

CLAY MINERALS AT A PENNSYLVANIAN DISCONFORMITY¹

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ABSTRACT

At the Desmoinesian-Missourian disconformity in southeastern Kansas a fossil soil zone is recognized by variations in clay mineralogy in the uppermost Desmoinesian Holdenville shale, which underlies basal Missourian Hepler sandstone. The clay fraction of the overlying basal Missourian Hepler sandstone contains kaolinite, slightly hydrated illite, quartz, and vermiculite. Chlorite (rather than vermiculite) is present in shaly portions of the basal Hepler sandstone. Clay-size minerals of the typical Holdenville shale (marine) are predominantly illite, chlorite, quartz, feldspar, and a very small quantity of kaolinite. The clay-mineral assemblages in samples from the upper part of the Holdenville shale indicate hydration of illite, sporadic increase in kaolinite, possible decrease in feldspar, and progressive modification and destruction of chlorite resulting in production of mixed-layer minerals.

INTRODUCTION

The Holdenville (Memorial) shale is the uppermost formation of the Marmaton group at the top of the Desmoinesian Series. The formation, which has a maximum thickness of 30 feet, consists of gray to dark-gray and yellowish clay shale, generally unfossiliferous but bearing marine fossils at a few localities. The Desmoinesian deposits are set off from the overlying Missourian rocks by pronounced lithologic and paleontologic differences (Moore and others, 1951, p. 94), and the base of the Missourian is marked by a regional disconformity. This disconformity below the basal Missourian Hepler sandstone brings lowermost Missourian deposits into contact with rocks ranging from the Holdenville shale downward to the upper part of the Bandera shale, a stratigraphic interval of more than 60 feet (Moore and others, 1951, p. 91, 95). A slight discordance also is indicated (Jewett, 1945, p. 20). Figure 1 is a generalized stratigraphic section showing the Hepler sandstone and the upper part of the Marmaton group. The basal Hepler is characteristically a sheetlike deposit of fine-grained sand, silt, or even shale (Moore, 1949, p. 73) rather than channel sandstone.

The purpose of this paper is to describe the variations in clay mineralogy of the Holdenville in relation to the overlying disconformity, and to determine the extent of modification of the clay minerals during the pre-Missourian erosional interval.

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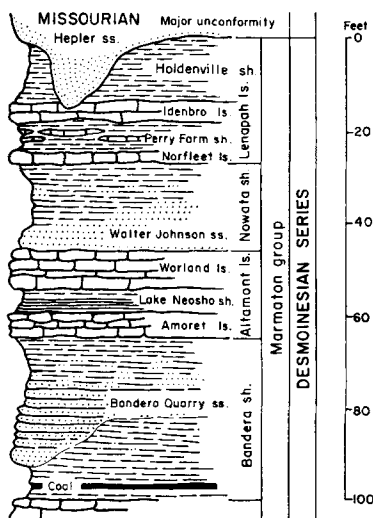


FIGURE 1. — Upper Desmoinesian rocks in Kansas (after Moore and others, 1951, p. 95).

The clay fraction was studied in detail from samples of Holdenville shale and Hepler sandstone (and shale) collected at 5 localities ranging from Linn County on the northeast to Labette County on the southwest—a straight-line distance of about 84 miles (Fig. 2).

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FIELD WORK AND METHODS OF STUDY

The samples described in this report were collected from localities described by Jewett (1945). The sample numbers, localities, and stratigraphic locations with respect to the overlying Hepler sandstone and underlying Lenapah limestone (where known) are listed in Table 1.

In the laboratory, the particle size distribution of 8 samples of shale was determined by the pipette method. Ammonium hydroxide was used as the dispersing agent.

Oriented -2 micron size clay particles on glass slides were used to obtain the x-ray diffraction patterns. A General Electric XRD-3 unit was used with nickel-filtered copper radiation. Each sample was x-rayed in the dry state, after being glycerated, after heating to 450°C , and after heating at 550°C to 600°C for 30 minutes. In addition, several samples were boiled for 5 minutes in HCl in an attempt to destroy any chlorite present. After the samples had been washed, oriented slides were prepared and diffraction patterns were made.

Chemical analyses of sample 16, a typical unmodified Holdenville sample,

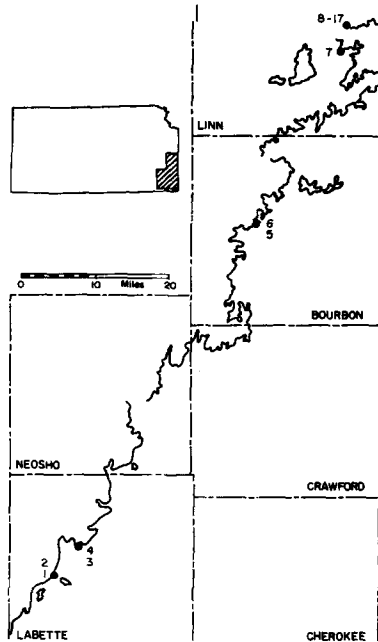


FIGURE 2.— Sample localities and trace of Hepler-Holdenville boundary in southeast Kansas.

and sample 6, from just below the disconformity, were made in the geochemistry laboratories of the State Geological Survey under the direction of Russell Runnels. The results are reported in Table 2.

HEPLER SANDSTONE AND SHALE

The clay minerals were examined from one sample (7) of basal Hepler sandstone and two samples (8, 9) of basal Hepler shale.

The sandstone sample is represented by diffractometer patterns in Figure 3. The minerals present are kaolinite, slightly hydrated illite, a small quantity of quartz, and a nonexpanding 14.5A mineral. This 14.5A spacing, although slightly broad, is in part stable after heating to 450°C, but it shifts to 11.9A after the clay is heated to 575°C. It is attributed to a vermiculite mineral, probably mixed-layer chlorite-vermiculite. The symmetry of the illite 001 reflection improves with glyceration and also with heating to 450°C, so it is thought that the illite has no chloritic (Nelson, 1956, p. 120) or vermiculitic component. No feldspar reflections were observed.

The basal Hepler shale samples contain kaolinite, illite, and normal chlorite. They are described in a later section.

TABLE 1. — LOCATIONS OF SAMPLES DESCRIBED; PARTICLE SIZE AND SORTING

| No. | Location | Depth Below Hepler | Height Above Lenapah | Phi Mean Diameter | Phi Standard Deviation |
|-----|-------------------------------------|--------------------------|----------------------------|-------------------------|------------------------------|
| 1 | NE 11-33-18E, Labette Co. | 10 ft | 8 ft | 8.64 | 1.97 |
| 2 | do | 9 | 9 | | |
| 3 | Cen. N line 20-32-19 E, Labette Co. | 5.3 | | 7.32 | 2.21 |
| 4 | do | 0.5 | | 7.53 | 2.51 |
| 5 | SE SE 18-25-23E, Bourbon Co. | .5-1 | | 8.30 | 2.18 |
| 6 | do | 0-5 | | 8.66 | 2.27 |
| 7 | Cen. 19-21-25E, Linn Co. | —1 | | | |
| 8 | Cen. 5-21-25E, Linn Co. | —2 | | | |
| 9 | do | —3 | | | |
| 10 | do | 1.5 | 25 | | |
| 11 | do | 2.5 | 24 | | |
| 12 | do | 3.5 | 23 | 7.03 | 1.94 |
| 13 | do | 4.5 | 22 | | |
| 14 | do | 5.5 | 21 | | |
| 15 | do | 6.5 | 20 | | |
| 16 | do | 7.5 | 19 | 9.22 | 1.86 |
| 17 | do | 13.5 | 13 | 9.56 | 1.64 |

¹ Basal Hepler sandstone

² 1.5 feet above base of 7-foot Hepler shale section

³ 0.5 foot above base of Hepler shale

TABLE 2. — CHEMICAL ANALYSES OF TWO SAMPLES FROM THE HOLDENVILLE SHALE
(by Russell Runnels, State Geological Survey of Kansas)

| | 16 ¹ | | 6 ² | |
|---|-------------------|-------|----------------|-------|
| | Whole Shale | —2μ | Whole Shale | —2μ |
| SiO ₂ | 54.21 | 47.43 | 50.97 | 48.49 |
| Al ₂ O ₃ | 21.89 | 25.72 | 22.10 | 25.33 |
| Fe ₂ O ₃ ³ | 8.20 | 9.17 | 6.20 | 8.69 |
| TiO ₂ ⁴ | 1.19 | 0.93 | 1.47 | 0.68 |
| CaO | 0.31 | 0.28 | 4.47 | 1.60 |
| MgO | 2.79 | 2.88 | 2.13 | 2.21 |
| P ₂ O ₅ | 0.09 | ND | 1.89 | ND |
| SO ₃ | nil | ND | 0.05 | ND |
| K ₂ O | 4.39 | 5.57 | 4.14 | 5.41 |
| Na ₂ O | 0.81 | 0.45 | 0.37 | 0.18 |
| Sulfide S | 0.05 ⁵ | ND | tr | ND |
| LOI 140-550° | 1.05 | 3.34 | 2.92 | 3.32 |
| LOI 550-600° | 2.62 | 2.45 | 1.42 | 2.36 |
| LOI 1000° | 1.90 | 1.05 | 1.72 | 1.09 |
| Total | 99.45 | 99.27 | 99.73 | 99.36 |

¹ 7.5 feet below Hepler

² Less than 6 inches below Hepler

³ Total iron expressed as ferric oxide

⁴ Includes V₂O₅ and ZrO₂ if present

⁵ Not included in total

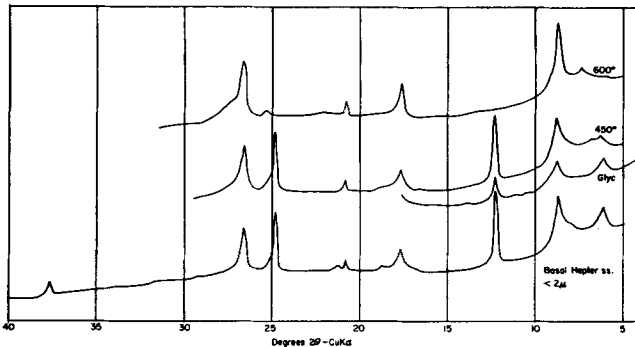


FIGURE 3.—X-ray diffractometer patterns of -2 micron fraction, basal Hepler sandstone (sample 7).

TYPICAL HOLDENVILLE SHALE

Four of the samples analyzed and described herein (1, 2, 16, 17) are believed to be characteristic of the essentially unmodified Holdenville. These range in position from about 8 to 19 feet above the base of the formation, and are 7 to 13 feet below the base of the Hepler sandstone. Two of them (1 and 2) contain abundant marine fossils, particularly bryozoans and corals, in the coarser fractions.

The minerals present in the fraction finer than 2 microns, as shown by x-ray diffractometer patterns, are illite, chlorite, quartz, and feldspar, and very small quantities of kaolinite and illite-montmorillonite. The 14.5, 10, and 7A basal reflections are sharp and well defined (Fig. 4), but there is slight asymmetry in the 10A reflection. Feldspar is identified by a reflection at about 3.2A in the oriented samples. The 14.5A reflection and higher-order basal chlorite reflections (7.13A, 4.77A, 3.56A, 2.84A) in all four samples are unmodified by heating the sample to 450°C, but after the clay was heated at 575°C for one-half hour all but the 14.5A reflection were destroyed. The intensity of this peak increased and its spacing shifted to 14.2A.

Treatment of the oriented clay with glycerol increased the symmetry of the 10A reflection in all samples; the diffraction patterns were otherwise unmodified. Destruction of the chlorite with hot HCl revealed the presence of a minute quantity of kaolinite. Typical Holdenville diffractometer patterns are shown in Figure 4.

CHARACTER OF HOLDENVILLE CLAY MINERALS NEAR DISCONFORMITY

Five changes are observed in the various samples of Holdenville shale from near the base of the Hepler: (a) destruction or modification of the chlorite; (b) formation or addition of either a kaolin mineral or "soil" chlorite or both; (c) decrease in feldspar; (d) broadening of the illite basal reflections;

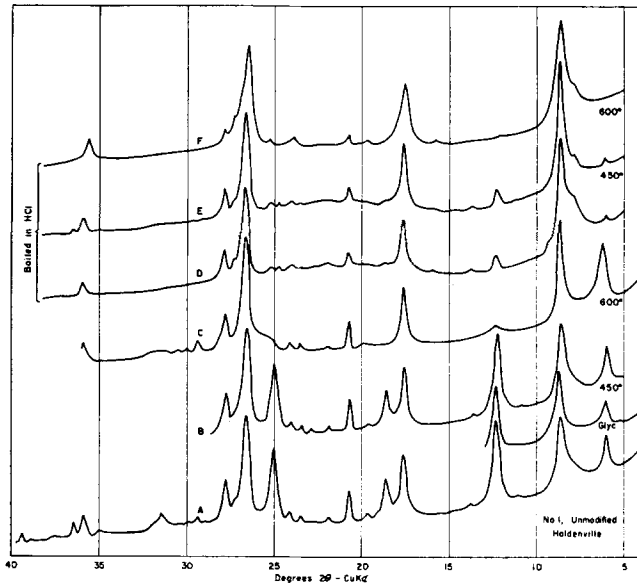


FIGURE 4.—X-ray diffractometer patterns of -2 micron fraction, unmodified Holdenville shale (sample 1).

and (e) increase in mixed-layer minerals. There is also a trend toward poor sorting with respect to particle-size distribution.

The clay minerals in a single outcrop will first be described and tabulated. Each of five samples from other localities will then be described individually, in order of decreasing distance below the Hepler contact.

Section Below Basal Hepler Shale

In a stream bank near the center of sec. 5, T. 21 S., R. 25 E., Linn County, is a complete section of Hepler sandstone and Holdenville shale. Inasmuch as the basal few feet (about 7 feet) of the Hepler at this locality is predominantly shaly and hence relatively impermeable to percolating ground water, this section was chosen for detailed study. Samples were taken at one-foot intervals from the gray Holdenville shale upward through increasingly yellowish limonitic zones, and across the disconformity into the dark gray basal Hepler shale. The clay mineral assemblages are shown in Table 3.

This is the only locality from which a "soil" chlorite was identified. Otherwise, the general picture is similar to that at other localities: illite becomes degraded, illite-montmorillonite increases, and normal chlorite gives way to vermiculite.

Description of Individual Samples

The clay-mineral content of each of five samples from localities in Linn,

TABLE 3.—CLAY MINERALS IN BASAL HEPLER SHALE AND UPPER HOLDENVILLE SHALE IN THE CEN. SEC. 5, T. 21 S., R. 25 E., LINN COUNTY

| Distance Above or Below Disconformity | Clay Minerals |
|---|---|
| 1.5 ft above | Kaolinite, illite, chlorite ¹ |
| 0.5 ft above | Kaolinite, illite, chlorite |
| DISCONFORMITY | |
| 0.5 ft below | Illite (degraded), "soil" chlorite, illite-montmorillonite, vermiculitic mineral, trace kaolinite (?) |
| 1.5 ft below | Same, but no kaolinite |
| 2.5 ft below | Illite, "soil" chlorite, chlorite, vermiculitic mineral, trace illite-montmorillonite |
| 3.5 ft below | Same as above, but chlorite more heat-resistant, trace kaolinite |
| 4.5 ft below | As above, but no vermiculite. Chlorite and illite reflections strong |
| 5.5 ft below | As above |
| 6.5 ft below | As above, but no "soil" chlorite. Chlorite and illite reflections very strong, nearly symmetrical |
| 7.5 ft below | As above |
| 13.5 ft below | As above |

¹ The term *chlorite* here refers to normal chlorite having a 14A basal spacing that is retained after heating to 575°C. "Soil" *chlorite* refers to chlorite whose basal spacings are destroyed at 450°C.

Bourbon, and Labette counties are described in order of decreasing distance below the disconformity.

Sample 3 (5.3 feet below base of Hepler).—The diffraction pattern from the unheated oriented clay is identical with those from the unmodified Holdenville, except that the illite reflections are slightly broader and the 001 illite reflection is markedly asymmetrical. However, a portion of the 14.5A spacing (vermiculite in part?) decreases to about 13.3A after the clay is heated to 450°C, and to 12.1A after heating to 575°C. This sample also contains a small quantity of calcite and only a suggestion of kaolinite (small 003 reflection at 37.8° 2θ). The asymmetrical illite 001 reflection is made symmetrical by glyceration and also by heating (as in the unmodified Holdenville). A diffraction pattern from sample 3 is shown in Figure 5.

Sample 12 (3.5 feet below base of Hepler).—This sample was collected from 3 feet above sample 15 (Table 1), which is near the top of the typical unmodified Holdenville. It is from the locality for which the clay minerals are shown in Table 3. The chlorite is still heat-resistant, as in 15, but other strong basal reflections (including 3.59 and 2.38A) are also present. These reflections are attributed to a "soil" chlorite (for the most part, although kaolinite is also present), because the spacings are almost entirely destroyed when the sample is heated to 450°C. Another spot sample from this locality at the same depth contained slightly less "soil" chlorite than the first. Quartz and feldspar are present, but the 3.2A feldspar reflection is less pronounced than in typical

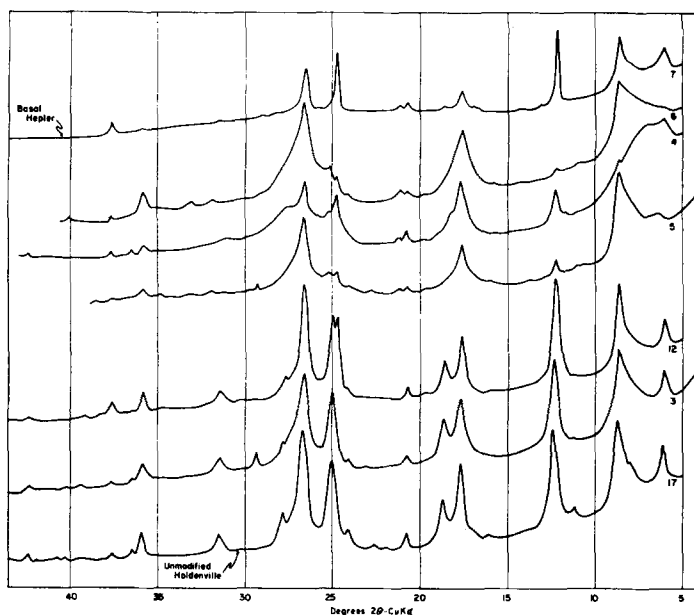


FIGURE 5.—X-ray diffractometer patterns of air-dried samples from various localities in order of depth of sample below disconformity.

Holdenville samples. A diffractometer pattern of sample 12 is shown in Figure 5. The illite 001 peak in this clay is somewhat asymmetrical, but the symmetry is increased by glyceration and by heating. Boiling the clay fraction for 5 minutes in HCl decreases the chlorite reflections, making the kaolinite reflections more prominent.

Sample 5 (0.5 to 1.0 foot below Hepler).—The clay consists chiefly of hydrated illite (asymmetrical 001 reflection, very broad 002 and 003 reflections), kaolinite, some quartz, and a mineral that expands to 14.5Å. After the sample was heated to 450°C, this 14.5Å basal spacing shrank to 12.6Å. After heating at 550° to 600°C, the basal spacing was 11.3Å, and other spacings for this mineral (which may be chlorite-vermiculite) were destroyed. No feldspar was observed, but it may be obscured by the broad illite 003 reflection. A weak 8Å spacing was observed in all the patterns (Fig. 6).

Sample 4 (0.5 foot below Hepler).—Diffraction patterns from this sample, which is taken from about 5 feet above sample 3, show further broadening of the illite reflections and degradation of the chlorite. A broad band from a mixed-layer mineral is also present at about 11.5Å (Fig. 5). There is some indication that this spacing expands to 14.5Å when the clay is glycerated. The 11.5Å spacing is reduced in intensity but not changed in position by heating the sample to 450°C. In the glycerated clay there is a broad spacing at 9.6Å.

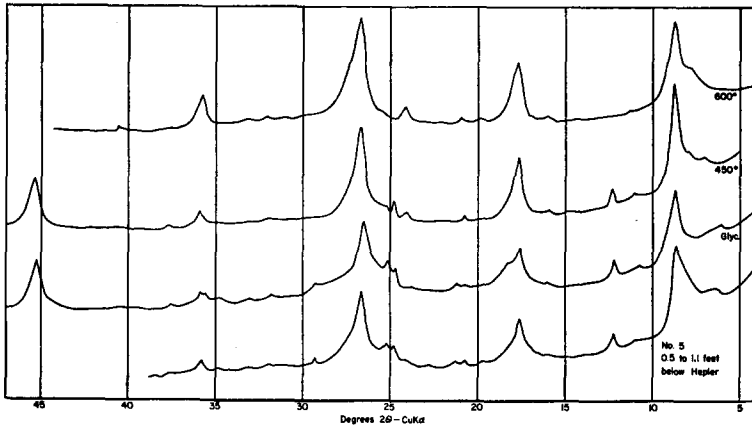


FIGURE 6.—X-ray diffractometer patterns of -2 micron fraction of shale 0.5 to 1 foot below Hepler (sample 5).

The 14A reflection is broad but pointed, and is destroyed by heating to 450°C .

Sample 6 (immediately below Hepler).—This sample is predominantly hydrated illite and a small quantity of kaolinite. There is no clear evidence of a 14A mineral, but there is a mixed-layer mineral having a broad, indistinct, basal spacing that expands to about 13.3A when the clay is saturated with glycerol. This spacing seemingly contracts to about 12.1A at 450°C and to about 11A at $550\text{--}600^{\circ}\text{C}$. Quartz and a small quantity of feldspar are present. There is also a weak 8A reflection.

Boiling in HCl sharpens the 002 and 003 illite reflections, and subsequent heating to 450°C reveals the presence of feldspar. (Fig. 7).

CONCLUSIONS

Starting with a mineral assemblage of well-crystallized illite, normal chlorite, and minor quartz, feldspar, and kaolinite in the marine Holdenville shale, the trend of alteration in the soil zone at the uppermost Desmoinesian erosional surface was as follows: *Progressive hydration of illite*, as shown by the broadening of the illite basal reflections. *Production of "soil" chlorite* in at least one locality. *Sporadic increase in kaolinite*, not directly related to depth below Hepler. Some unknown factors influence the kaolinite content. Although the Hepler sandstone (and shale) contains relatively large quantities of kaolinite, which, in the sandstone, may have been formed by circulating ground water after deposition, no large concentration of kaolinite was observed at the very top of the Holdenville. Thus the kaolinite in the upper part of the Holdenville probably developed at the erosional surface and was not derived from the overlying Hepler. *Slight decrease in feldspar*, perhaps related genetically to increase in kaolinite. *Progressive modification and destruction of chlorite*,

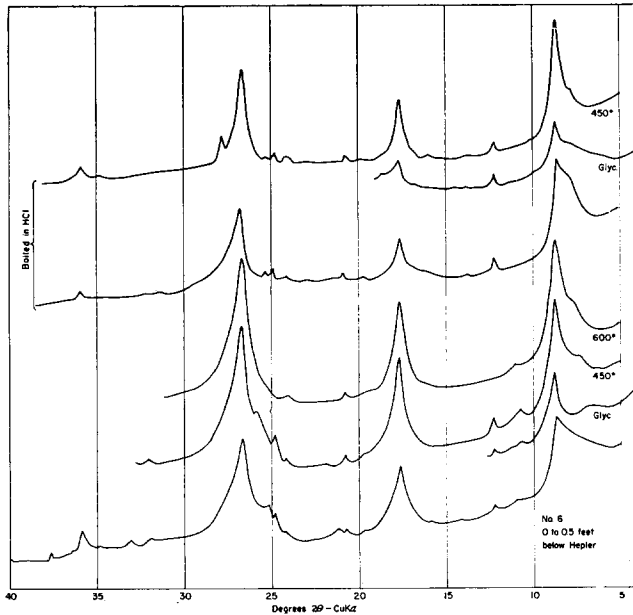


FIGURE 7.—X-ray diffractometer patterns of -2 micron fraction of shale immediately below Hepler (sample 6).

with concomitant production of mixed-layer and vermiculite minerals. The variations in basal spacings are summarized in Figure 5.

Although vermiculite is abundant in the Hepler sandstone, little was detected in the shale samples.

Mechanical analysis of 8 samples revealed no progressive increase or decrease in particle size with depth below the disconformity, but in general there is a greater spread in particle size (larger phi standard deviation, indicating poorer sorting) in samples nearer the disconformity (Table 1).

The chemical data (Table 2) suggest slight depletion of alkalis and magnesium during the interval of weathering. A marked increase in P_2O_5 also is indicated. Alkalis were probably removed by leaching processes; the decrease in magnesium reflects the destruction of chlorite.

The Hepler sandstone at the localities studied is not a coarse-grained, highly permeable sandstone in deeply incised narrow channels, but seemingly is a sheetlike deposit. We have not found similar weathering characteristics in shales cut by deep narrow channel sands, although it is expected that some will be found in the future. It is assumed that a deep erosional channel might cut entirely through a soil profile into fresh shale beneath. Future study of the soil zones below similar regional unconformities may provide some information on the time intervals involved and the relative stratigraphic importance of the unconformities.

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