Morphology, Hydrology, and Management of Clermont Soils

J. J. King and D. P. Franzmeier
Department of Agronomy
Purdue University, West Lafayette, Indiana 47907

Introduction

The Clermont soil occurs extensively on nearly level tabular divides of the Illinoian till plain in southeastern Indiana. Generally, it has been accepted that the soil formed in 50 to 120 cm of loess over Illinoian glacial till. Recent investigations, however, have shown that the soil has a distinct paleosol surface, probably Sangamon in age, about 2 to 3 m deep (Steinhardt and Franzmeier, 1979; Ruhe and Olson, 1980), which makes the origin of the material above the paleosol uncertain. It is usually silt loam or silty clay loam in texture, but has a higher sand content than classical loess from the major loess sources such as the lower Wabash and White River Valleys, and usually it has no distinct lithologic discontinuities. The 2 to 3 m deposit is also thicker than loess is usually thought to be in southeastern Indiana. In spite of these relationships, however, it seems that eolian activity is a more plausible explanation of the origin of the silty materials than any of the alternatives.

Within this surface silty deposit is a brittle subsurface horizon often called a fragipan. Earlier, this layer was considered to be one of the strongest fragipans in the soils of Indiana. Then, during a field study in Ohio and Indiana in 1971, pedologists decided that most of the Clermont pedons did *not* have horizons that qualified as fragipans according to the then current definitions which were subsequently published in Soil Taxonomy (Soil Survey Staff, 1975). This definition requires that a horizon must contain more than 60% brittle material which is in prisms that average more than 10 cm across. The pans observed had some brittle material but they were so riddled with krotovinas, probably crayfish burrows, that generally they did not meet the 60% brittle requirement. Also, many of the prisms in the upper part of the pan were less than 10 cm across, which again did not meet the requirements for a fragipan. This layer, however, is usually designated a Bx horizon to indicate its brittle nature. As a result of this study the classification of the Clermont series was changed from Typic Fragiaqualf to Typic Ochraqualf indicating that there is no fragipan in the control section. It is in the fine-silty, mixed, mesic family. However, many pedons of the soil, as it occurs in the field, do have fragipans. Thus the natural soil landscape unit recognized as Clermont has a borderline fragipan but the classification of the taxonomic unit does not recognize it.

The Clermont soil (natural landscape unit) is a difficult one to manage. It is excessively wet in the spring and planting is often late. In a dry summer crops suffer from drought because plant roots are not developed very deeply. Tile drainage generally has not been recommended because of the low permeability of the subsoil, especially the fragipan (or fragipan-like horizon), and because it is difficult to find suitable outlets for the tile in the broad divides. Instead, surface drainage has been emphasized. This practice, however, increases surface runoff and results in significant erosion during intense rainfall when the soil is bare or the crop is small.

The objectives of this study were to study the hydrologic properties of the Clermont soil, to identify which soil horizons are most limiting to water movement, and to relate these observations to soil management.

Materials and Methods

The study was conducted in cooperation with the Agricultural Engineering Department, Ohio State University. They were studying how drainage systems functioned in soils that are difficult to drain (Schwab et al., 1979). The general approach was to completely saturate a soil and then, by monitoring the drop in water table levels and the rate of flow from a tile line, to calculate the drainable porosity (x) and the hydraulic conductivity-drainable porosity ratio (K/x) of the drained layers.

The site selected was on the D. Wilson farm near Greensburg, Indiana (640 m E and 425 m S of NW corner, Sec. 32, T 10N, R 10E, Decatur Co.), in which a drainage system with a 15 m (50 ft.) tile spacing had been installed in 1968 at a depth of about 1 m. During the spring of 1979 three rows of piezometers were installed at right angles to the tile lines to monitor ground water levels. Then, during periods when natural rainfall was high, about five more cm of water was added by irrigation to insure a saturated soil. Two soil pits were dug in the saturated soil, one to intercept a tile line for outflow measurements and one halfway between tile lines to study and sample the soil.

The soil was sampled by horizons and particle-size distribution, exchangeable cations, organic carbon, and pH were determined by standard procedures (Franzmeier et al., 1977). Bulk density was measured by the National Soil Survey Laboratory at ⅓-bar tension (field capacity) and oven dryness using natural clod samples (Soil Survey Staff, 1972). Hydraulic conductivity, Ksat, was measured, by the Piezometer method. This procedure involved measuring the rate at which water entered a 10-cm deep hole augered below the bottom of a 5-cm diameter steel conduit called a piezometer (Luthin and Kirkham, 1949). The results plotted represent averages of two to six replicate measurements.

Results and Discussion

Soil Morphology and Characterization

The Clermont profile is dominated by silt loam texture and gray color to a depth of 235 cm. Below the plow layer, the A2 (24 to 38 cm) and B1 (38 to 64 cm) horizons have very weak platy and weak subangular blocky structure, respectively. The B21t (64 to 96 cm) has moderate subangular blocky structure with some clay films on ped surfaces. The Bxl horizon (96 to 145 cm) has brittle material within the prisms, but the prisms are relatively small, 5 to 10 cm across. The Bx2 horizon (145 to 235 cm) has very coarse prisms ($>$ 10 cm across), and conspicuous silt and clay films on the prism surfaces. It is a well developed fragipan according to current definitions. Below the fragipan, at a depth at 235 cm, is the paleosol surface. The change in soil properties there is quite apparent when boring with an auger because of the 10% clay increase, the increase in firmness and the morphology of the paleosol. Details of the profile morphology are reported elsewhere (Indiana Soil Survey Staff, 1980).

In this Clermont profile the upper material, 0 to 235 cm, has $>$ 53% silt; below 235 cm the material has $<$ 43% silt (FIGURE 1). The sand content of the upper material, 9-26%, is higher than in typical loess. The clay content of the Clermont soil reaches an upper maximum of 26% (FIGURE 1) in the Bxl horizon and a second maximum of 36% in the paleosol (IIB22tb horizon). Sand content increases downward in the paleosol. Organic carbon content is low—0.7% C in the Ap horizons and 0.3% C in the A2 and B1 horizons.

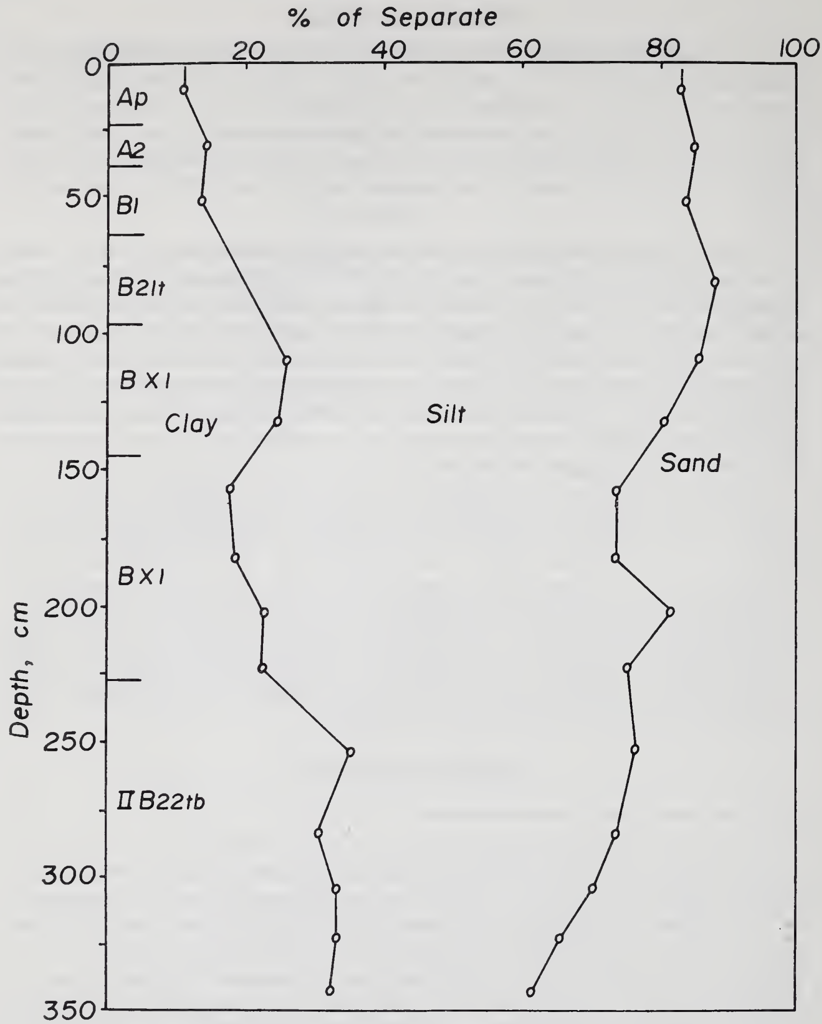

FIGURE 1. *Particle-size distribution for Clermont silt loam.*

Hydraulic Conductivity

When the pits were dug, after rain and irrigation, water was standing in small depressions in the field. The track-tractor with a back-hoe had difficulty crossing the field in corn stubble because the soil surface was so wet and soft. Because of these very wet conditions we expected the soil pit to fill with water immediately after digging, making it impossible to collect soil samples. We were surprised, however, to find that little water entered the soil pit. Most of what did enter seeped in at the lower boundary of the Ap horizon. Where a corn stalk protruded into the pit it acted as a conduit with water running from it in a steady drip. Occasionally, slabs of soil caved into the pit exposing large vertical planar surfaces of the subsoil and water could be seen moving along these surfaces. From these inter-

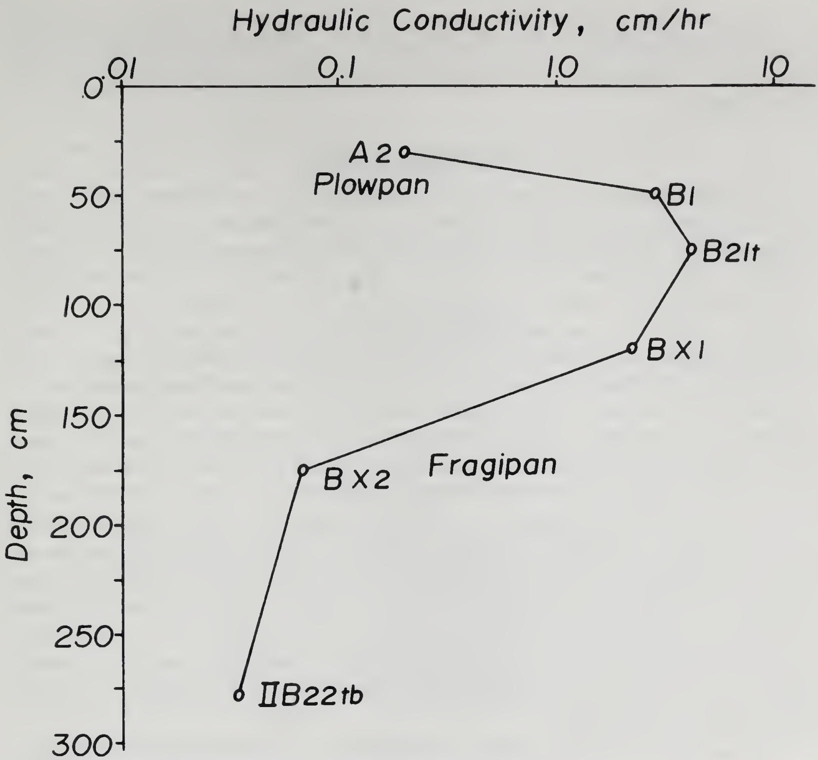

FIGURE 2. *Saturated hydraulic conductivity for Clermont silt loam.*

pretations it appeared to us that the layer limiting water movement was the A2 horizon immediately below the plow layer and that once water got through this layer it had a clear channel to the tile line through the well developed planar voids of the B21t and Bx1 horizons.

Measurement of hydraulic conductivity on individual layers (FIGURE 2) confirmed this observation. The slowest conductivities were in the paleosol (11B22tb) and the fragipan (Bx2) horizons, both of which are below the 1 m tile depth, and in the A2 horizon, 24 to 38 cm deep.

TABLE 1. *Bulk density from saran-coated natural clods for Clermont silt loam (data from National Soil Survey Laboratory, SCC).*

Depth	Horizon	Bulk density ⅓-bar	 oven dry
cm		g/cm^3	
24-38	A2	1.57	1.63
38-64	B1	1.58	1.88
64-96	B21t	1.54	1.59
96-145	Bx1	1.49	1.77
145-235	Bx2	1.77	1.82

The low Ksat of the Bx2 horizon probably is related to its high bulk density (Table 1). The low Ksat of the A2 horizon, however, cannot be attributed to high bulk density; it might be related more to the arrangement, rather than the amount, of pore space.

Tile Drainage Study

The drawdown curve from the tile drainage study on Clermont is compared with curves from two other soils studied by the Ohio State group, Hoytville (Mollic Ochraqulf, fine, illitic, mesic), and Nappanee (Aeric Ochraqualf, fine, illitic, mesic). In Figure 3 the comparison shows that the shape of the curve for Clermont is different from that for the other two soils, which is the more typical shape for slowly permeable soils. The latter soils are high in clay in most of the profile and it is likely that the horizons around the depth of the tile are the least permeable ones. In Clermont, on the other hand, the lowest Ksat values above the tile lines are in the A2 horizon. Thus, the limiting layer is near the top of the drainage column in Clermont but near the bottom of the column in the other soils. In the Hoytville and Nappanee soils drainage begins quickly (FIGURE 3) and slows down as the water level is lowered. In Clermont, however, drainage begins slowly and then accelerates.

The conditions are analogous to draining water from a drinking straw. In one case, as in Clermont, the straw is filled with water and one places a thumb over the top of it to hold the water. The water stays in it until the thumb is released enough to allow air to enter and then the straw drains quickly. If the straw were cripmed at the bottom to reduce its flow rate but not sealed completely, then filled with water, and allowed to drain, it would begin to drain immediately and the rate would slow down with time as the head of water decreases. This is analogous to the Nappanee and Hoytville soils.

According to the tile spacing study (Schwab et al., 1979) the hydraulic conductivity for a water table drop from 0 to 20 cm is 2.2 cm/hr. This measurement is

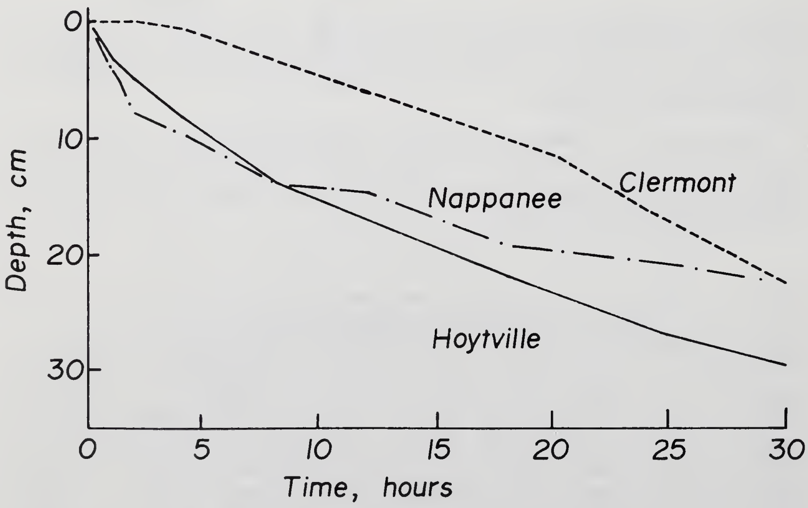

FIGURE 3. *Water table drawdown midway between tile lines for three soils (Schwab, et al. 1979. Their plot 2 of each soil.)*

within the range of Ksat values for the profile (FIGURE 2). Conductivity (k) measured by the tile drainage study is an equivalent K that is independent of evaporation from the soil surface, but is influenced by the convergence of flow lines to the tile, by restriction of flow lines at the tile openings, and by deep seepage below the tile to lower horizons. The drainage study also represents a much larger soil area than does the piezometer method which is more specific for differences among horizons. For comparison, Ksat measurements by the piezometer method ranged from about 0.01 to 100 cm/hr for selected horizons of soils in Indiana, but these horizons probably did not represent the full range of hydraulic conductivity rates.

Soil Management

These results raise some interesting questions about management and drainage of the Clermont soil. The rate-limiting horizon, instead of being quite deep, is near the surface where it can be more readily managed. The question is how best to manage it. Because surface drainage systems often result in erosion of bare soil it appears that it would be desirable to remove some of the water through the profile in a tile line rather than across the soil surface. This requires that the conductivity of the A2 horizon-plowpan be increased which could be done by mechanical (tillage) or biological (plants, worms, etc.) methods. Because of the very weakly developed structure of the A2 horizon we believe that tillage would have very little lasting effect. Also, we question whether a layer that has deteriorated in structure under tillage can be improved by more tillage. On the other hand, vertical mulching, the practice of placing plant residues in vertical slits in the soil, might be investigated on these soils. Kohnke (1971) studied the practice on some well-structured soils and found no pronounced runoff reduction or corn yield increase. It may be more beneficial, however, on poorly-structured soils such as Clermont.

A more promising method may be biological, through winter cover crops or crop rotations with a forage crop. A winter cover crop which has live roots during the fall, winter and early spring should have these advantages:

1. The roots would penetrate the A2-plowpan horizon allowing water and air to pass through it more readily. In the analogy of the drinking straw this would allow air to enter through the top of the column to drain it.
2. Plant growth during spring would help dry the soil when it is usually too wet for farming.
3. Addition of organic matter, over several years, would increase the aggregation and structural development of the upper soil horizons. This would result in better conductivity and root penetration.
4. Plant cover would increase the infiltration of these soils, which form surface crusts readily, and result in less erosion because of the direct effect of plant cover and the indirect effect of more infiltration and less runoff.

A possible disadvantage of a winter cover crop is that it may reduce soil temperatures and slow early growth of the next crop.

We believe that tile drainage, tillage, and cropping practices should be studied on the Clermont soil.

Summary

Measurements of saturated hydraulic conductivity by the piezometer method and tile-drainage studies in the Clermont soil showed that the least permeable

horizons are the A2-plowpan, fragipan, and paleosol horizons. Since the last two are below the depth of tile lines, the A2-plowpan must be the one that limits water movement to the tile. This horizon is shallow enough so that its conductivity can be improved by growing plants and, possibly, tillage. We suggest that tile drainage of Clermont combined with a winter cover crop will reduce soil erosion and provide better growing conditions for the subsequent crop.

Literature Cited

1. FRANZMEIER, D. P., G. C. STEINHARDT, J. R. CRUM, and L. D. NORTON. 1977. Soil characterization in Indiana: I. Field and laboratory procedures. Purdue Univ. Ag. Exp. Sta. Res. Bull. 943. 30p.
2. Indiana Soil Survey Staff. 1980. Soil characterization in Indiana: V. 1978 Data. Purdue Univ. Agr. Exp. Sta. Bull. 274. 194 p.
3. KOHNKE, H. 1971. Experiences with vertical mulching. Proc. Indiana Acad. Sci. 80:468-475.
4. LUTHIN, J. N. and D. KIRKHAM. 1949. Piezometer method for measuring permeability of soil in situ below a water table. Soil Sci. 68:349-358.
5. RUHE, R. V. and C. G. OLSON. 1980. Soil welding. Soil Sci. 130:132-139.
6. SCHWAB, G. O., D. E. KOPCAK, J. D. GORDOS, and C. J. OLOSKY. 1979. Field evaluation of subsurface drainage (Phase II research report). Ag. Eng. Dept., Ohio Ag. Res. and Dev. Center, Columbus. 21 p. (mimeo).
7. Soil Survey Staff 1972. Soil survey laboratory methods and procedures for collecting soil samples. Soil Survey investigations Report No. 1. U.S. Dept. Ag. Soil Conservation Service. 63 p.
8. Soil Survey Staff. 1975. Soil taxonomy. U.S. Govt. Printing Of. 754 p.
9. STEINHARDT, G. C. and D. P. FRANZMEIER. 1979. Chemical and mineralogical properties of the fragipans of the Cincinnati catena. Soil Sci. Soc. Am. J. 43:1008-1013.