

## REGULARLY INTERSTRATIFIED CHLORITE/VERMICULITE IN SOILS OVER META-IGNEOUS MAFIC ROCKS IN MARYLAND<sup>1</sup>

**Key Words**—Chlorite, Interstratification, Mixed layer, Soil, Vermiculite, Weathering.

### INTRODUCTION

The random interstratification of chlorite and vermiculite layers in 2:1 phyllosilicates in geologic and pedologic materials is quite common. Regular interstratification is considerably less common. Regularly interstratified chlorite/vermiculite with dolomite and calcite was reported in Mississippian carbonate rocks (Peterson, 1961). It has also been reported as a hydrothermal alteration product of hornblende (Harvey and Beck, 1962) and in weathered slate as an alteration product of chlorite (Post and Janke, 1974). Johnson (1964) reported an abundance of such a mineral in the fine silt (2–5  $\mu\text{m}$ ) fraction of the Highfield soil of Pennsylvania, which formed from a chlorite-rich metabasalt. A regularly interstratified chlorite/vermiculite was also reported in a soil formed from chlorite schist in Zaire where it dominated both the 2–20- $\mu\text{m}$  and 20–50- $\mu\text{m}$  fractions, but was replaced by smectite and randomly interstratified chlorite/vermiculite in the clay (<2  $\mu\text{m}$ ) fraction (Herbillon and Makumbi, 1975). Using a chlorite from the Middletown Valley of Maryland (similar to the parent material of the Highfield soil studied by Johnson), Ross and Kodama (1976) formed a regularly interstratified chlorite/vermiculite by chemical oxidation with bromine water.

This note reports the occurrence of regularly interstratified chlorite/vermiculite in two soils of the Maryland Piedmont formed from meta-igneous mafic rocks. The findings were made during a study of the genesis and mineralogy of soils developed in serpentinitic and associated mafic parent materials (Rabenhorst, 1978).

### MATERIALS AND METHODS

Two soil profiles in Harford County, Maryland, were described and sampled according to standard soil survey procedures. Profile 1 is a fine silty, mixed, mesic, Aquic Fragiudalf (by the system of Soil Survey Staff, 1975) formed in about 1 m of loess overlying metagabbro residuum and is mapped as the Kelly soil series (Smith and Matthews, 1975). The parent rock is a medium-grained metagabbro comprised of about 50–60% plagioclase (An 48–54) and 35–45% tremolite-actinolite that is altered in part (about half) to chlorite. The rock also contains about 5% zoisite. Profile 2 is a fine, mixed, mesic Typic Hapludalf formed in amphibolite residuum and is mapped in the Aldino soil series (Smith and Matthews, 1975). The rock at the site is a medium-grained amphibolite containing roughly equal proportions of clino- and orthoamphiboles.

X-ray powder diffractometer (XRD) patterns of the fine (<0.2  $\mu\text{m}$ ) and coarse (0.2–2  $\mu\text{m}$ ) clay and fine silt (2–5  $\mu\text{m}$ ) fractions from selected horizons were prepared using parallel oriented specimens on glass slides by methods similar to those of Jackson (1969) and a Philips X-ray diffractometer equipped with a single crystal (graphite) monochromator and  $\text{CoK}\alpha$  radiation.

The horizon from each profile showing the largest amount of the regularly interstratified mineral was further analyzed. The materials were particle-size fractionated by methods similar to those described by Kittrick and Hope (1963). The fine

and coarse clay (<0.2  $\mu\text{m}$ , 0.2–2  $\mu\text{m}$ ), the fine, medium, and coarse silt (2–5  $\mu\text{m}$ , 5–20  $\mu\text{m}$ , 20–50  $\mu\text{m}$ ), and the very fine, fine, and medium sand (50–100  $\mu\text{m}$ , 100–250  $\mu\text{m}$ , 250–500  $\mu\text{m}$ ) were examined by XRD, but due to instrumentation "upgrade," using a theta compensating slit, the previously described monochromator, and  $\text{CuK}\alpha$  radiations. Parallel oriented specimens on glass slides were examined for the following conditions: Mg saturation and glycerol solvation at 25°C; K-saturation after heating at 300°C for 2 hr; K-saturation after heating at 550°C for 2 hr.

Thin sections were prepared from the probable parent rocks at each of the sites and examined with a petrographic microscope.

### RESULTS AND DISCUSSION

The upper meter of profile 1 formed in loess whereas the lower portion formed from a metagabbro. The discontinuity in the profile is reflected by the presence of feldspar, quartz, and mica in the upper meter and the absence of these minerals in the (<5  $\mu\text{m}$ ) fractions examined below the discontinuity (Rabenhorst, 1978). The 0.2–2- $\mu\text{m}$  and 2–5- $\mu\text{m}$  fractions of the residual portion of the profile were dominated by a regularly interstratified chlorite/vermiculite accompanied by small amounts of kaolinite, smectite, and vermiculite. The interstratified mineral was absent entirely from the overlying loessial material. Figure 1 shows the XRD patterns for the fine silt fraction of the IIC1 horizon (130–155 cm) from profile 1. The regularly interstratified mineral is indicated by the 001 peak at 24.4 Å and the 002 peak at 12.2 Å in the 550°C heated, K-saturated specimens. These peaks were obtained for the condition in which the vermiculite interlayer is collapsed. With Mg saturation and glycerol solvation, an 001 spacing of 28.3 Å was obtained. Several higher order reflections were also obtained—more before heating the specimens to 550°C than after. In general the even-order peaks were more pronounced with Mg saturation and glycerol and the odd-order peaks were more pronounced with K saturation, except that the 002 peak was very strong for the K-saturated, 550°C heated specimen. With Mg-saturated and glycerol-solvated specimens, peaks for 10th, 12th and 14th orders were also observed and peaks for the 9th and 12th orders with K saturation after heating at 550°C. In general, the sharpness of the peaks for the various orders is about the same, as is desired by some (S. W. Bailey, Department of Geology, University of Wisconsin, Madison, Wisconsin, personal communication) for recognition of regularly interstratified minerals. Some kaolinite in this fraction apparently contributes to the peaks at 7.24 and 3.56 Å.

From thin section examination of the parent rock, chlorite is present in grains generally <50  $\mu\text{m}$  in size. If this chlorite was the precursor of the regularly interstratified mineral, the grain size of the chlorite would constitute an upper limit on the particle size of the regularly interstratified product in the soils. As shown in Figure 2 (note particularly the 12-Å peak for the K-saturated, 550°C heated specimens) regularly interstratified chlorite/vermiculite was found in all fractions greater than 0.2  $\mu\text{m}$  in size in the IIC1 horizon, and was most abundant in the 2–5- $\mu\text{m}$  fraction. Moderate amounts are present up to the 20–50- $\mu\text{m}$  fraction, but only trace amounts in coarser fractions. In Figure 2 the 001 peaks are weaker than in Figure 1. This difference is the result of the theta compensating divergence slit which reduced the intensity of low-angle peaks relative to

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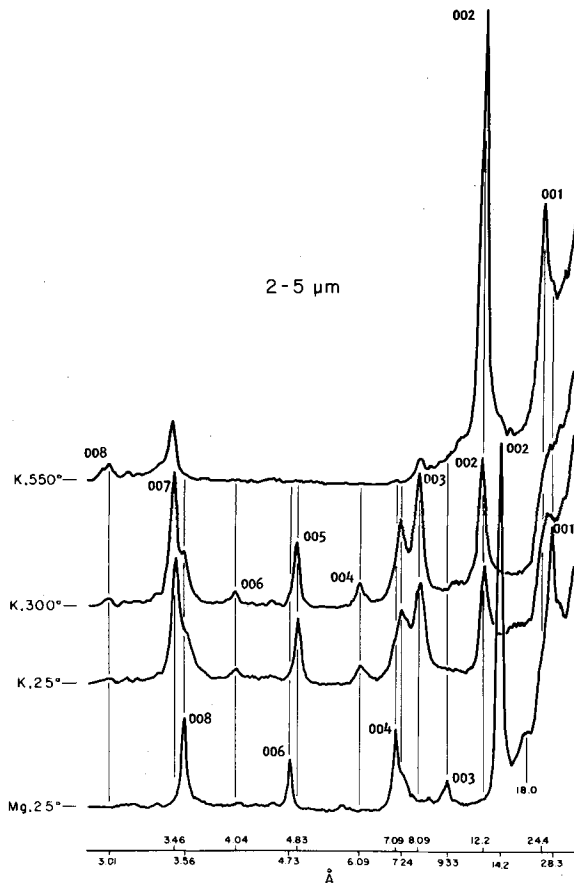


Figure 1. X-ray powder diffraction patterns for parallel oriented specimens of the fine silt fraction from the IIC1 horizon of profile 1. CoK $\alpha$  radiation and instrument without theta compensator were employed. Specimens at 25°C were glycerol solvated.

peaks at higher angles compared to the fixed-angle divergence slit used to produce the patterns shown in Figure 1.

Tremolite grains in the thin sections of the parent rock were mainly in the 0.3- to 3-mm size range, which may explain the dominance of tremolite in the >100- $\mu$ m fractions of the soil. The absence of the regularly interstratified mineral and the presence of smectite and a random interstratification of chlorite and vermiculite in the <0.2- $\mu$ m fraction indicates that the regular interstratification may be an intermediate stage in the weathering process as suggested, for example, by Herbillon and Makumbi (1975).

In profile 2 the regularly interstratified chlorite/vermiculite is accompanied by considerable smectite and a small amount of chlorite. It is most abundant in the C1 horizon (183–211 cm) and decreases with depth, and is absent from the lowest horizons (372–430 cm) and from the solum above. Because all other occurrences of a mineral of this nature in soils have been related to the alteration of trioctahedral chlorite, it is likely that some chlorite was present in the parent rock. The XRD patterns of the 2–5- $\mu$ m and 5–20- $\mu$ m fractions of the C1 horizon of the soil (Figure 3) show a small amount of discrete chlorite. Chlorite was not found, however, in the rock samples from this site or in the sand fractions from the lowest horizon

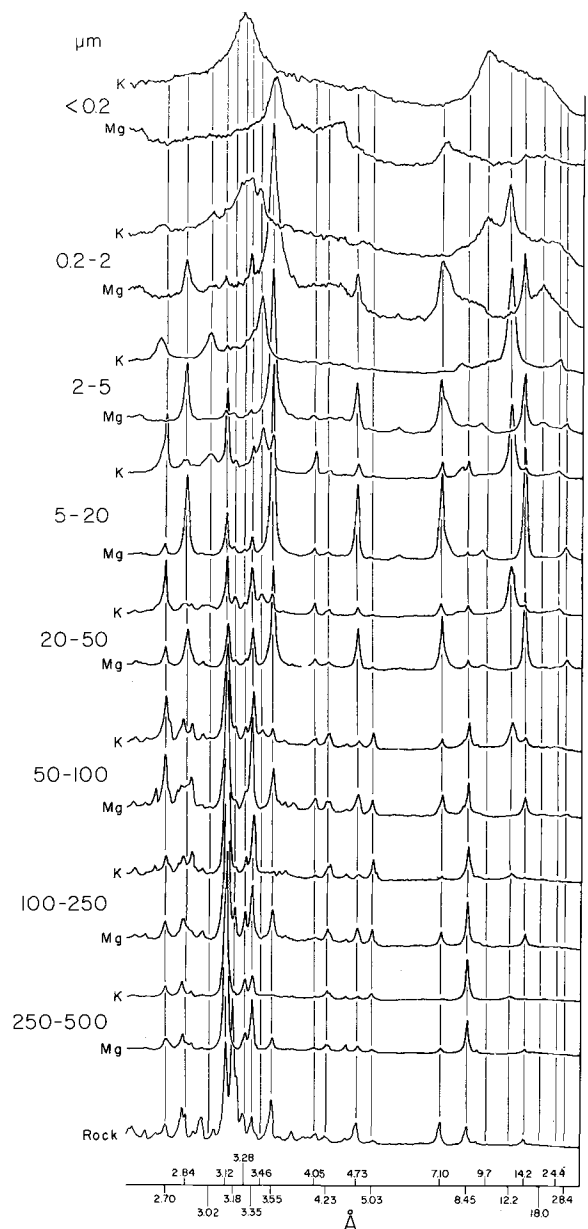


Figure 2. X-ray powder diffraction patterns for parallel oriented specimens of various size fractions from the IIC1 horizon of profile 1 under conditions of Mg saturation with glycerol solvation and K saturation after heating at 550°C for 2 hr. CuK $\alpha$  radiation and instrument with theta compensator were employed.

of the profile. Elemental analysis by X-ray spectroscopy of the silt fractions revealed irregular elemental (with implied mineralogical) variations with depth (Rabenhorst, 1978), suggesting that the mineralogy of the rock may vary significantly with depth at this site. A heterogeneous geologic column containing a chlorite-rich zone could explain the restricted occurrence of both the regularly interstratified mineral and the vestigial discrete chlorite in this profile.

The regularly interstratified mineral in profile 2 is present in

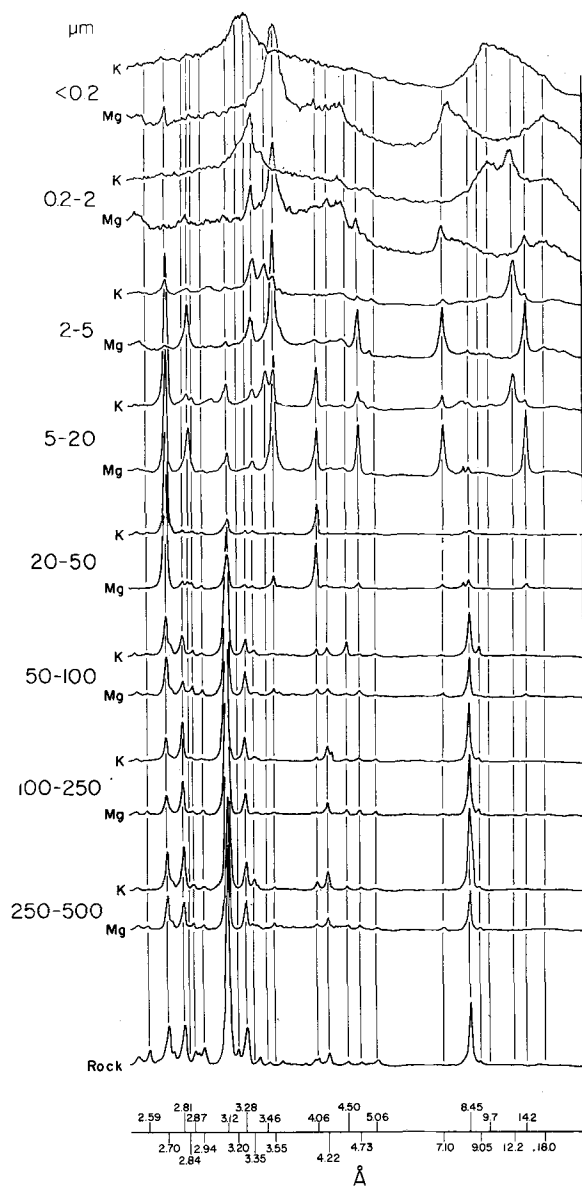


Figure 3. X-ray powder diffraction patterns for parallel oriented specimens of various size fractions from the C1 horizon of profile 2 under conditions of Mg saturation with glycerol solvation and K saturation after heating at 550°C for 2 hr. CuK $\alpha$  radiation and instrument with theta compensator were employed.

the 0.2-2-, 2-5-, and 5-20- $\mu\text{m}$  fractions (Figure 3). As in profile 1, the mineral is most abundant in the 2-5- $\mu\text{m}$  fraction. Also, as in profile 1, random interstratifications of chlorite and expandable 2:1 minerals are present in the <math><0.2\text{-}\mu\text{m}</math> fraction. An abrupt change in mineralogy takes place between the 5-20- and the 20-50- $\mu\text{m}$  fractions, wherein the levels of the regularly interstratified chlorite/vermiculite decrease from mod-

erate to trace amounts. This decrease suggests that the grain size of the chlorite in the parent material was generally <math><20\ \mu\text{m}</math>. The mineralogy of the >20- $\mu\text{m}$  size particles is dominated by an amphibole (8.45 and 3.12  $\text{\AA}$  peaks, Figure 3). The prominent XRD peaks at 4.06  $\text{\AA}$  and 2.70  $\text{\AA}$  in the 5-20- and 20-50- $\mu\text{m}$  fractions of profile 2 represent the 400 and 600 reflections, respectively, of zoisite. This mineral constitutes approximately half of the 20-50- $\mu\text{m}$  fraction, based on optical examination. Apparently the parent rock contained zoisite grains in a narrow size range. The peaks at about 4.06 and 2.70  $\text{\AA}$  in XRD patterns of the >50- $\mu\text{m}$  fractions are due to the 201, 111, and 151 spacings of the tremolite-actinolite that dominates the coarser fractions.

In both profiles there appears to be some hydroxy-interlayered, expandable 2:1 minerals in the <math><0.2\text{-}\mu\text{m}</math> fraction that may in part represent a further weathering product of the regularly interstratified mineral.

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