[Journal of the Arkansas Academy of Science](https://scholarworks.uark.edu/jaas)

[Volume 43](https://scholarworks.uark.edu/jaas/vol43) [Article 18](https://scholarworks.uark.edu/jaas/vol43/iss1/18)

1989

Soil Micromorphologic Features of Holocene Surface Weathering and a Possible Late Quaternary Buried Soil, Northwest Arkansas

Diane Phillips
University of Arkansas, Fayetteville

Margaret J. Guccione
University of Arkansas, Fayetteville

SOIL MICROMORPHOLOGIC FEATURES OF HOLOCENE SURFACE WEATHERING AND A POSSIBLE LATE QUATERNARY BURIED SOIL, NORTHWEST ARKANSAS

DIANNE PHILLIPS
Student, Dept. of Geology
University of Arkansas
Fayetteville, AR 72701

M.J. GUCCIONE
Assistant Professor, Dept. of Geology
University of Arkansas
Fayetteville, AR 72701

ABSTRACT

Micromorphologic features of an alfisol developed in White River alluvium near Fayetteville, Arkansas are typical for this soil order. The A horizon has a relatively high organic matter content and an abundance of quartz sand grains with a silt and clay matrix. Voids are relatively common and some have been partly infilled. In contrast to the A horizon, the E horizon has less organic matter, larger voids, and some weak orientation of the clay matrix. The parent material for these horizons was deposited in the past 4,700 years and these pedologic horizons have formed since that time. In the underlying B horizon clay has accumulated in the form of grain coatings and caps and as void linings.

Translocation of clay into this horizon has relatively decreased the abundance of matrix silt and clay, and the amount of void space. The clay matrix that remains has extensively become oriented and some of the void space that remains is planar in shape. Both these features are partly responsible for the subangular blocky structure of this horizon. Deposition of this parent material began more than 8,000 to 10,000 years ago and was complete by 4,700 years ago. Many of the soil features have formed since 4,700 BP as the soil surface accreted upward.

The lower portion of the B horizon (2B) is developed in an older alluvial parent material, more than 10,000 years old. Some micromorphologic features suggest that the upper portion of this 2B horizon originally was an A/E horizon that has been modified after burial by subsequent weathering of the present ground soil. Some relict surface horizon features, such as relatively abundant voids, infilled vughs, and matrix, have persisted after burial. Other features characteristic of A horizons, such as organic matter, have been destroyed by oxidation. Many of the micromorphologic features in this 2B horizon have developed since burial, more than 10,000 years ago. Translocated clay features are abundant and partially mask the relict A/E horizon features. The lower part of the 2B horizon was a B horizon that continued to develop as a B horizon after burial. Translocated clay features are more abundant in this horizon than in the overlying relict A/E horizon.

INTRODUCTION

Soil is formed by the interaction of climate, living organisms, parent material, and relief over a period of time (Harper *et al.*, 1969). The environment in which a soil is formed greatly affects the formation of that soil and its respective horizons and profile. The larger features are best seen and described in the field. Detail, significance, and interpretation of these features can be increased at a microscopic level of investigation called soil micromorphology. It is an invaluable tool for examining small-scale pedogenic processes and determining the sequence of those processes, using cross-cutting relationships and ghost structures.

The purpose of this study is first to megascopically and microscopically describe pedologic features of an alfisol developed in alluvial sediments. The second purpose is to interpret the genesis of these features. Finally, the maximum age of the features can be determined. From archaeologic and sedimentologic information it is known that two stratigraphic layers are present and that the upper 75-90 cm has slowly accreted during the last 8,000 to 10,000 years (Guccione and Rieper, 1988). This aggradational environment may have affected soil formation by overthickening horizons, burying horizons, and/or overprinting new horizon features on older horizon features as the soil evolved.

STUDY AREA

The study area is located along the White River near Fayetteville, Arkansas, in the south-central U.S. The White River Valley is located approximately four kilometers (2.5 miles) east of Fayetteville and includes a north-flowing river, a flood plain, and several terraces. Three branches of the White River head in the Boston Mountain Plateau to the south and join to form a single channel just south of the study site (Fig. 1). At the study site, the White River makes a right-angle bend, changing from a north-flowing stream to an east-flowing stream (Fig. 1).

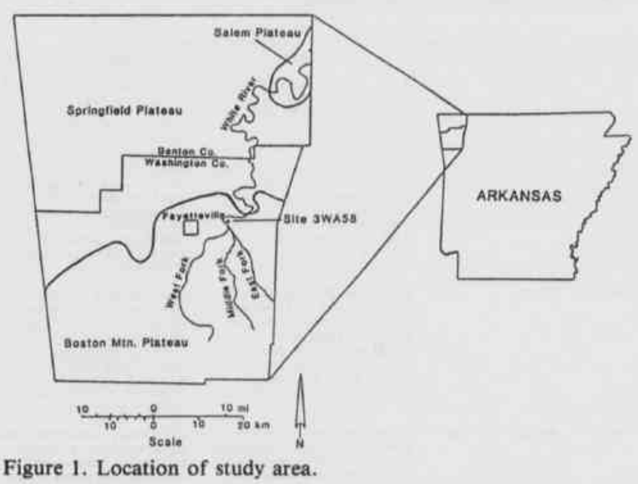

Figure 1. Location of study area.

Alfisols, ultisols, and mollisols are present in the White River Valley in the study area. Mollisols occur on the youngest and lowest part of the flood plain, alfisols occur on the older and higher part of the flood plain, and alfisols and ultisols occur on terraces. The Cleora (mollisol) and Razort (alfisol) soils are present on the flood plain at the study site. On the terrace, the moderately well-drained Savannah Soil, an ultisol, is developed in loam-textured overbank sediment and the underlying sandy clay loam-textured natural-levee sediment. Adjacent to the natural levee is a swale where the poorly drained Cherokee soil, an alfisol, is developed in silt loam and loam-textured distal overbank sediment. The paleochannel that was the source of the sediments was just west of the terrace margin.

The pedon used for this study was a Cherokee soil, which is classified as an alfisol (Harper *et al.*, 1969). Prominent subsurface zones of clay enrichment are formed by the accumulation of translocated clay from the horizons above. Translocation of the weathering products occurs during periods of moisture and precipitation of the weathering products occurs during alternating dry periods (Rust, 1983). The Cherokee soil is poorly drained, very slowly permeable, and develops on stream terraces (Table 1). It forms in alluvium and colluvium derived from acid sandstone, siltstone, and shale; and has a base saturation of 35-50 percent. Generally, the A horizon of the Cherokee soil is dark-gray (10YR 4/1) or dark grayish-brown (10YR 4/2) and the E horizon is light grayish-brown (10YR 6/2) or gray (10YR 5/1). Both have a silt loam texture and have a combined thickness of approximately 28 to 50 cm. The B horizon is mottled gray, brown, and yellowish-brown, plastic silty clay or clay and is 71 to 127 cm thick. Bedrock may occur at a depth of 152 to 365 cm (Harper *et al.*, 1969), but it was not penetrated in the 387 cm deep core used in this study.

METHODS AND MATERIALS

The pedon examined in this study was taken from a swale on a terrace at archeological site 3WA58 because soil descriptions, size analysis, radiocarbon dates, and archeological data were available (Lafferty *et al.*, 1988). A swale on the terrace was chosen to maximize the amount of sediment accumulation that occurred during soil formation. The site was cored using a truck-mounted Giddings coring device and the depth, thickness, and color of each horizon were noted (Table 1). Vertically-oriented samples of approximately 6 cm thickness were taken from each horizon at appropriate intervals. These samples were wrapped in cellophane and aluminum foil to ensure that the sample would remain moist and intact until the sample was impregnated with blue epoxy and a thin section was made. Eleven thin sections were analyzed using a petrographic microscope. Micromorphological features were point counted, using 100 points per slide.

Table 1. Cherokee Soil description.

HORIZON	DEPTH (cm)	THICKNESS (cm)	DESCRIPTION Field	Micromorphology
A	0-50	50	Silt loam; dark yellowish brown (10YR 5/4); platy to medium moderate granular; few Mn coatings.	Granular, s-matrix of silt and clay; some vugh infillings; organic material; channels and vughs.
E	50-73	23	Silt loam; dark yellowish brown (10YR 4/4) with common light gray (10YR 7/2) and a few yellowish red (5YR 5/8) mottles; weak coarse platy; Fe and Mn coatings.	Granular; s-matrix of silt and clay, uppermost presence of birefrigence fabric (b-fabric); clay coatings; organic material; many large void spaces.
Bt1	73-99	26	Loam; dark yellowish brown (10YR 4/4) with common coarse brownish yellow (10YR 6/8) reddish yellow (5YR 6/8), and light brownish gray (10YR 6/2) mottles; coarse subangular blocky.	Granular; s-matrix of silt and clay, some with b-fabric; large stained nodules; channel coatings; vugh infillings; deepest presence of organic matter; large voids, some planar.
Bt2	99-117	18	Loam; yellowish brown (10YR 5/6) with abundant coarse reddish yellow (5YR 6/8) and grayish brown (10YR 5/2) mottles; medium subangular blocky.	Granular; s-matrix, some with vosepic plasmic b-fabric; compound channel coatings, few vugh infillings; planar voids common.
Bt3	117-163	46	Loam; yellowish brown (10YR 5/4) with coarse reddish yellow (5YR 6/8) and grayish brown (10YR 5/2) mottles; medium subangluar blocky; Fe and Mn nodules.	Granular; s-matrix, some lattisepic b-fabric; compound vugh, grain, and chamber coatings, some Fe and Mn stains; grain and void coats; some vugh infilling.
Bt4	163-203	60	Dark yellowish brown (10YR 4/6) with some grayish brown (10YR 5/2) mottles; common Fe and some Mn nodules.	Granular; s-matrix with b-fabric; abundant clay coats and some stress channel, vugh, and grain coats; few vughs and vugh infillings.
2Bt1b	203-280	77	Dark yellowish brown (10YR 4/6) with indistinct light yellowish brown (10YR 6/4) mottles; common Fe and Mn coatings.	Granular; s-matrix with mosepic plasmic b-fabric; many compound void coats and some grain coats; vugh infillings.
2Bt2b	280-317	37	Dark yellowish brown (10YR 4/4) with abundant coarse grayish brown (10YR 5/2) mottles; few Mn coatings.	Granular; s-matrix with vosepic plasmic b-fabric; compound grain coats; vugh infillings.

MICROMORPHOLOGY FEATURES

The terminology applied to micromorphologic features in the literature is quite variable and the same terms are used in different ways by different researchers. To avoid confusion, the terms utilized in this research project are defined.

TERM	DESCRIPTION
B-fabric	Birefringence fabric - fabric of the fine material in a soil thin section as evaluated by the pattern of birefringence of oriented clay grains (Fig. 8) (Douglas and Thompson, 1982).
Chambers	Spherical voids which are connected to channels and often contain faunal excrement (Kemp, 1985).
Channels	Voids which may be linear but differ from planar voids in that they are generally cylindrical in three dimensions. Certain cross-sections are circular due to their tendency to change direction in relation to the thin section orientation. For this reason they are also frequently discontinuous in longitudinal extent (Fig. 2) (Kemp, 1985).
Clay Coatings	Cutans, clay coats, argillans, etc. A modification of the texture, structure, or fabric at natural surfaces in soil materials due to concentration of particular soil constituents or in situ modification of the plasma. Cutans can be composed of any of the component substances of the soil material. Cutans are named according to the surfaces affected, composition and complexity of the cutanic material, and interpretation of the process of formation (Fig. 9) (Douglas and Thompson, 1982).
Coating	Layer of any substance covering a surface (Douglas and Thompson, 1982).
Compound clay coatings	Series of coatings of different composition around the same void or grain/aggregate surface (Douglas and Thompson, 1982).
Grain coating	Grain cutan - a cutan associated with the surface of a skeleton grain or other discrete unit (nodule, concretion, etc.) (Kemp, 1985).
Grain capping	Coating only on the upper surface of grains or aggregates (Kemp, 1985).
Lattisepic plasma fabric	Plasma generally with a flecked orientation pattern that is, there are two short, discontinuous plasma separations usually oriented approximately at right angles to each other (Brewer, 1964).
Mosepic fabric	Abundant plasma separations with striated orientation that occur as isolated patches. These patches are unoriented with regard to one another (Brewer, 1964).

Planar Voids	Voids which are planar in three dimensions but appear linear and are continuous in thin section. They are of variable diameter and over long distances have common sharp changes in direction. They separate and occur within or across aggregates (Fig.8) (Kemp, 1985).
Plasma	That part of soil material which is capable of being or has been moved, reorganized, and/or concentrated by the processes of soil formation. It is a mobile, active part of the soil material. The plasma includes all the material, mineral or organic, of colloidal size and relatively soluble material which is not bound up in skeletal grains (Douglas and Thompson, 1982).
S-matrix	The material within the simplest (primary) ped or that composing apedal soil material in which pedological features occur. It consists of plasma that does not occur in pedological features. It does not include skeletal grains and voids.
Vesicles	Regular, smoothed voids which do not fit the criteria of any other types of void structures and may have equant, prolate, or oblate cross sections (Kemp, 1985).
Vosepic plasma fabric	Plasma that has a flecked orientation pattern, but plasma separations with striated orientation pattern occur parallel to adjoining natural surfaces. The striated orientation of the plasma separations is dominantly parallel to the walls of the voids, especially if they are planar (Brewer, 1964).
Vugh infilling	Soil material infilling a vugh (Figs. 6 and 10).

RESULTS AND DISCUSSION

MICROMORPHOLOGIC FEATURES

The A horizon is characterized by the accumulation of organic matter and the removal of unstable mineral material. In the Cherokee Soil the A horizon contains megascopic root fragments (Fig. 2), which are relatively abundant for an alfisol (6-8%) (Fig. 3). The mineral material is dominated by quartz mineral grains with a relatively large amount of silt and clay matrix (18%) (Fig. 4) and some iron staining. The matrix is light-colored, probably due to the partial removal of clay and Fe oxides. Many voids are present, including channels, vughs, and vesicles (Figs. 2 and 5). These form by burrowing of organisms and the formation of root pores. Some of the voids are subsequently infilled as bioturbation and pedoturbation continues, but the infilling preserves the void structure (Figs. 6 and 7). No translocated clay coatings are present (Fig. 8).

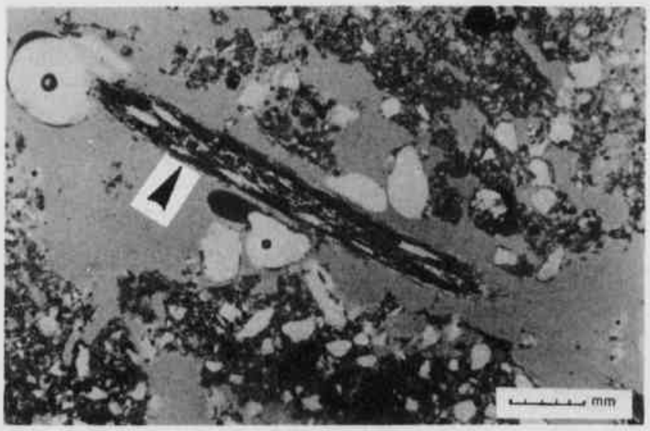

Figure 2. Plant root in channel, A horizon.

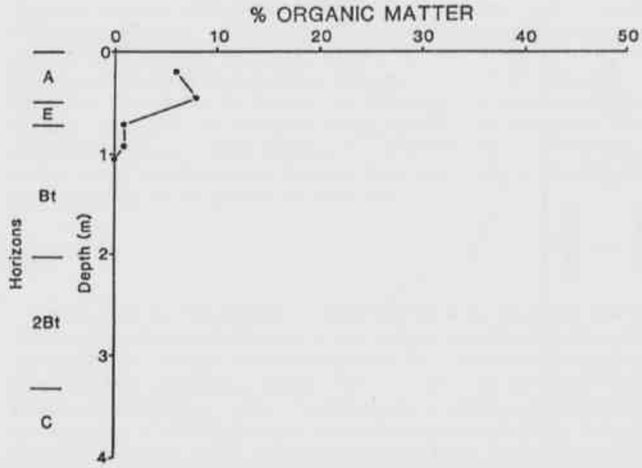

Figure 3. Graph of percent organic matter versus depth and soil horizon in the Cherokee pedon.

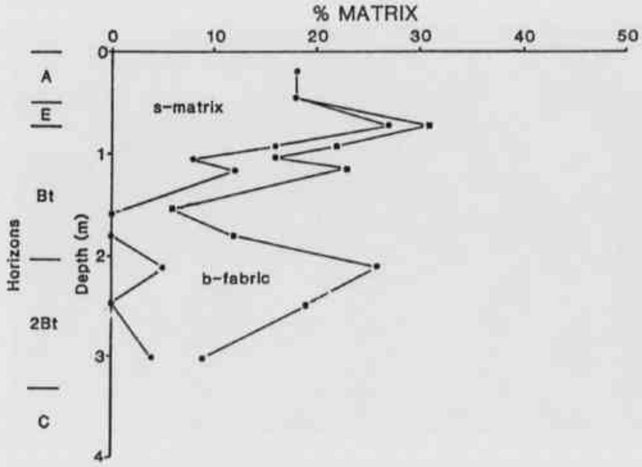

Figure 4. Graph of percents s-matrix and b-fabric versus depth and soil horizon in the Cherokee pedon.

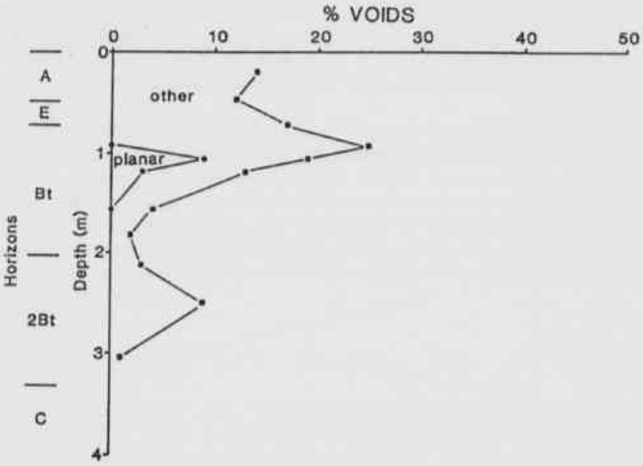

Figure 5. Graph of percents planar and other voids versus depth and soil horizon in the Cherokee pedon.

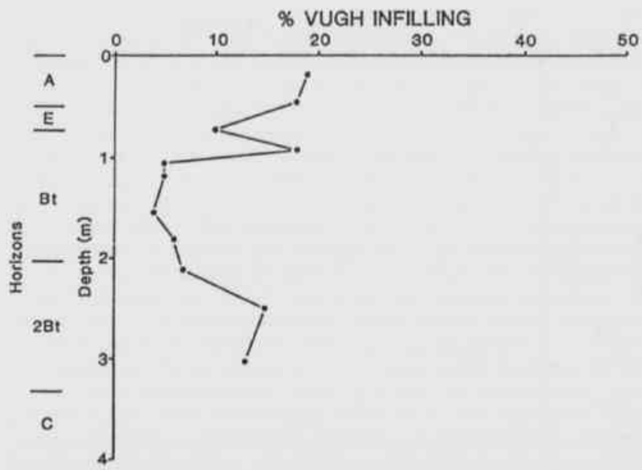

Figure 6. Graph of percent vugh infillings versus depth and soil horizon in the Cherokee pedon.

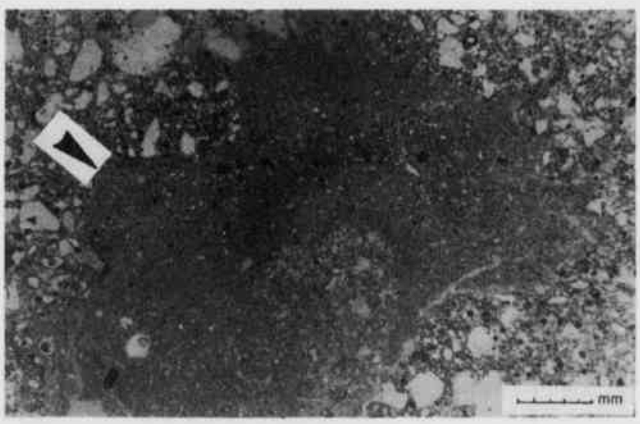

Figure 7. Vugh infilled with finer soil matrix, A horizon.

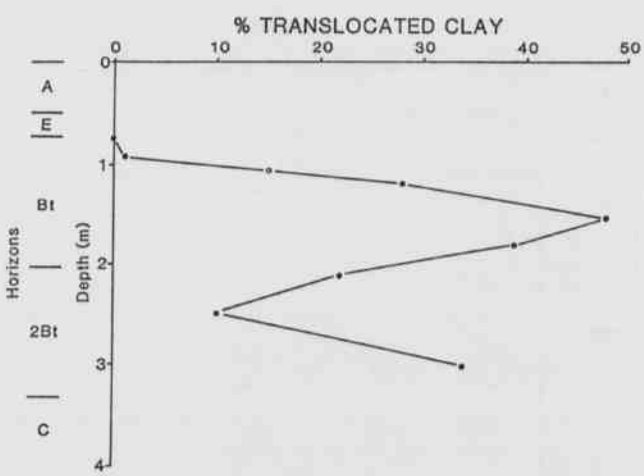

Figure 8. Graph of percent translocated clay features versus depth and soil horizon in the Cherokee pedon.

Like the A horizon, the E horizon is an eluvial horizon from which labile materials are removed, but unlike the A horizon it contains only a small amount (1%) of organic matter (Fig. 3) and the loss of clay and iron (Bullock and Thompson, 1985). The E horizon of this soil (Table 2) is also comprised of quartz grains within a very abundant silt and clay matrix (Fig. 4). Some of the clay in the s-matrix has become oriented forming birefringence fabric (b-fabric). Trace amounts of clay coatings, which become more abundant in the underlying B horizon, were noted (Fig. 8). Qualitatively, voids increase in volume and in size with depth, from the A to the uppermost part of the B horizon. Channels are the most abundant void structures preserved.

Table 2. Components of Cherokee Soil.

HORIZON	DEPTH (cm)	GRAINS	MATRIX			TRANSLOCATED CLAY	ORGANIC MATTER	VOIDS			VUGH INFILLING
			s-matrix	b-fabric	total			channels vughs vesicles	planar	total	
A	14-23	43	18	0	18	0	6	14	0	14	19
A	43-51	45	10	0	10	0	0	11	0	11	10
E	67-75	41	27	4	31	0	1	17	0	17	10
Bt1	88-95	21	16	6	22	1	1	27	0	27	18
Bt2	103-107	43	8	8	16	15	0	12	9	21	5
Bt2	118-124	31	12	11	23	20	0	10	3	13	5
Bt3	154-158	38	0	6	6	48	0	4	0	4	4
Bt4	176-183	48	0	13	13	39	0	3	0	3	6
2Bt1b	208-215	43	5	21	26	22	0	3	0	3	7
2Bt1b	244-252	45	0	19	19	13	0	9	0	9	15
2Bt2b	299-307	43	4	5	9	34	0	1	0	1	13

The B horizon is an accumulation of the weathered materials that have been removed from the overlying horizons. Processes that vertically transport clay dominate over processes that mix horizons or destroy clay (Bullock and Thompson, 1985). In this soil the B horizon has been subdivided into four horizons: Bt1, Bt2, Bt3, and Bt4. Only a minor amount of organic material (1%) is present in the uppermost Bt1 horizon and is comparable to that in the E horizon (Fig. 3). All of the horizons have quartz grains with a silt and clay matrix. This matrix is less abundant than that in the overlying E horizon and it decreases with depth (Fig. 4). However, the amount of matrix with b-fabric (Fig. 9) is greater than that in the E horizon, and it increases slightly with depth. Because the B horizon is the zone of clay accumulation, the amount of translocated clay features is relatively great (Fig. 8). It increases from a minimal 1% at the top of the horizon to 48% in the middle of the horizon and then decreases in the lower part of the horizon. These translocated clay features occur as grain and void coats and as grain caps. Compound clay coats (Fig. 10) are most abundant in the same horizons that contain the most translocated clay (Table 2). Channels and planar voids (Fig. 9) are present in the upper and middle part of the B horizon, but at depths where translocated clay increases, the abundance of voids and infilled vughs decreases (Figs. 5 and 6). Iron and manganese staining is also abundant in the central part of the B horizon.

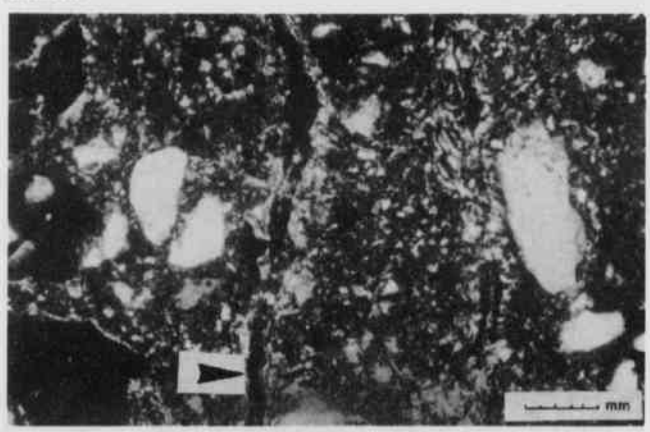

Figure 9. Planar void and b-fabric, Bt2 horizon.

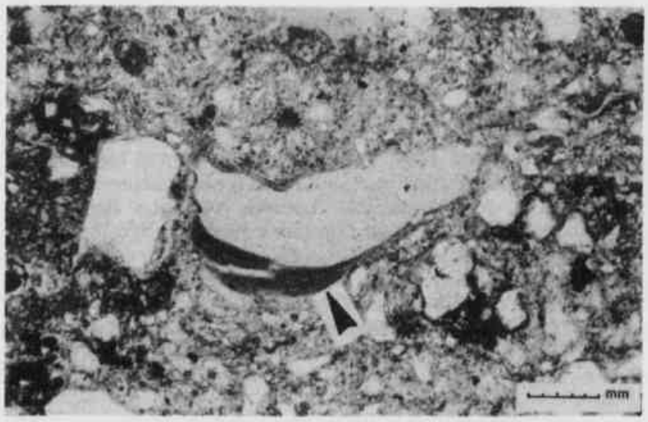

Figure 10. Compound clay coating in void, Bt1 horizon.

The lowest portion of the soil that was sampled is formed in a second parent material (2Btl and 2Bt2). This may be the upper part of a buried soil that has been welded to the overlying soil developing at the surface today. No megascopic organic material was present (Fig. 3). Many features in the 2Bt horizons are similar to the B horizons above. For example, translocated clay features are present in both the Bt and the 2Bt horizons, but the amount in the upper part of the 2Bt horizon is considerably less than that in the overlying Bt horizon (Fig. 8). The amount of total matrix, most of which has a b-fabric, is greatest in the upper portion of the 2B horizon (Fig. 4). This amount is comparable to that in the surface E horizon and is considerably more than that in the overlying Bt horizon. It decreases with depth in the 2B horizon to an amount comparable to that in the overlying B horizon. Voids and vugh infillings (Figs. 5, 6, and 11) increase in abundance in the 2B horizons compared to that in the Bt horizons, and are almost as abundant as in the surface A and E horizons.

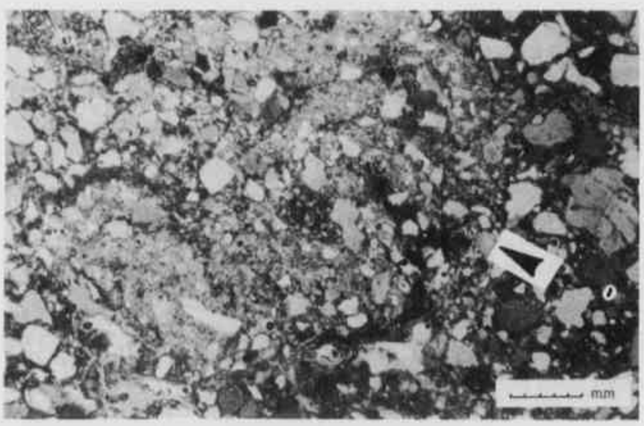

Figure 11. Vugh infilling, 2Bt1b horizon.

BURIED SOIL?

Soil micromorphologic evidence supports the hypothesis that the lower parent material was weathered prior to its burial by the upper alluvium. The abundance of matrix, voids, and vugh infillings in the upper part of the 2Bt horizon increases to values approaching that found in the A and E horizons. Conversely, the abundance of translocated clay features that are dominant in B horizons, are reduced in abundance in the upper part of the 2Bt horizon. This suggests that the material was originally an A/E horizon of a soil. Some of the micromorphologic features characteristic of an epipedon (voids, infilled vughs, matrix) have been preserved, whereas other features (organic matter) have been destroyed. Subsequent burial and weathering of the present ground soil has superimposed some B-horizon features on the buried epipedon. In the lower part of the 2Bt horizon the abundance of translocated clay features increases and the abundance of features associated with epipedons decreases. This suggests that the horizon was a B horizon before burial and B-horizon features have continued to develop due to weathering of the present ground soil.

AGE

The age of the soil parent material examined in this study can be determined using stratified organic and archeologic material. Charcoal from a Middle Archaic cultural feature in the E horizon at a depth of 60 cm has been radiocarbon dated 4,700 +/− 100 years BP (Beta-19892) (Guccione and Rieper, 1988). Therefore, the sediment accumulated at a mean rate of 0.013 cm/year and soil micromorphologic features observed in the A and E horizons have developed in less than 4,700 years. Artifacts present at depths of 75-90 cm have been identified as Early Archaic projectile points which are thought to have been in use 8,000 to 10,000 years ago. Therefore, soil micromorphologic features in the lower E and upper B horizons have developed in less than 10,000 years. Because the sediment has slowly accreted during the Holocene, the B horizon features are probably younger than 10,000 years. If 30 cm of parent material had to accumulate before this parent material was buried deeply enough to develop B-horizon features, the translocated clay features would also have developed in less than 4,700 years.

SUMMARY

The micromorphologic features observed in this study are consistent with those expected in an alfisol (Figures 3, 4, and 6). The presence of organic material and relatively large voids and the absence of clay coatings in the upper three samples is characteristic of an ochric epipedon. The lack of organic material and abundance of translocated clay features in the middle five samples of the solum are characteristic of an argillic horizon. Both ochric epipedons and argillic horizons such as these are present in alfisols.

The evidence for a buried soil in this pedon is suggestive but is not conclusive. Soil micromorphologic features that are distinctive of surface horizons and have persisted after burial and are evidence for a buried soil. It is hypothesized that the upper 2B horizon was originally an epipedon that developed when alluviation temporarily ceased. This A/E horizon was later buried when alluvial deposition reoccurred. The present ground soil developed in this younger deposit and into the underlying buried soil. Clay was subsequently translocated into the buried A horizon by modern soil-forming processes. Although the A horizon was modified to a B horizon, not all of the original A horizon features, such as relatively abundant voids, infilled vughs, and s-matrix, were destroyed.

This hypothesized buried soil formed more than 8,000 years ago and was buried by younger overbank sediments, of which the upper 90 cm were deposited in the last 8,000 to 10,000 years and the upper 60 cm were deposited in the last 4,700 years (Guccione and Rieper, 1988). Slow aggradation during the Holocene has caused the modern soil horizons to become overthickened. Most, if not all, of the pedologic features in the upper 90 cm of the Cherokee soil have developed in less than 4,700 years.

LITERATURE CITED

BREWER, R. 1964. Fabric and mineral analysis of soils. John Wiley & Sons, Inc., New York. 470 pp.

BULLOCK, P. and M.L. THOMPSON. 1985. Micromorphology of alfisols. pp. 17-47, *in* L.A. Douglas and M.L. Thompson, ed. Soil micromorphology and soil classification. Soil Science Society of America Special Publication No. 15. Madison.

DOUGLAS, L.A. and M.L. THOMPSON. 1985. Soil micromorphology and soil classification. Soil Science Society of American Special Publication No. 15, 216 pp.

GUCCIONE, M.J. and B. RIEPER. 1988. Late Quaternary history of the White River, Fayetteville, Arkansas. The Compass 65:199-206.

HARPER, M.D., W.W. PHILLIPS and G.J. HALEY. 1969. Soil survey of Washington County, Arkansas. U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C. 94 pp.

KEMP, R.A. 1985. Soil micromorphology and the Quaternary. Quaternary Research Association Technical Guide No. 2, Cambridge, 80 pp.

LAFFERTY, R.H. III, L.G. SANTEFORD, M.J. GUCCIONE, M.C. SIERZCHULA, N.H. LOPINOT, K. KING, K.M. HESS, and J.O. HOLMES. 1988. The Mitchell site: 3WA58 archeological investigations at a prehistoric open-field site in Washington County, Arkansas. Mid-Continental Research Associates Report 87-4 submitted to McClelland Consulting Engineers and the City of Fayetteville, 405 pp.

RUST, R.H. 1983. Alfisols. pp. 253-281, *in* L.P. Wilding, N.E. Smeck, and G.F. Hall, ed. Pedogenesis and soil taxonomy: II the soil orders. Developments in Soil Science 11B, Elsevier, New York.