 | 3.44 | 3.44 | 2.66 | — |
| 0010 | 2.92 | 2.92 | 3.10 | 3.08 | 2.40 | — |

of 00*l* reflections extending from a fundamental periodicity of about 29 Å (Fig. 1). When the sample is exposed to ethylene glycol vapor, a regular 00*l* series with a fundamental periodicity of approximately 31 Å is obtained. After the sample has been heated to 550° C. for two hours, the fundamental periodicity decreases to approximately 24 Å and the remaining 00*l* series is still a very nearly regular sequence of the funda-

TABLE 2. ESTIMATED RELATIVE *F* VALUES FOR JUNIPER CANYON SAMPLE

| | Natural after heating to 550° C. 24 Å | Natural 29 Å | Ethylene glycol complex 31 Å |
|---|---|---|---|
| 001 | +1.6 | +3.8 | +5.0 |
| 002 | −6.1 | −9.2 | −10.0 |
| 003 | +6.3 | +4.0 | +1.9 |
| 004 | +2.0 | +6.5 | +8.0 |
| 005 | +6.6 | +2.7 | +1.7 |
| 006 | +2.2 | +8.6 | +7.2 |
| 007 | +8.1 | +2.2 | +5.0 |
| 008 | −5.9 | +7.8 | +3.4 |
| 009 | | +3.0 | +9.8 |
| 00·10 | −1.8 | −5.9 | −2.0 |
| 00·11 | | | −5.8 |
| 00·12 | +2.8 | −1 (?)<br>(omitted) | −2.0 |
| 00·13 | | | −2.3 |
| 00·14 | | +2.1 | |
| 00·15 | | | +2.4 |

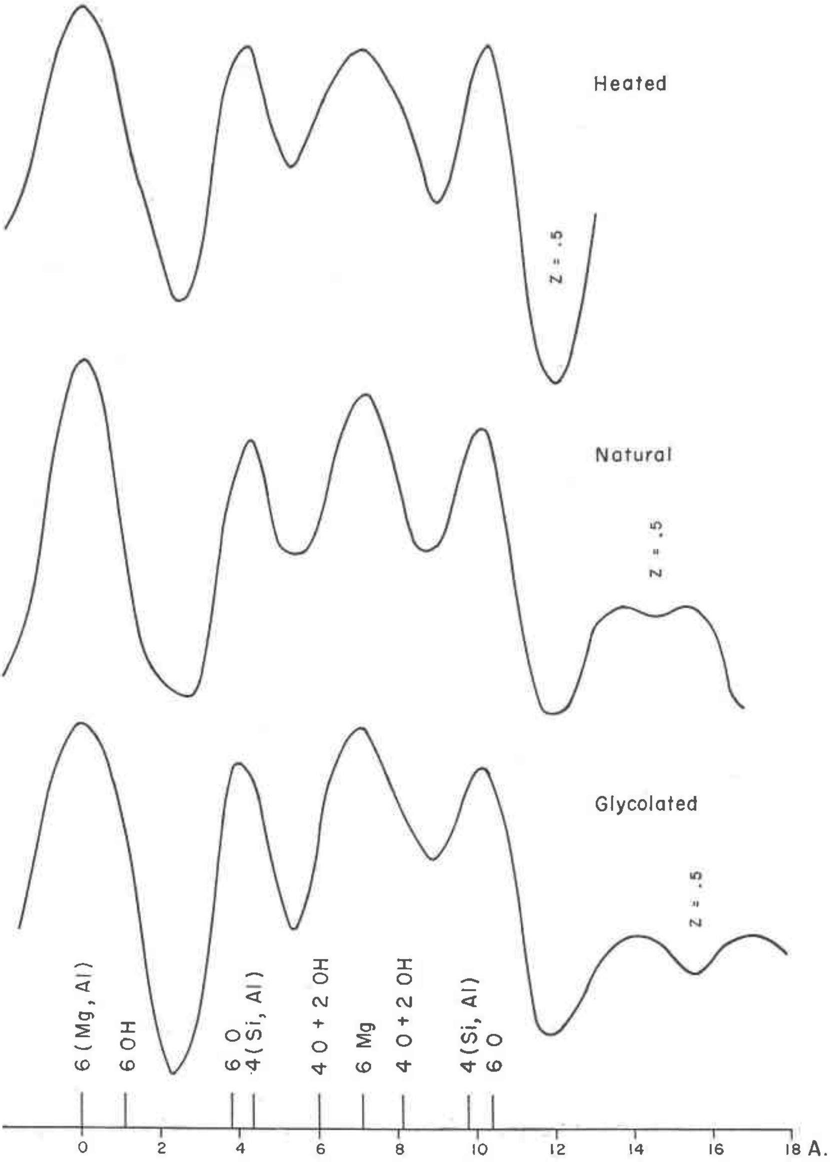

FIG. 2. One-dimensional Fourier syntheses of data from the traces of Fig. 1.

mental period. Table 1 lists the measured and calculated 00*l* values for these three periodicities.

Spectrometer traces of the 00*l* series for the three conditions noted are reproduced in Fig. 1. The successive 00*l* orders and the quartz diagram

TABLE 3. CHEMICAL ANALYSIS AND CATION DISTRIBUTION IN JUNIPER CANYON SAMPLE

| | Per cent | Distribution of cations in ideal formula | |
|---|---|---|---|
| $SiO_2$ | 41.2 { about 20% free<br>23.2 comb. | 5.47 | tetrahedral coordination |
| $Al_2O_3$ | 12.1 | 2.53<br>.84 | octahedral coordination |
| $Fe_2O_3$ | 1.74 | .31 | |
| FeO | 0.39 | .07 | |
| MgO | 22.0 | 7.78 | |
| $TiO_2$ | 0.04 | — | |
| CaO | 1.4 | .71 | interlayer (equivalents) |
| $Na_2O$ | 0.07 | .03 | |
| $K_2O$ | 0.22 | .07 | |
| bec | 40 *me*/100 gr. | .57 | |
| | | | Total (+) charge =50.00 |
| $H_2O$ (105° C.) | 6.80 | 5.4 mol. | |
| $H_2O$ (1000° C.) | 15.4 | 12.1 mol. | |

appear as the major features. Table 2 lists the relative importance of *F* values, reduced from the spectrometer curves and modified by an arbitrary temperature factor chosen to equal one-half at 45° $2\theta$. Although the series are short, the existence of the three sets of values for three different fundamental periods permits one to establish signs and view the major features with some confidence. The three one-dimensional Fourier syntheses illustrated in Fig. 2 are arrived at by application of the signs noted, based on the alternation of layers cited by Lippmann.

The prominence of the maxima representing octahedral levels, as compared with those for tetrahedral, strongly suggests trioctahedral character. The implication is stronger in the natural and glycolated syntheses, in keeping with their clearer conformity to regular alternation.** The implication of trioctahedral character also is supported by the measured (060) diffraction spacing of 1.54. Accuracy of measurement, but not of identity, is limited by incomplete resolution from the almost coincident quartz line.

The chemical analysis of the specimen as collected from an acid medium is listed in Table 3. The diffraction implications cited above permit

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** It frequently has been demonstrated that even macrocrystalline chlorites suffer some degradation in heating which reduces the scattering power of some octahedral layers and the perfection with which all layers conform to a typical thickness.

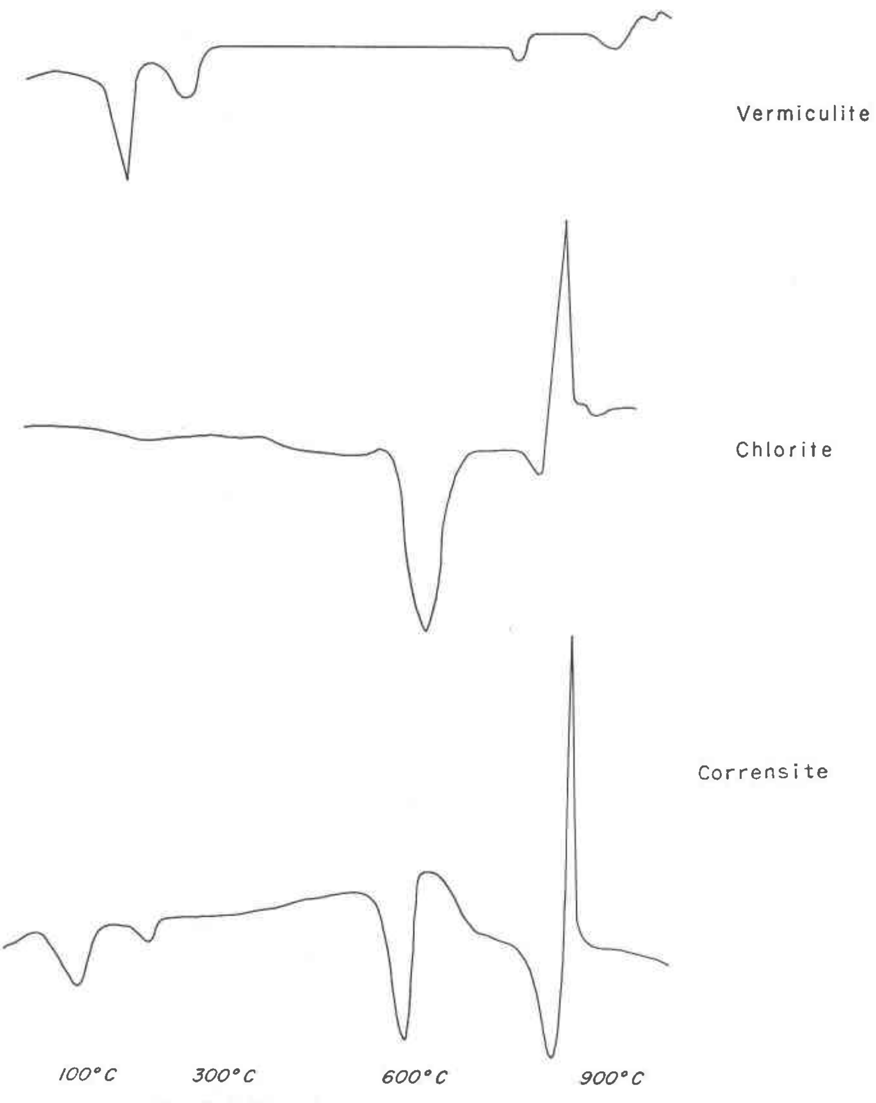

FIG. 3. Differential thermal curves of a typical vermiculite, a typical chlorite, and the Juniper Canyon corrensite.

the following rationalization. It may be assumed that this well-defined complex originally must have been a chlorite, and that it has resulted from replacement of alternate charged "brucite" layers by water and exchange bases. In such case the ideal formula would be

$$Mg_8Al_3Si_6O_{20}(OH)_{10}\cdot 4H_2O + 1 \text{ exchange charge.}$$

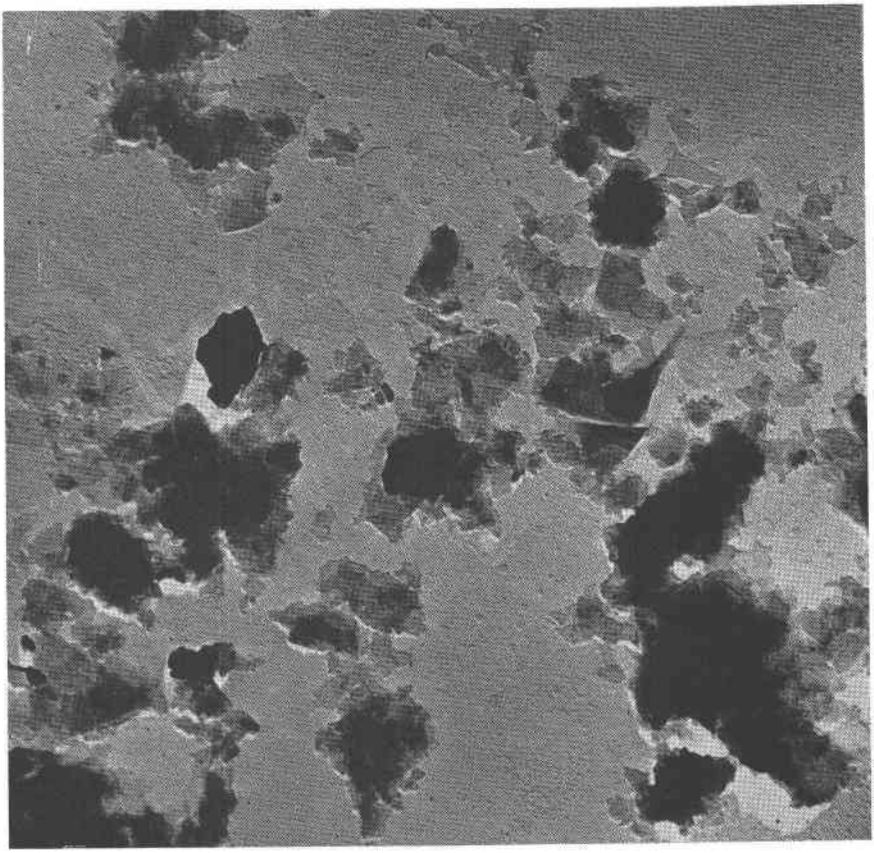

FIG. 4. Electron micrograph of the less-than 2 micron fraction of the Juniper Canyon clay. ×29,000.

For the actual case at hand the sum, in equivalents, of fixed interlayer ions+base-exchange capacity+charge gain by oxidation of iron+octahedral aluminum, must equal the tetrahedral aluminum. This distribution of aluminum affords the allocation of cation populations listed with the chemical analysis. The calculated excess of silica, 18 per cent, compares favorably with the diffraction estimate of 20 per cent free quartz. The proportion of silicon and tetrahedral aluminum is in the range of average compositions of vermiculites and of chlorites. The analyzed $H_2O$ contents are notably higher than the ideal, but this also is commonly true of macrocrystalline vermiculites, and is not considered to be a serious fault.

A differential thermal analysis curve for the Juniper Canyon specimen is compared with curves for a typical vermiculite and a typical chlorite in Fig. 3. The major features qualitatively confirm the foregoing interpretations of the diffraction analysis. Molecular water is lost from the Juniper Canyon specimen in two fractions at about 100° C. and about 210° C. The features do not appear to differ from those of a typical vermiculite to a greater degree than can be attributed to the lesser particle size of the clay. Hydroxyl water features indicate losses in three stages. The first, at about 550° C., is analogous with but of lesser magnitude than the first chlorite hydroxyl feature, commonly attributed to hydroxyl loss from "brucite" layers. The two subsequent features presumably may be attributed to water loss consequent to the proton occupancy of exchange positions, and to the hydroxyl content originally associated with the brucite member of the complex silicate triple layer.

Electron micrographs (Fig. 4) show that the clay consists of thin flakes with sharp, discrete edges.

## References

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