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SOILS DEVELOPED FROM THE KOPE GEOLOGIC FORMATION[1]

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Abstract. Soils formed from the Kope formation of Ordovician Age limestone and soft calcareous shales which occur in southwestern Ohio, southeastern Indiana and northern Kentucky were studied to see whether a new soil series should be established. These soils were developed in different geologic formations which previously were mapped as one series. The 2 areas of concern were the amount of coarse fragments in the soils and the type of clay minerals in the clay fraction. These soils contained less than 35% by volume of coarse fragments in the control section, therefore would not belong in a skeletal family as previously classified. Clay mineralogy was mixed, with no one clay mineral dominant in the clay fraction. Kope formation soils classify as members of the fine, mixed, mesic Typic Hapludalfs and are now mapped as the Pate series.

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The study area was part of the Cincinnati arch which includes the Dillsboro and Kope formations. The Kope formation of Ordovician Age is the oldest bedrock formation exposed by the arch. Overlying the Kope formation are the Dillsboro and Whitewater formations and soils developed from these three formations cover a large portion of southwestern Ohio.

The area, for the most part, is underlain by interbedded limestone and calcareous shale, and the weathering of these rocks has provided the major part of the parent materials of these soils. On the steep hillsides and valley walls where natural erosion has almost kept pace with soil formation, the surface soil materials are composed of weathered limestone fragments and disintegrated, soft, calcareous, clay shale. In some areas, where more shaley material is present, this material is weathered more deeply (Fenneman 1916).

The most noticeable differences between these soils occurred as a result of slope, or landscape position, and the amount of coarse fragments in the soil. The soils formed in the Dillsboro formation were too high in coarse fragments to be tilled, and have been left mainly in forest. The Kope formation soils had less coarse fragments in the surface layer and occurred on a less steeply sloping footslope position (figure 1). These soils were the most productive soils in the area before modern fertilizer practices were used. The farmers cleared the land on the footslope positions up to the point where Dillsboro formation soils occurred. In early times, the footslopes soils were used extensively for the production of tobacco and were called "black tobacco land" or "burley ground" by the residents. Today, these soils, known as Pate soils, are used extensively for pasture in rural areas and in the Cincinnati area for building developments.

METHODS

From field observations of several thousand acres of soils developed from the Kope formation; 2 soil sites representing modal pedons of these soils were chosen for sampling and detailed soil analyses. The sites were located on typical footslope positions in the NW¼, NW¼, NW¼, Section 33, Township 4N, Range 2W, Ohio County Indiana. Pits were dug, soil profile descriptions made, and each profile evaluated to determine the percentage of coarse fragments per horizon. Amount of coarse fragments was determined by sieving a known weight of soil from each horizon through 15 cm, 7.5 cm and 2 cm diameter sieves. Separations were made for stones (<38 cm), flaggs (15–38 cm) and channers (7.5–15 cm) (Soil Survey Staff 1951). The samples were analyzed at the laboratory for particle-size distribution, cation exchange capacity, organic carbon content, pH, available phosphorus and potassium, and the clay mineralogy, in each horizon.

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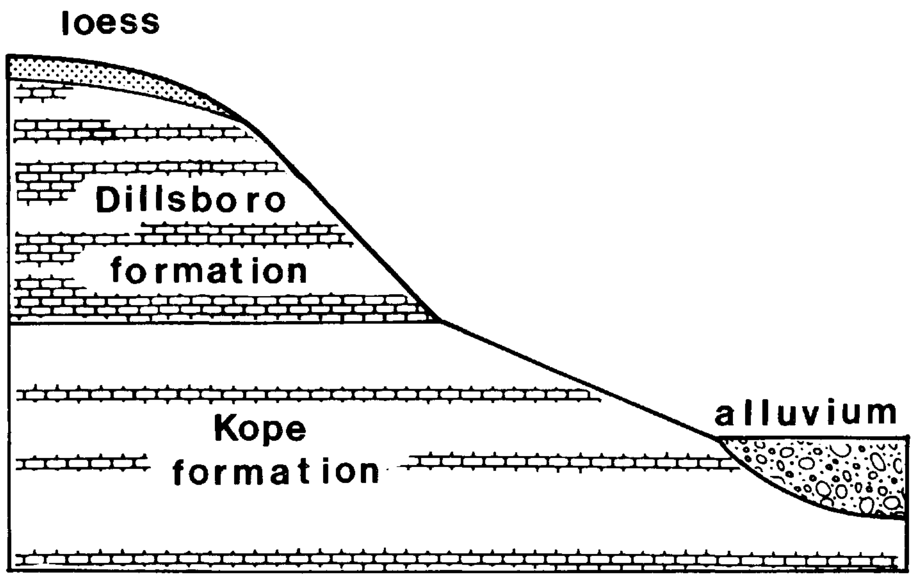

FIGURE 1. Topographic cross-section showing the relationship of bedrock of the Cincinnati arch geology to topography. This was at the W ½ of the NW ¼ of Section 33 township 4 N range 2 W of Ohio County, Indiana.

The mineralogy of the clay fraction was determined by using the X-ray diffraction method of Jackson (1956). The particle size distribution was determined by the pipette method and sieving after samples were dispersed in sodium hexametaphosphate. Separations were made for clay (<2 μm), fine silt (2–20 μm), and sand (50–200 μm). The cation exchange capacity was determined by the summation of cations after extraction with ammonium acetate. The organic carbon content was determined by wet oxidation with dichromic acid (Mebuis 1960). Both 1 part soil to 1 part water and 1N KCl to 1 part soil were used in making the determination of pH. The phosphorus was determined by the Bray P1 extractant and analyzed colorimetrically with molybdate blue. The potassium was extracted by ammonium acetate and determined by flame photometry (Franzmeier, *et al* (1977)).

RESULTS AND DISCUSSION

The amount of coarse fragments in both soils consistently increased with depth. The C horizons of these soils

TABLE 1
Coarse fragment percentages for Kope Formation Soil.

Depth cm.	Horiz.*	Estimated % by Volume				% Less Than 15 cm by Weight		
		Stones	Flaggs	Channers	Total	<2 cm	2–7.5 cm	7.5–15 cm
Pedon 1								
0–18	Ap	5	0	0	5	100	0	0
18–28	A12	0	0	0	0	100	0	0
28–40	B21t	0	0	0	0	100	0	0
40–66	B22t	0	5	0	5	97	3	0
66–91	B23t	3	20	4	27	88	3	9
91–142	C	40	10	8	58	77	3	20
Pedon 2								
0–18	Ap	0	0	0	0	100	0	0
18–41	B21t	0	0	0	0	100	0	0
41–69	B22t	0	3	0	3	98	1	1
69–99	B23t	0	20	2	22	97	2	1
99–145	C	15	10	6	31	78	8	14

*Standard horizon nomenclature described by Soil Survey Staff (1951).

TABLE 2

Physical and chemical data for Kope formation soils.

Dept cm.	Particle Size Dist. % Total Sand	Silt	Fine Silt	Clay	pH H_2O 1:1	1N KCl	Exch. ions meq/100 g Ca	Mg	Na	K	Ext. acid	Base sat.
Pedon 1												
0–18	3.0	71.8	51.3	25.1	6.3	5.2	17.6	1.0	.08	.33	9.6	66.4
18–28	4.7	53.8	4.24	41.5	6.7	5.5	16.4	.83	.06	.29	7.9	69.1
28–40	3.5	46.3	34.6	50.1	6.7	5.5	19.5	.41	.04	.23	9.5	68.0
40–66	5.7	45.5	31.8	48.6	6.6	5.5	19.5	.41	.04	.22	9.2	68.7
66–91	8.3	53.0	37.4	38.6	7.7	6.6	21.6	.41	.72	.23	3.1	87.7
91–142	6.2	56.6	41.4	37.1	7.9	6.8	29.8	.45	.08	.25	2.0	93.4
Pedon 2												
0–18	3.2	74.0	48.4	22.7	6.5	5.6	17.6	.82	.07	.30	7.7	70.8
18–41	3.2	63.5	46.1	33.2	6.6	5.2	15.7	.41	.07	.25	8.4	66.2
41–69	4.5	49.7	34.6	45.7	6.6	5.0	13.9	.41	.09	.34	7.4	66.7
69–99	4.6	51.4	35.3	43.9	7.4	6.0	16.9	.41	.09	.29	4.8	78.4
99–145	5.9	56.2	38.2	37.7	8.0	6.7	28.5	.41	.09	.18	.63	97.9

contained as much or more coarse rocky material by weight as unconsolidated finer material (table 1). It was previously reported (Fenneman 1916) that these soils had thin soil profiles, but some pedons I observed in excavations were as thick as 6.6 meters to the unweathered bedrock. My observations suggest that colluviation downslope of weathered material and the ease of weathering of the shales are the reasons for this thickness. The coarse fragments were mostly weathered from the more resistant limestone beds within the Kope formation. It appeared that the differences in the soils formed from the Dillsboro formation and the Kope formation were due to the differences in the percentage composition of the limestone in the bedrock. The Kope formation averaged 80–90% shale whereas the Dillsboro formation averaged less than 50%.

Soils having an average of coarse fragments (over 35% by volume) in the upper 50 cm of the argillic horizon are classified in a skeletal family (Soil Survey Staff 1975). The Kope formation soils did not have enough coarse fragments by volume to classify them into a skeletal family.

The laboratory data of these 2 pedons showed that they would fit into the fine textural family, which means that the control section averaged over 35% clay. The clay distribution for both pedons illustrated well pronounced argillic horizons. Pedon 1 showed more argillic development than Pedon 2. The fine silt and total silt decreased with depth, whereas the total sand increased with depth (table 2). The mineralogical classification of these soils was determined by the mineralogy of the clay fraction (table 3) and indicated that Kaolinite was constant throughout the profile. The Illitic minerals were higher in the upper B horizons while Vermiculite was highest in the C horizons. This may indicate

TABLE 3

Percentage composition of clay minerals in the less than 2 μm soil fraction.

Depth cm.	Horiz.*	Vermiculite	Micas & Illite	Kaolinite
Pedon 1				
0–18	Ap	5	83	12
18–28	A12	13	62	25
28–40	B21t	33	45	32
40–66	B22t**	32	42	21
66–91	B23t	25	59	16
91–142	C	34	52	14
Pedon 2				
0–18	Ap	9	81	10
18–41	B21t**	26	53	19
41–69	B22t**	30	42	25
69–99	B23t	31	45	24
99–145	C	34	46	20

*Standard horizon nomenclature described Soil Survey Staff (1951).

**These horizons showed 2 to 5% Montmorillonite. Only trace amounts were found in the other horizons.

that Vermiculite was present in the parent material and the crystal lattice is being collapsed by potassium in the upper horizons to form an Illitic-like mineral, or that the upper horizons of these soils have had Illitic minerals added along with a small amount of loess. These soils contained no predominant clay mineral and were of mixed mineralogy.

The organic carbon content in Kope formation soils was slightly higher than normal for soils developed under forest vegetation. The dry color of the surface horizon of Pedon 1 was not dark enough to be classified as a Mollisol, but was somewhat darker than a typical Alfisol. The surface layer of Pedon 2 was lighter in color than the surface of Pedon 1. The saturation of base elements was high throughout the profile. Both soils had well developed argillic horizons and were well drained. These soils would be classified as fine, mixed, mesic Typic Hapludalfs (Soil Survey Staff 1975).

Kope formation soils are characterized by high cation exchange capacity, high base saturation and high available phosphorus and potassium. The cation exchange capacity was highest in the C horizon. This can be explained by the higher percentage of vermiculite that was present in the C horizon.

Coarse fragments increased with depth in Kope formation soils. They were developed on less slope and had less coarse fragments than soils developed in the Dillsboro formation and were high in available phosphorus and potassium, high in cation exchange capacity, fine textured and of mixed mineralogy. These soils did not contain enough coarse fragments to be classified as skeletal, had an argillic horizon, an ochric epipedon and were classified in Soil Taxonomy as members of the fine, mixed, mesic Typic Hapludalfs. Pate, a new soil series (Soil Survey Staff 1979) has been established to include the soils developed from the Kope formation, and the soils formed on the Dillsboro formation will be mapped in the Eden series.

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