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A recent roadcut along County Road 18 in northeastern Houston County has exposed two variants of a morphologically well-expressed, Sangamon Soil. The paleosol is covered by the equivalent of the Roxana Silt, as defined in Illinois. The Farmdale Soil is developed into the Roxana Silt. The section is capped by late Wisconsinan Peoria Loess. The Sangamon Soil was developed into slope wash deposits composed of, or derived from, pre-Wisconsinan loess. No direct evidence of pre-Wisconsinan glacial till was found at the site. Two radiocarbon ages, one from the Ab horizon of the Sangamon Soil and one from the Ab horizon of the Farmdale Soil yield results of 25,690 and 23,760 respectively. These are minimum ages that suggest that the Roxana Silt buried the older Sangamon Soil prior to 26,000 radiocarbon years ago and that the Peoria Loess buried the Farmdale Soil by 24,000 radiocarbon years ago.

INDEX DESCRIPTORS: Paleosols, Quaternary, Sangamon Soil, radiocarbon, southeastern Minnesota, soil descriptions.

Pre-Wisconsinan soils (paleosols) in the glaciated Upper Midwest have been extensively documented in Iowa and Illinois through outcrop and subsurface studies (e.g., Ruhe, 1969; Willman and Frye, 1970; Hallberg, 1980). In Wisconsin, a soil buried beneath late Wisconsinan till was recently identified by Schneider and Follmer as the Sangamon Soil (1983). "Mucky soils" and "weathered tills" were noted in southeastern Minnesota by Leverett (1932); Meyer (1986) has found evidence of paleosols between till units in the subsurface in central Minnesota; and McCormick (1986) mentions the presence of buried soils in Mower County, Minnesota. In addition, morphologically well-expressed paleosols buried by Wisconsinan loess have been studied in Iowa (e.g., Ruhe, 1969; Canfield et al., 1984; Hallberg et al., 1984), in Illinois (e.g., Willman and Frye, 1970; Follmer, 1983 and references therein) and in Wisconsin (e.g., Knox, 1982; Baker, 1984). This paper reports on a recently discovered exposure of two variants of a morphologically well-expressed Sangamon Soil buried beneath Wisconsinan loess in southeastern Minnesota.

The exposure, near the town of Hokah in northeastern Houston County, is located along a secondary upland divide that descends to the Root River valley (Fig. 1). The exposure was made during rerouting of Houston County Road 18 in 1984. The site is several kilometers east of the margin of pre-Wisconsin glacial till in Houston County as currently understood (Lueth, 1984, p. 3). Pre-Illinoian glacial till has been mapped as far east as the Mississippi Valley in northeastern Iowa (Trowbridge, 1966; Hallberg et al., 1984; Hallberg and Bettis, 1985) and into southwestern Wisconsin (Knox, 1982). The patchy distribution of pre-Wisconsinan Quaternary deposits in this region results from several episodes of late Pleistocene erosion which have affected the upland landscape to varying degrees (Hallberg et al., 1978a; Bettis et al., 1984). On the relatively stable uplands, erosion surfaces, paleosols, and pre-Wisconsinan deposits are buried beneath one to several meters of late Wisconsinan Peoria Loess.

New Richmond Sandstone of Early Ordovician age forms the uppermost bedrock at Hokah and is underlain by karstic Oneota Dolomite. The relatively thin New Richmond Sandstone has collapsed into several solution cavities in the Oneota Dolomite. Surface relief ranges from 5-10 m as a result of stepped erosion surfaces cut into Quaternary sediments and the underlying bedrock. The erosion surfaces become progressively younger to the north as the interfluve descends into the Root River valley.

On the southern end of the Hokah exposure (Fig. 1), where the Quaternary sequence is most complete, about 6 m of sediment overlie the New Richmond Sandstone (Fig. 2). The present land surface is developed on 2.5 to 3.5 m of Peoria Loess. The Peoria Loess overlies a weakly expressed paleosol developed in Roxana Silt, referred to as the

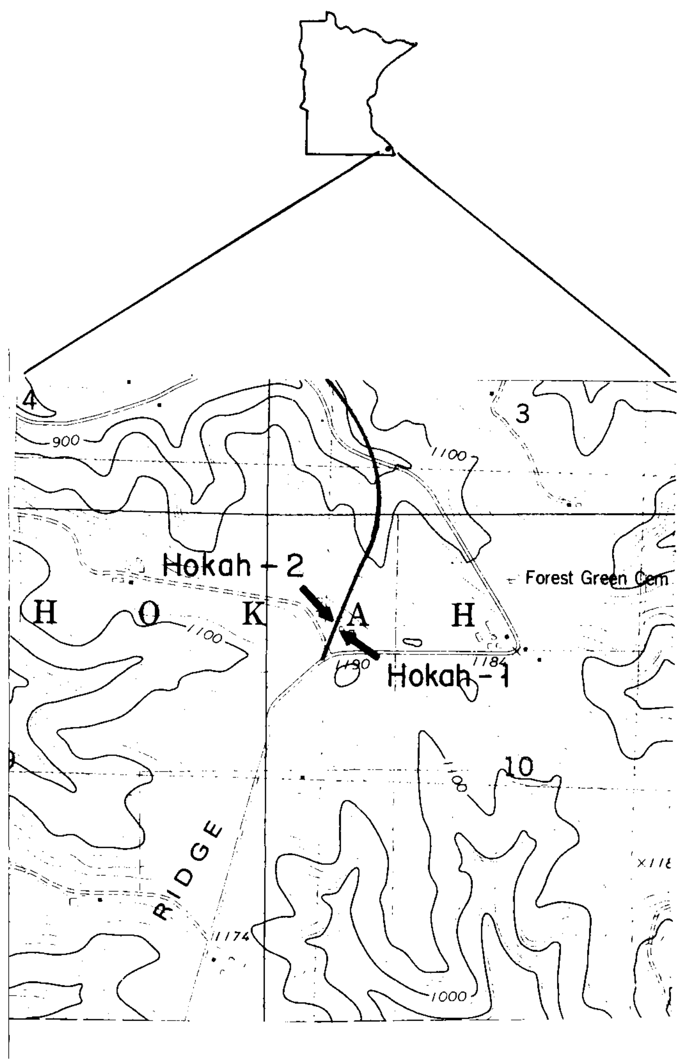

Fig. 1. Location of Hokah Paleosol along new road cut, County Road 18, Brownsville 7.5-minute quadrangle (T. 103 N., R. 4 W., sec. 10).

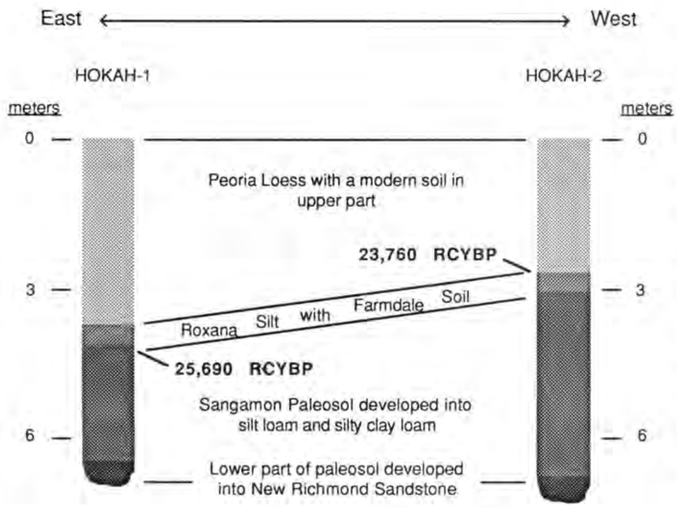

Fig. 2. Generalized profiles of paleosols at Hokah.

Farmdale Soil by Willman and Frye (1970). The Roxana Silt covers a Sangamon Soil that developed in 2 to 3 m of silt loam and silty clay loam slope wash sediment. The contact between the Bw horizon of the Farmdale Soil and the top of the Sangamon Soil has been obscured by Farmdale pedogenesis. Within the Sangamon Soil there are several discontinuous stone lines composed of locally derived rock types. The stone lines probably accumulated as erosional lags (Canfield and others, 1984) and suggest episodic deposition of the slope wash sediment. The base of the Sangamon Soil and of the exposure extend into weathered New Richmond Sandstone.

Two contrasting Sangmaon Soil profiles are exposed on the east and west sides of the roadcut. On the east side (Hokah-1) the paleosol is morphologically well-expressed with an A-EB-Btg-Bt horizon sequence. This paleosolum is 2.5 m thick. The dominance of gray hues in the upper part and the presence of secondary accumulations of iron and manganese, indicate that this profile developed on a poorly to somewhat-poorly drained landscape position. On the west side of the road (Hokah-2) the paleosol exhibits a BE-Bt-Bg-BC horizon sequence (see description). Here the paleosolum is 4.0 m thick. Brown and yellowish brown hues dominate the upper horizons of this paleosolum, indicating that it developed on a moderately well-drained landscape position. Gray hues in the lower part of the B horizon (Bg) indicate poor internal drainage, possibly due to the heavy matrix texture. Both paleosols show evidence of polygenesis, such as thick soil horizons, zones with subtle stratification, and several distinct layers of argillans on some peds.

To the north, on the next lowest step on the interfluve, the Sangamon Soil is truncated. Younger, thinner and morphologically less well-expressed paleosols have developed into the truncated soil and the underlying weathered Paleozoic rock. These relationships are typical of the "Late-Sangamon" erosion surfaces and paleosols as recognized in Iowa (Ruhe et al., 1967; Hallberg et al., 1978a; Bettis et al., 1984).

Bulk samples of the organic-rich Ab horizon of the Sangamon Soil at Hokah-1 and of the Ab horizon of the Farmdale Soil at Hokah-2 were submitted for radiocarbon analysis. The Ab horizon of the Sangamon Soil at Hokah-1 yielded a date of 25,690±780 RCYBP (Beta-13729). Organic material in the Ab horizon of the Farmdale Soil at Hokah-2 was dated at 23,760±630 RCYBP (Beta-14886).

We interpret the date of 25,690 RCYBP to be a minimum age for the Roxana Silt at Hokah. In Illinois, the Roxana Silt has been dated between 30,000 to 45,000 radiocarbon years. There are two possibilities to explain the disparity in ages. One is that the accumulation of a unit at Hokah stratigraphically and morphologically correlative with the Roxana Silt occurred after the type Roxana in Illinois. The second and strongest possibility is that Farmdalian pedogenesis, extending through the Roxana, has mixed younger organic carbon into the Ab horizon of the Sangamon Soil resulting in an apparent age that is younger than the Roxana Silt, as dated in Illinois. It is also possible that the true age is some combination of the two processes that cannot be resolved with the present data.

The date of 23,760 RCYBP from the Ab horizon of the Farmdale Soil marks the beginning of deposition of the Peoria Loess. This date is more consistant with dates on the Farmdale in Illinois (Willman and Frye, 1970), although still somewhat younger. Translocation of younger organic carbon from the weak, modern soil in the Peoria Loess could have occurred, although the Ab horizon of the Farmdale Soil is over 2 m below the modern soil. Again there is a possibility that deposition of Peoria Loess at Hokah was not synchronous with loess deposition at the Farmdale type section in Illinois.

Preliminary clay mineral analyses indicate that the paleosols contain a high proportion of expandable clays. Illite and kaolinite occur in nearly equal proportions but are less abundant than the expandables. The parent sediments are mineralogically similar to other Quaternary deposits in southeastern Minnesota and northeastern Iowa (Hallberg, 1980; Hallberg and Bettis, 1985) and bear little resemblance to the illite-dominated clay-mineral suites of the Paleozoic bedrock in the area.

SUMMARY

The morphologically well-expressed paleosols at Hokah are the first well-documented evidence of the Sangamon Soil in this part of Minnesota. The two variants (poorly drained, Hokah-1; moderately well drained, Hokah-2) exposed by the roadcut, reflect drainage patterns controlled by the uneven erosion surfaces that predate the paleosoil development. The parent material of the paleosol appears, from preliminary data, to have been derived from loess. The stone lines and stepped erosion surfaces indicate that several periods of erosion and slope wash deposition contributed to the sediments in which the Sangamon Soil developed. We did not find any evidence of pre-Wisconsinan till at Hokah. The mapped pre-Wisconsinan till boundary is located several kilometers to the west.

Two radiocarbon dates were obtained, one from the Ab horizon of the Sangamon Soil (25,590±780 RCYBP) and one from the Ab horizon of the Farmdale Soil (23,760±630 RCYBP). Both results were younger than dates from the respective type sections in Illinois. The probable cause for the discrepancies in ages is that younger episodes of pedogenesis translocated organic carbon from the upper horizons into lower, older horizons. However, we cannot at this time rule out that there may have been nonsynchronous deposition between the Hokah site and the type sections in Illinois.

Detailed analyses of the deposits and soils at the Hokah site are currently underway. These studies will provide additional information on the paleopedology of the various soils exposed, the origin and sedimentology of the sub-Peoria deposits, and the relationships among the several landscape elements exposed along the cut. This and other ongoing studies, will further our understanding of the Quaternary landscape evolution of southeastern Minnesota and the Upper Mississippi River valley.

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APPENDIX — Detailed descriptions of two Quaternary sediment profiles. County Road 18, Hokah, Minnesota

HOKAH-1

Location: T103N R4W Sec. 10 (SE¼NW¼NW¼)
Elevation: 1192 ft.
Date described: October 8, 1985
Described by: G.R. Hallberg and D.J. Quade
Remarks: C-14 date (4.14-4.44 m; 25,690±780 B.P.) on disseminated organics from Ab horizon of the Sangamon Soil on east side of roadcut (Fig. 1). Descriptions of the weathering zone terminology used below can be found in Hallberg and others, (1978b).

Depth m (inches)	Soil Horizon (weathering zone)	Description
		PEORIA LOESS
3.20-3.81 (126-150)	(MDU)	Light brownish gray (2.5Y 6/2) silt loam, weak fine platy structure to massive, very friable, strong effervescence, abrupt smooth lower boundary, common coarse strong brown (7.5YR 5/8) mottles, common coarse iron concretions spherical and elongate pipestems
		FARMDALE SOIL DEVELOPED IN ROXANA SILT
3.81-3.96 (150-156)	2EB	Brown (7.5YR 5/2-5/4) silt loam, weak fine platy structure to massive, firm, noneffervescent, clear wavy lower boundary, common medium to fine dark yellowish brown (10YR 4/4) mottles, occasional fine charcoal flecks
3.96-4.14 (156-163)	2Bwb	Pink (7.5YR 7/4) silty clay loam with occasional very coarse sand grains, weak fine subangular blocky structure to massive, firm, noneffervescent, abrupt wavy lower boundary, few medium and coarse strong brown (7.5YR 5/6-5/8) mottles, few coarse iron concretions, few thin discontinuous argillans and silans, occasional root tubules
		SANGAMON SOIL DEVELOPED IN SLOPE DEPOSITS
4.14-4.44 (163-175)	3Ab	Very dark gray to dark grayish brown (10YR 3/1-4/2) silty clay loam, subtle variegation evident (stratified), weak to moderate granular to weak fine subangular blocky structure, firm, noneffervescent, C-14 date on disseminated organics 25,690±780 B.P. (Beta-13729); laterally, turbations are evident in this and underlying soil horizons
4.44-4.54 (175-179)	3EBb	Light gray, very dark grayish brown, grayish brown, and dark yellowish brown (10YR 6/1, 3/2,5/2, and 4/4) weakly stratified silty clay loam, weak fine platy to weak fine subangular blocky structure, firm, noneffervescent, abrupt smooth boundary, common thin discontinuous argillans, few thin discontinuous silans
4.54-5.00 (179-197)	3Btg1b	Gray (10YR 5/1) clay, strong fine angular blocky structure, firm, noneffervescent, gradual smooth boundary, common fine yellowish brown (10YR 5/6) mottles, thick continuous argillans, organs in root tubules
5.00-5.48 (197-216)	3Btg2b	Gray (10YR 5/1) clay with occasional coarse sand grains and chert fragments, strong fine subangular blocky structure, firm, noneffervescent, gradual smooth lower boundary, common thick (2 to 5 cm; 1 to 2 in) brown to strong brown (7.5YR 5/2-5/8) horizontal bands, black (N 2/0) organs along weakly expressed subvertical joints, few to common oxide accumulations along joints, few medium oxide concretions, common slickensides along larger ped surfaces, occasional root tubules with organs
5.48-5.68	3Bt1b	Strong brown (7.5YR 5/6-5/8) clay with

(216-224)		few friable sandstone pebbles, strong fine angular blocky structure, firm, noneffervescent, gradual smooth lower boundary, common medium olive gray to grayish brown (5Y 5/2-10YR 5/2) mottles, thick continuous argillans on ped surfaces, occasional oxide coatings on ped surfaces and along weakly expressed subvertical joints
5.68-5.96 (224-235)	3Bt2b	Strong brown (7.5YR 5/6-5/8) clay to sandy clay with common friable sandstone pebbles, strong medium to fine angular blocky structure, firm, noneffervescent, clear wavy lower boundary, occasional discontinuous zones of clay loam with weaker structure (burrows?), thick continuous argillans on faces of larger peds, thin argillans on smaller peds, common discontinuous silans on all ped faces
		LOWER PORTION OF SANGAMON SOIL DEVELOPED IN WEATHERED NEW RICHMOND SANDSTONE
5.96-6.60 (235-260-base of exposure)	4Btb	Dark red to red (2.5 YR 3/6-4/6) sandy clay loam and sandy loam with common large yellowish brown (10YR 5/6) masses of weathered sandstone of sandy loam texture, moderate medium subangular blocky structure in weathered sandstone masses, firm to friable, noneffervescent, thick discontinuous argillans on ped faces, thick continuous argillans on exterior of sandstone masses, white, light brownish gray, and yellowish brown (10YR 8/1, 6/2, and 5/6) clay to clay loam accumulations around weathered sandstone masses, abundant almost continuous oxide accumulatons on peds and around weathered sandstone masses, common subvertical joints filled with white (10YR 8/1) clay

HOKAH-2

Location: T103N R4W Sec. 10 (SE¼NW¼NW¼)
Elevation: 1195 ft.
Date described: October 8, 1985
Described by: E.A. Bettis III, J.P. Littke, and T.J. Kemmis
Remarks: C-14 date (2.71-2.84 m; 23,760±630 B.P.) on disseminated organics from Ab horizon of Farmdale Soil. Hokah-2 profile about 20 m west of Hokah-1 (Fig. 1). Top of modern soil profile missing.

Depth m (inches)	Soil Horizon (weathering zone)	Description
		MODERN SOLUM DEVELOPED IN PEORIA LOESS
0-0.45 (0-18)	BC	Dark yellowish brown to yellowish brown (10YR 4/4-5/4) silt loam, moderate coarse subangular blocky structure, friable, noneffervescent, clear smooth lower boundary, common fine oxides, abundant root tubules.
0.45-0.93 (18-37)	C1 (MOL)	Yellowish brown (10YR 5/4) silt loam, massive, friable, noneffervescent, gradual smooth lower boundary, abundant fine oxides, common fine iron concretions, common to abundant fine to medium grayish brown (2.5Y 5/2) mottles, common to abundant root tubules.
0.93-1.52 (37-60)	C2 (MOL)	Yellowish brown (10YR 5/4) silt loam, massive, friable, noneffervescent, clear smooth lower boundary, abundant fine oxides, common medium iron concretions, abundant medium grayish brown (2.5Y 5/2) and common medium yellowish brown (10YR 5/6) mottles
1.52-1.82 (60-72)	C3 (MOU)	Yellowish brown (10YR 5/4) silt loam, massive, friable, moderate to strong effervescence, gradual smooth lower boundary, abundant fine oxides, abundant medium grayish brown (2.5Y 5/2), common medium yellowish brown (10YR 5/6), and few fine dark reddish gray (5YR 4/2) mottles and streaks
1.82-2.26 (72-89)	C4 (MOU2)	Light yellowish brown (10YR 6/4) silt loam, massive, friable, strong effervescence, clear smooth lower boundary, abundant fine oxides, few fine iron concretions, few fine carbonate concretions, abundant coarse grayish brown (2.5YR 5/2) and few fine strong brown (7.5YR 4/6) mottles, abundant medium to fine grayish brown (10YR 5/2) streaks
2.26-2.61 (89-103)	C5 (DU)	Grayish brown (10YR 5/2) silt loam, massive, firm, moderate to strong effervescence, abrupt smooth lower boundary, abundant fine oxides in upper 15 cm (6 in), abundant coarse yellowish brown to brownish yellow (10YR 5/6-6/8) iron concretions (pipestems) with brown (7.5YR 4/2) centers, common yellowish brown to brownish yellow (10YR 5/6-6/8) streaks, oxide accumulations around pipestems in lower portion of horizon, few gastropod shells
		PEDISEDIMENT
2.61-2.71 (103-107)	2C (OU2)	Brown to grayish brown (7.5YR 5/2-2.5Y 5/2) weakly stratified silt loam, massive, firm, moderate to weak effervescence, abrupt smooth lower boundary, common fine oxides, few fine carbonate concretions, pipestems as above
		FARMDALE SOIL DEVELOPED IN ROXANA SILT
2.71-2.81 (107-111)	3Ab	Brown (7.5YR 5/2) silt loam, massive, firm, noneffervescent, abrupt wavy lower boundary, abundant fine oxides, abundant fine iron concretions, common coarse grayish brown (2.5Y 5/2) mottles, few medium pipestems, common charcoal flecks, C-14 date on disseminated organics 23,760±630 B.P. (Beta-14886)
2.81-2.84 (111-112)	3Asb	Strong brown (7.5YR 5/6) silt loam, massive, firm, hard, noneffervescent, clear smooth lower boundary, abundant fine oxides, abundant fine iron concretions, this horizon is a slightly indurated iron band
2.84-2.92 (112-115)	3E1b	Brown to yellowish brown (10YR 5/3-5/4) silt loam with very few fine pebbles, weak

to moderate medium platy structure, friable, noneffervescent, gradual smooth lower boundary, abundant fine to medium oxides, few fine iron concretions, very few thin discontinuous silans, occasional charcoal flecks

2.92-3.02 (115-119) 3E2b — Brown to yellowish brown (10YR 5/3-5/4) silt loam, weak to moderate medium platy structure, friable, noneffervescent, gradual smooth lower boundary, abundant fine to medium oxides, common medium iron concretions, common to abundant thin discontinuous silans

3.02-3.14 (119-124) 3Bwb — Yellowish brown (10YR 5/4) silt loam with few fine pebbles, moderate medium subangular blocky structure, friable, noneffervescent, abrupt smooth lower boundary, few medium oxides, abundant fine to medium iron concretions, occasional iron and oxide coatings on ped faces

SANGAMON SOIL DEVELOPED IN SLOPE WASH SEDIMENTS

3.14-3.30 (124-130) 4EBb — Yellowish brown (10YR 5/4-5/6) silt loam, weak to moderate medium subangular blocky structure, friable, noneffervescent, clear smooth lower boundary, abundant medium oxides, abundant fine iron concretions, abundant fine to medium yellowish brown (10YR 5/8) mottles, few thin discontinuous light gray (10YR 7/2) silans

3.30-3.55 (130-140) 4Bt1b — Brown to strong brown (7.5YR 5/4-5/6) silty clay loam, moderate medium subangular blocky breaking to moderate fine angular blocky structure, friable, noneffervescent, gradual smooth lower boundary, abundant fine oxides and iron concretions, common medium concretions, common medium yellowish brown (10YR 5/4) mottles, common thin discontinuous brown (7.5YR 4/2) argillans on angular blocks

3.55-3.78 (140-149) 4BEt1b — Brown (7.5YR 4/4-5/4) silty clay loam, moderate medium to coarse subangular blocky breaking to strong fine angular blocky structure, friable, noneffervescent gradual smooth lower boundary, common fine oxides and iron concretions, abundant thin continuous brown (7.5YR 4/2-4/4) argillans on angular blocks, few thin discontinuous patches of silans, the top of this horizon may mark a former soil surface now welded to the overlying soil

3.78-4.08 (149-161) 4BEt2b — Brown (7.5YR 5/4) and yellowish brown (10YR 5/4) silt loam, moderate medium subangular blocky breaking to moderate medium angular blocky structure, friable (subangular blocks) to firm (angular blocks), noneffervescent, gradual smooth lower boundary, few fine oxides, few medium iron concretions, thin continuous brown (7.5YR 5/4 and 10YR 4/3) argillans, common thin discontinuous silans occurring in 10 cm diameter patches

4.08-4.36 (161-172) 4BEt3b — Dark yellowish brown to yellowish brown (10YR 4/4-5/6) silt loam, strong medium subangular blocky breaking to strong medium angular blocky structure, firm, noneffervescent, clear smooth lower boundary, common fine oxides and iron concretions, thick continuous argillans, iron and oxide accumulations along weakly expressed coarse columnar peds, almost continuous silans on tops of large columns

4.36-4.69 (172-185) 4Bt2b — Brown to yellowish brown (10YR 5/3-5/4) silty clay loam, moderate medium subangular blocky breaking to strong fine angular blocky structure, friable, noneffervescent, gradual smooth lower boundary, common fine oxides, abundant medium iron concretions, thick continuous dark yellowish brown (10YR 4/4) argillans on ped surfaces, thick almost continuous argillans along large columns extending from overlying horizon, very few discontinuous silans

4.69-5.02 (185-198) 4Bt3b — Dark yellowish brown (10YR 4/4) silty clay to silty clay loam, moderate medium subangular blocky breaking to strong fine angular blocky structure, friable, noneffervescent, abrupt smooth lower boundary, few fine oxides and iron concretions, thick continuous brown (10YR 4/3 and 7.5YR 4/2) argillans, oxide accumulation along large columns extending from overlying horizons

5.02-5.13 (198-202) 5Btb — Brown to pale brown (10YR 5/3-6/3) silty clay loam with few chert pebbles, strong medium to fine angular blocky structure, firm, noneffervescent, abrupt smooth lower boundary, abundant fine to medium oxides, thick continuous yellowish brown (10YR 5/4) argillans, few fine dark red (2.5YR 3/6) iron accumulations

5.13-5.38 (202-212) 6Bg1b — Gray (10YR 5/1) clay, weak to moderate medium subangular blocky structure, plastic and sticky, noneffervescent, gradual smooth lower boundary, abundant medium oxides, abundant medium to fine reddish brown (5YR 4/4) mottles, common gray (5Y 5/1) subvertical streaks, abundant slickensides, oxide accumulations along slickensides

5.38-5.81 (212-229) 6Bg2b — Gray (10YR 5/1) clay, weak coarse subangular blocky structure, plastic and sticky, noneffervescent, clear smooth lower boundary, abundant medium oxides, abundant medium to coarse red (2.5YR 4/6) mottles, abundant slickensides, oxide accumulations along slickensides, occasional pebbles up to 8 cm in diameter

5.81-6.78 (229-267) 6BC — Dark yellowish brown (10YR 3/4-4/4) clay, weak to moderate coarse subangular blocky structure, friable, noneffervescent, abrupt smooth lower boundary, common fine oxides, very few fine iron concretions, abundant coarse light gray to light brownish gray (10YR 6/1-6/2) mottles

WEATHERED NEW RICHMOND SANDSTONE

6.78 (267-base of exposure) 7C — Light brownish gray (2.5Y 6/2) clay to sandy clay loam, massive to single grain, friable to loose, noneffervescent, abundant medium to coarse strong brown (7.5YR 5/6) and abundant medium light gray (7.5YR 5/6) mottles