Surficial Geology and Soils of the Elmira-Williamsport Region, New York and Pennsylvania

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Prepared cooperatively by the U.S. Department of the Interior, Geological Survey and the U.S. Department of Agriculture, Soil Conservation Service

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By CHARLES S. DENNY, Geological Survey, *and* WALTER H. LYFORD, Soil Conservation Service

With a section on FOREST REGIONS AND GREAT SOIL GROUPS

By JOHN C. GOODLETT *and* WALTER H. LYFORD

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By CHARLES S. DENNY, Geological Survey, and WALTER H. LYFORD, Soil Conservation Service *

ABSTRACT

The Elmira-Williamsport region, lying south of the Finger Lakes in central New York and northern Pennsylvania, is part of the Appalachian Plateaus physiographic province. A small segment of the Valley and Ridge province is included near the south border. In 1953 and 1954, the authors, a geologist and a soil scientist, made a reconnaissance of about 5,000 square miles extending southward from the Finger Lakes, N.Y., to Williamsport, Pa., and eastward from Wellsboro, Pa., to Towanda, Pa. Glacial drift of Wisconsin age, covering the central and most of the northern parts of the region, belongs to the Olean substage of MacClintock and Apfel. This drift is thin and patchy, is composed of the relatively soft sandstones, siltstone, shales, and conglomerates of the plateaus, commonly has a low calcium carbonate content, and is deeply leached. Mantling its surface are extensive rubbly colluvial deposits. No conspicuous terminal moraine marks the relatively straight border of Olean drift. The Valley Heads moraine of Fairchild near the south ends of the Finger Lakes is composed of relatively thick drift containing a considerable amount of somewhat resistant sedimentary and crystalline rocks. Commonly this drift has a relatively high carbonate content and is leached to only shallow depths. The Valley Heads drift is younger than Olean, but its precise age is undetermined. The age of the Olean is perhaps between Sangamon and Farmdale, on the basis of, in part, a carbon-14 date from peat at Otto, N.Y.

All differences in soil development on these two Wisconsin drifts are clearly related to the lithology of the parent material or the drainage, rather than to weathering differing in kind or in duration. The authors believe that the soils are relatively young, are in equilibrium with the present environment, and contain few, if any, features acquired during past weathering intervals. The effect of tree throw on soil profiles and the presence of soils on slopes clearly indicate that soils form rapidly. Sols Bruns Acides are the most extensive great soil group occurring throughout the region. Podzols and Gray-Brown Podzolic soils are also widespread, and on long, smooth slopes Low Humic-Gley soils are common. Organic soils are of small extent.

South of the Wisconsin drift border, the surficial mantle consists chiefly of alluvial, colluvial, or residual deposits of Wisconsin or of Recent age, but there are many small isolated patches of older, strongly weathered materials of pre-Wisconsin age. Although such older materials are commonly overlain or mixed with less weathered mantle, the yellowish-red color, characteristic of the strongly weathered material, is generally not masked. Some of the older material is drift, presumed to be of Illionian age, that was probably strongly weathered to a considerable depth in Sangamon time and has been greatly eroded since the last interglacial period. No clear-cut exposure of Wisconsin drift resting on older drift or other strongly weathered mantle has been found. The old drift and the other strongly weathered materials apparently acquired their present red color in pre-Wisconsin time. Where exposed at the surface, such strongly weathered mantle is the parent material of modern Red-Yellow Podzolic soils. Sols Bruns Acides and Gray-Brown Podzolic soils, developed on slightly weathered parent materials, are found adjacent to these red soils. This suggests that these Red-Yellow Podzolic soils probably developed from strongly weathered parent materials. No buried soils were found nor were any soils recognized as relics from pre-Wisconsin time.

Comparison of a map of the great soil groups with a map of the vegetation of the region, prepared by John C. Goodlett, does not reveal a close relation.

Laboratory analyses of samples collected furnish data on textural, mineralogical, and chemical changes caused by weathering and soil formation. The results indicate that the amount of chemical weathering which the Wisconsin drift has undergone is slight. The Red-Yellow Podzolic soils on strongly weathered pre-Wisconsin drift have B_2 horizons that have a finer texture than the A_2 or C horizons. The parent materials of these soils seem to be strongly weathered because of the high chromas, reddish hues, friable condition of most rock fragments, relatively high kaolinite content, and presence of gibbsite in the clay fraction. Measurements at numerous localities show that the depth of leaching increases with decreasing carbonate content and is not a criterion of the age of the drift. Pebble counts of gravels also show that the depth of leaching of gravel is related to its limestone content. The location of the gravel deposits is probably due primarily to the presence of pebbles of resistant rock rather than to ice wastage involving abundant glacial melt water.

The region is in the Susquehanna drainage basin except for its north fringe, which drains to Lake Ontario. Most of the region is a dissected plateau ranging in altitude from 700 to 2,500 feet and underlain by gently folded sedimentary rocks of Paleozoic age. Much of the region slopes moderately or steeply; the most extensive areas of gently sloping land are on the uplands. In the northern part are several straight and deep valleys—the southern extension of the Finger Lakes basins—separated by uplands with several low cuestas that face north. Similarly, some streams such as the Canisteo, Cohocton, and Chemung Rivers, and the part of the Susquehanna River that is in New York, trend at right angles to the Finger Lakes, flowing in valleys that parallel the regional strike of the bedrock.

The Olean drift border is marked by a change from drift containing very few rounded or striated rock fragments to a mantle containing only angular rock fragments and traces of red, strongly weathered materials. A reconstruction of the surface of the ice sheet, at its maximum extent shows an inferred slope of its distal margin ranging from 100 to 500 feet per mile.

* Now of Harvard University.

Glaciofluvial deposits of Wisconsin age consist of kames and valley-train terraces; the kames, chiefly of Olean subage, occur in the large tributary valleys found chiefly in the central and northern part of the region; the valley-train terraces, largely of Valley Heads subage, are restricted to through valleys that head near the Valley Heads moraine. Lake beds occur beneath the glaciofluvial sand and gravel and are known chiefly from well records.

At the south ends of the Finger Lakes valleys are thick masses of glacial debris that include both till and stratified drift. These deposits and a discontinuous belt of moraine on the adjacent uplands, commonly at the base of north-facing escarpments, constitute the Valley Heads moraine of Fairchild. The thickening of the drift that is the moraine may be related to ice movement across bedrock divides as much as to a balance between ice movement and wastage of the ice terminus.

The Binghamton drift of MacClintock and Apfel is apparently absent from the region. The Valley Heads ice probably advanced south of the southern limit of the Binghamton. Elsewhere, the Binghamton drift border probably marks the maximum line of advance of the ice sheet that built the Valley Heads moraine.

Colluvium, essentially unsorted and unstratified material derived from adjacent bedrock or surficial debris and ranging in texture from rubble to loam, covers ridgetops, slopes, or valley bottoms in all parts of the region. It is a surface mantle of Wisconsin or younger age and rests on drift, older colluvial or alluvial deposits, residuum, and bedrock. Since it seems to be more extensive south of the Valley Heads moraine than north of it, much of the colluvium is probably of Wisconsin age, but some of it is Recent.

The soils are grouped into eleven soil associations. The Allenwood and Weikert soil series are found largely south of the Wisconsin drift border. The Bath and Mardin soil series are widespread within the area of Wisconsin drift. The Chenango soil series is generally found on glaciofluvial deposits with a low content of free carbonates compared with that of the deposits on which the Howard soil series is developed.

INTRODUCTION

The results of a reconnaissance study of the surficial geology and the soils of the region south of the Finger Lakes in central New York and northern Pennsylvania (pl. 1) are presented in this paper. The region is a part of the Appalachian Plateaus physiographic province, which is underlain by gently folded sedimentary rocks of Paleozoic age. A small segment of the Valley and Ridge province is included near the southern border. Glacial drift of Wisconsin age covers the central and northern parts. Although the surficial mantle south of the drift border is chiefly alluvial, colluvial, or residual deposits of Wisconsin or of Recent date, there are many isolated patches of older, strongly weathered materials of pre-Wisconsin age. Sols Bruns Acides are the most extensive great soil group occurring throughout the region. Podzols and Gray-Brown Podzolic soils are also widespread, and on long, smooth slopes Low Humic-Gley and Humic-Gley soils are common. Organic soils are of small extent. Red-Yellow Podzolic soils are found only in very small areas south of the Wisconsin drift border where they are developed on strongly weathered parent materials.

We studied the region together in 1953 and 1954 and found that the drift is dominantly of early Wisconsin age, the Olean substage of MacClintock and Apfel (1944.) This drift is thin and patchy, is composed of the relatively soft sandstones, siltstones, and shales of the Appalachian Plateaus, commonly has a low calcium carbonate content, and is deeply leached; its surface is mantled by extensive rubbly colluvial deposits. The Valley Heads moraine of Fairchild (1932) near the southern ends of the Finger Lakes is composed of relatively thick drift containing a considerable amount of somewhat resistant sedimentary and crystalline rocks. This drift has a relatively high free carbonate content and is leached to only shallow depth. Its correlation with drifts in other areas is in doubt (Denny, 1956a). Olean drift is older than Valley Heads drift and is perhaps post-Sangamon but pre-Farmdale in age, on the basis, in part, of a carbon-14 date from peat at Otto, N.Y. (Suess, 1954). Differences in soil development on these two Wisconsin drifts are clearly related to the lithology of the parent material or the drainage, rather than to weathering. We believe that the soils are relatively young, are in equilibrium with the present environment, and contain few, if any, features acquired during past weathering intervals. The effect of tree throw on soil profiles clearly indicates that soils form rapidly following disturbance or removal.

South of the Wisconsin drift border are isolated patches of strongly weathered drift, colluvium, and residuum of pre-Wisconsin age. Although such materials are commonly overlain or mixed with less weathered mantle, the yellowish-red color, characteristic of the strongly weathered materials, is generally not masked. This drift is presumed to be of Illinoian age, and it was probably strongly weathered to considerable depths in Sangamon time and greatly eroded since the last interglacial period. The old drift and the other materials of pre-Wisconsin age apparently acquired their present red color in pre-Wisconsin time. Where exposed at the surface, such strongly weathered mantle is the parent material of modern Red-Yellow Podzolic soils. Sols Bruns Acides or Gray-Brown Podzolic soils, developed on slightly weathered parent materials that are well, moderately well, and somewhat poorly drained, are found adjacent to these red soils. We believe that the development of these Red-Yellow Podzolic soils is due to the presence of strongly weathered parent materials.

The distribution of great soil groups compared with forest areas shown on the small-scale map of Hough and Forbes (1943, fig. 1) shows a reasonably close relationship. However, in 1954, John C. Goodlett, of

Johns Hopkins University, made a reconnaissance map of the vegetation of the region, and a comparison of this map (pl. 6), which employs vegetation units used previously by Goodlett in Potter County, Pa. (Goodlett, 1954), with the distribution of the great soil groups does not show a close relationship.

The Elmira-Williamsport region comprises about 5,000 square miles in northeastern Pennsylvania and south-central New York (pl. 3). The region extends from the heads of the Finger Lakes in central New York southward to the West Branch Susquehanna River near Williamsport, Pa. (pl. 1). The region's west boundary is near the longitude of Bath, N.Y., and Wellsboro, Pa. Its eastern boundary passes east of Owego, N.Y. and Towanda, Pa.

The project, one of several cooperative studies by the Geological Survey and the Soil Survey, Soil Conservation Service, U.S. Department of Agriculture, was a reconnaissance of about twenty-five 15-minute quadrangles, including all or parts of the following counties: Chemung, Schuyler, Steuben, Tioga, and Tompkins Counties in New York, and Bradford, Columbia, Lycoming, Sullivan, and Tioga Counties in Pennsylvania. The project involved no detailed mapping; the chief localities studied were the rather numerous deep exposures, where surficial deposits and soils were examined and samples were collected for laboratory analysis. Pebble counts were made of gravels at many borrow pits. The maps of the surficial geology and of the great soil groups (pls. 1, 5) are based on this reconnaissance field study, published geologic maps, and interpretation of soil maps of the several counties in the region.

Paul Blackmon of the Geological Survey assisted for several weeks in 1954 and has made a preliminary study of the clays in some of the surficial deposits. Samples from a number of soil profiles were analyzed in the laboratory of the Soil Conservation Service at Beltsville, Md. The numerical symbols of the Munsell color system are placed in parentheses after the color names, which are those of the Soil Conservation Service (Soil Survey Staff, 1951).

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Finally, it is a pleasure to acknowledge our indebtedness to the Friends of the Pleistocene for their stimulating discussion of our outrageous hypotheses on the occasion of their 17th annual reunion at Wellsboro, Pa., in May 1954.

TOPOGRAPHY

The Elmira-Williamsport region is a dissected plateau mainly within the Susquehanna River drainage system; only the northern fringe is tributary to Lake Ontario. The central and southern part of the region, largely within the Allegheny Mountain section of the Appalachian Plateaus province (pl. 2), is a plateau dissected to depths of more than a thousand feet. Ridges ranging in altitude from about 700 to 2,500 feet and composed in part of sandstone or conglomerate preserved in synclines are bordered by anticlinal lowlands of shale and siltstone. To the south, the region includes the broad valley of the West Branch Susquehanna River, a part of the Valley and Ridge province.

The northern segment is part of the Southern New York section of the Appalachian Plateaus province containing the southern ends of the Finger Lakes. The plateaus in New York have broad undulating summits and relatively steep side slopes, but the general aspect is not as rugged as in Pennsylvania. Low, northward-facing cuestas cross the uplands near the southern ends of the Finger Lakes basins (Von Engeln,1932, fig. 5; Fenneman, 1938, fig. 86).

Tarr described the Southern New York section as follows (Williams, Tarr, and Kindle, 1909, p. 1):

> Although the uplands are not rugged, they are far from level. * * * Owing to the influence of the nearly horizontal beds of shale and sandstone, the hills are commonly flat-topped and their upper slopes are usually smooth and well-rounded. They vary greatly in shape but are typically curved, inclosing broad, moderately sloping, shallow, cirquelike areas above which they rise 100 or 200 feet. In places the more resistant layers have been etched by denudation into terrace forms, but these upland divides and hilltops are, on the whole, * * * evenly sloping * * *.
>
> Below these mature uplands the slopes of the valley sides become much steeper * * *. These steeper slopes, which extend in places up to the very divide, are found here on one side only, there on both sides, in the latter case giving the valley the ap-

pearance of a broad gorge. * * * On the steeper slopes * * * and to a less extent on the hilltops themselves * * * are rock terraces contouring the hill sides, and at the bases of many of them springs emerge, forming swampy patches.

The deep straight valleys that contain the Finger Lakes were called "through valleys" by Tarr (Williams, Tarr, and Kindle, 1909, p. 2).

These valleys are all peculiar in character. They are very narrow, they do not progressively widen from head to mouth of the stream, their walls are steep, their sides are straight and show a marked absence of projecting spurs, and they have no pronounced divides at the heads of the streams, the present divides being on low morainic or other glacial deposits, and not in the narrowest parts of the valleys * * *. The narrowest part * * * is in that protion of the plateau which is highest and which may be considered to be the normal divide region between the St. Lawrence and Susquehanna systems; but the present divides of the larger streams are near the northern edge of this higher belt, not in the middle.

Because the rock floors of at least some of the Finger Lakes basins lie well below sea level, and some tributaries flow in hanging valleys or hanging gorges (such as Watkins Glen at the south end of Seneca Lake), geologists generally agree that the though valleys have been deepened by glacial erosion.

Much of the region slopes moderately or steeply. Terraces and flood plains, comprising about 10 percent of the region, are bordered by steep slopes; the most extensive areas of gently sloping land are on the uplands.

Many of the principal valleys follow courses that are probably adjusted to the geology. Some of these valleys trend parallel to the structural axes, other run across the axes nearly parallel to the regional strike. The valleys of the Cohocton and Canisteo Rivers, for example, are at right angles to the structural axes but are parallel to the belt of outcrop of the Upper Devonian rocks (pl. 2). Even some of the meanders of the Canisteo River seem to follow minor folds in the bedrock (Bradley and Pepper, 1938).

Some stream courses suggest glacial modification of an older drainage system. The gorge of Pine Creek southwest of Wellsboro, Pa., for example, owes its origin to erosion by glacial melt water. Before the gorge was cut, the headwaters of Pine Creek were tributary to the Tioga River and drained northeastward.

BEDROCK GEOLOGY

The bedrock beneath the surficial deposits, and from which the deposits were in large part derived, is sedimentary rock of Paleozoic age, gently folded except in the Valley and Ridge province (pl. 2). The rocks are chiefly sandstone, siltstone, and shale, together with lesser amounts of conglomerate, limestone, and coal. Of these, sandstone and conglomerate outcrops are the most conspicuous, but siltstone and shale probably underlie the larger area. The massive coarse-grained beds, chiefly of late Paleozoic age, underlie the Pennsylvania highlands. Finer grained rocks, chiefly of late Devonian age, form most of the uplands in New York.

Structurally, most of the rocks form broad, open folds that trend northeastward and are spaced about 5 to 10 miles apart. In the southern part of the region, the Valley and Ridge province, the rocks dip steeply, some as much as 90°. But in spite of local differences, the region is structurally unified by folds that extend across the entire region. In general, the structural axes plunge slightly southwestward, and the older rocks crop out in the northeastern part of the region.

SURFICIAL DEPOSITS OF PRE-WISCONSIN AGE

Strongly weathered red or yellowish-red drift, colluvium, alluvium, or residuum occur as isolated patches south of the Wisconsin drift border (pl. 1). Such material has been called "pre-Wisconsin paleosol" by Denny (1956b), who showed that scattered outcrops, at altitudes of up to 2,500 feet, can be traced just outside the Wisconsin drift border from New Jersey to New York (pl. 3). Red-Yellow Podzolic soils ordinarily are developed on such reddish material whose color is brighter (greater chroma) than any of the weathered Wisconsin drift or any surficial materials derived from the local red beds (Denny, 1956b, fig. 4). Commonly, the pre-Wisconsin materials consist of bedrock fragments so strongly weathered that the original nature of the deposit is difficult to determine (fig. 1).

The occurrence of old weathered drift south of the Wisconsin limit has long been recognized, but Leverett (1934) is the only geologist who has studied it in some detail. His map (Leverett, 1934, pl. 1) is highly generalized and shows pre-Wisconsin drift far more extensive than is actually the case. The old drift occurs as isolated patches, a few of which are shown on plate 1.

The only attempt at detailed mapping of the old drift is the county soil surveys, chiefly those of Lycoming, Columbia, Union, Montour, and Northumberland Counties, Pa. These soil surveys have limited geologic value because they interpret most surficial deposits as being pre-Wisconsin drift, whereas most of the surficial mantle in these counties is younger.

Because the old drift is strongly weathered to depths of many feet, it almost certainly is pre-Wisconsin (Denny, 1956b, p. 17). The period of weathering is tentatively assigned to the Sangamon interglacial stage. Leverett (1934) recognized two pre-Wisconsin drifts in northeastern Pennsylvania—the Illinoian and the Jerseyan—but the authors have been able to demonstrate the existence of only one, believed to be the Illinoian.

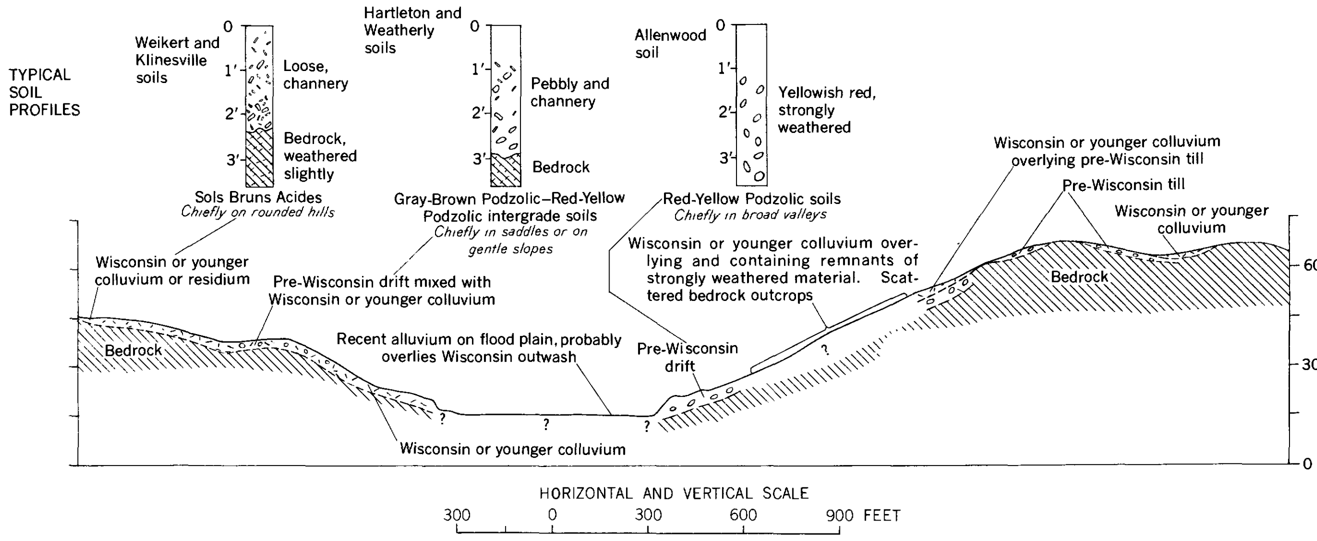


FIGURE 1.—Surficial deposits and soils in an area south of Wisconsin drift border. Idealized section of dissected uplands mantled by pre-Wisconsin drift, Wisconsin or younger residuum or colluvium, and mixtures of these deposits. Thickness of surficial deposits exaggerated. Stratigraphic relations shown only in some places.

The positive identification of strongly weathered material as glacial drift is, in fact, difficult. For example, streams flowing out of sandstone mountains into shale valleys build alluvial aprons. Thus, the pre-Wisconsin drift on the uplands east of Hughesville, Pa. (see p. 29), might be remnants of ancient alluvial deposits laid down by streams flowing southward to the Susquehanna River from highlands of sandstone and conglomerate. Although the smoothed and striated pebbles in the drift near Hughesville are not proof of transport by glacial ice, they suggest such an origin, which is supported by the distribution of the old drift—abundant remnants near the Wisconsin drift border and none further south.

DRIFT

The pre-Wisconsin drift includes both till and gravel commonly weathered to the base of the exposure; that is, to at least 5 feet. At a deep exposure near Montgomery, Pa., on the west side of the West Branch Susquehanna River south of Williamsport, fresh drift was reconized beneath a weathering profile 33 feet thick. This gravelly and well-drained drift has weathered red, perhaps by thorough oxidation. This thick weathering profile at Penny Hill near Montgomery (pl. 1, loc. 35), and a similar but shallower profile near Hughesville, about 18 miles east of Williamsport (pl. 1, loc. 33), are described in detail on page 30.

Strongly weathered gravel, perhaps glacial outwash of pre-Wisconsin age, occurs along the West Branch Susquehanna River and its principal tributaries, Pine, Lycoming, Loyalsock, and Muncy Creeks (Peltier, 1949; Denny, 1956b, p. 19). Whether such gravels are indeed glacial outwash or whether they are alluvial deposits of nonglacial origin derived from adjacent highlands has never been determined.

Gravel and sand weathered yellowish red occur in the the valley of Lycoming Creek north of Williamsport, Pa. At Cogan Station, about 5 miles south of the Wisconsin drift border (pl. 1, loc. 29), yellowish-red unstratified gravel and sand contain pebbles, mostly of sandstone but including some siltstone and conglomerate, held in a matrix of sand and silt mottled red, reddish brown, and black. All are weathered throughout and surrounded by clay skins. The pebbles break with only a light touch of the hammer and about 10 percent can be broken by hand. The gravel and sand near Cogan Station may well be outwash because pre-Wisconsin till crops out in the vicinity. Strongly weathered till containing striated rock fragments occurs along Lycoming Creek about 2½ miles to the north and on uplands 2 or 3 miles east.

The remnants of pre-Wisconsin drift occur on uplands, on slopes near valley floors, and as terraces adjacent to flood plains (fig. 1). Those remnants on uplands are entirely till containing erratics or striated rock fragments. The terrace deposits near valley bottoms are chiefly of fluvial origin and are identified as glacial because they are adjacent to bodies of pre-Wisconsin till. Other gravel deposits, similar in lithology, in topographic position, and in state of weathering, but not associated with till, are also assigned to glacial outwash.

Pre-Wisconsin drift has been seen beneath Wisconsin and younger alluvium and colluvium, but it has never been positively identified beneath Wisconsin drift. For example, an isolated outcrop of strongly weathered material, probably old drift, was seen about 1½ miles north of the Wisconsin drift border. The old drift is

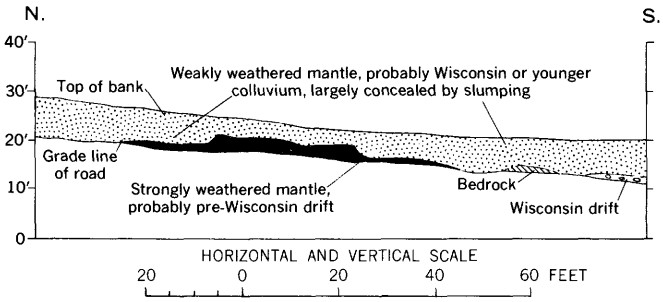


FIGURE 2.—Section of strongly weathered mantle overlain by weakly weathered mantle, Wisconsin colluvium resting on probable remnants of pre-Wisconsin drift. Exposure in road cut north of the Wisconsin drift border near Hughesville, Lycoming County, Pa., about 15 miles east of Williamsport (pl. 1, loc. 31). Wisconsin drift is exposed nearby.

overlain by colluvium (fig. 2), but the contact is largely concealed by slumping. Wisconsin drift is exposed nearby. The strongly weathered material is silty clay loam, mottled red (2.5*YR* 4/7–5/8), reddish yellow (5*YR* 6/8), very pale brown (10*YR* 7/3), and black, and is intersected by light-gray (10*YR* 7/2) bands, about a quarter of an inch wide, that apparently formed along narrow cracks. Throughout the material are scattered equidimensional subangular fragments of sandstone, siltstone, and conglomerate more than a quarter of an inch in diameter. Most of the fragments are weathered, and many can be cut with a shovel or broken by hand; a few are firm. The overlying silty material, weakly weathered yellowish to reddish brown, contains some rock fragments and supports a Sol Brun Acide (Lackawanna channery silt loam); the same soil is developed on adjacent reddish drift of Wisconsin age. The relations indicate but do not prove that this probable old drift and its strong weathering both antedate the Wisconsin stage.

COLLUVIUM AND RESIDUUM

Bodies of unconsolidated material covering several acres south of the Wisconsin drift border are weathered like the drift just described, but they lack striated fragments of rock. Accordingly, these bodies are regarded as colluvium or residuum, although precise identification is often impossible. For the most part the old residuum or colluvium is buried beneath several feet of younger colluvium (Denny, 1956b, fig. 7), but in a few places the strongly weathered deposits are exposed at the surface.

DRIFT OF WISCONSIN AGE

Wisconsin drift includes till, glaciofluvial deposits, and lake sediments (pl. 1). These deposits are described below, together with brief mention of the Valley Heads moraine of Fairchild. The soils developed on Wisconsin drift are predominantly Sol Brun Acide and Gray-Brown Podzolic. Representative examples of such soils are described on pages 37–51.

TILL

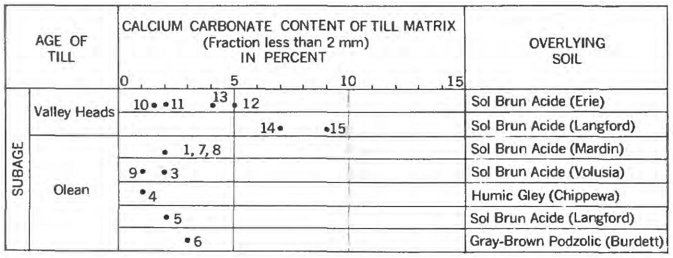
The character of the till depends primarily on the nature of the adjacent bedrock. Thus, sandy textures are found in till adjacent to coarse-grained sandstone and conglomerate, such as the rocks of Pennsylvanian age (pl. 2); and loamy till (silty clay loam or silt loam), is the most abundant type where the bedrock is chiefly fine-grained sandstone and siltstone, for example, rocks of Devonian age (pl. 2). Likewise, the Mississippian red beds impart their color to the till, massive sandstone and conglomerate of Pennsylvanian age contribute boulders and cobbles, and thin-bedded rocks of Mississippian and younger ages contribute many channers and flags. Although the majority of the rock fragments in till are not striated, such stones are easy to find. The till may be massive or it may have an irregular stratification in which the stratification planes are discontinuous and commonly several feet apart.

The till ranges from 1 foot to more than 20 feet in thickness, rests on bedrock, and is overlain by fluvial, lacustrine, and colluvial deposits. Till resting on water-laid drift was found only at one locality, in the uplands about 2 miles southeast of Horseheads, N.Y. (pl. 1, loc. 16). Other exposures of till resting on water-laid drift in the vicinity of Elmira have been reported by Tarr (Williams, Tarr, and Kindle, 1909), MacClintock and Apfel (1944), and Wetterhall (1958).

The lithology of the till in the Valley Heads moraine of Fairchild and northward nearly to Lake Ontario has been described by Holmes (1952), who divided samples of unweathered rock fragments ¼ to ½ inch in diameter into lithologic groups. His data show that near the Finger Lakes, the till contains many fragments that came largely from the region north of the lakes, whereas on the uplands between the lakes the fragments are chiefly local bedrock. Fragments of igneous and metamorphic rock are present in small amounts and are uniformly distributed both in the through valleys and on the uplands (Denny, 1956b, p. 24–27), although the amounts are slightly greater in the western part of the region.

Because depth of leaching of calcareous till has long been used as one method of correlation of drift sheets, we tried to determine the carbonate content of unweathered drift and its possible relation to leaching. Figure 3 shows no marked difference in carbonate content between tills of the two substages. The highest values are from samples of Valley Heads drift. Using these analyses, field observations, and Cline's (1955) soil-association map of New York, we have constructed a map showing the content of calcareous material in unweathered till (fig. 4).

This generalized map shows a decrease in carbonate content southward from the belt of outcrop of limestone



[Carbonate content (calcium carbonate equivalent) determined by U.S. Department of Agriculture, Soil Conservation Service, Soil Survey Laboratory, Beltsville, Md., using acid-neutralization method; and by Paul Blackmon, U.S. Geological Survey. Samples 3, 5, 14, 15 were determined by Blackmon in the field using an oil-displacement method]

Sample	*Location*
1	Bank of Caton Creek, 3 miles south of Corning, Steuben County, N.Y. (pl. 1, loc. 18).
3	Bank along Highway 17, 1 mile west of West Windsor, Broome County, N.Y. (pl. 3, loc. 9).
4	Bed of small stream, 1 mile west of Whittemore, Tioga County, N.Y. (pl. 3, loc. 7).
5	Bank of Jackson Creek, 3½ miles north-northeast of Breesport, Chemung County, N.Y. (pl. 1, loc. 11).
6	Bank of North Elk Run, 1½ miles northwest of Covington, Tioga County, Pa. (pl. 1, loc. 26, and fig. 10, sec. *E*).
7	Borrow pit along Highway 17, Vestal, Broome County, N.Y. (pl. 3, loc. 8).
8	Bank of small stream, 3 miles northwest of Seely Creek, Chemung County, N.Y. (pl. 1, loc. 19).
9	Streambank near mouth of Cuthrie Hollow, 2 miles north of Big Flats, Chemung County, N.Y. (pl. 1, loc. 13).
10	Highway cut, 1 mile west of Soldiers Home, Bath, Steuben County, N.Y. (pl. 1, loc. 7).
11	Highway cut, 3 miles northwest of Prattsburg, Steuben County, N.Y. (pl. 3, loc. 3).
12	East shore of lake, 3 miles northeast of Hammondsport, Steuben County, N.Y. (pl. 1, loc. 1).
13	Same as number 12.
14	Highway cut, Kellogg Corners, Tompkins County, N.Y. (pl. 1, loc. 8).
15	Highway cut, 2 miles southwest of Stratton, Tompkins County, N.Y. (pl. 1, loc. 9).

FIGURE 3.—Graph showing relation between age of till and calcium carbonate content of till matrix. Carbonate analyses are of till derived chiefly from gray fine-grained sandstone and siltstone.

bedrock (Helderberg, Oriskany, and Onondaga of Merrill, 1901), a pattern reflecting the initial deposition of the till. Near the through valleys, strongly calcareous till extends many miles farther south from its principal source rocks than on the adjacent uplands. Nonetheless, some of the carbonate was probably picked up farther south as the ice rode over calcareous sandstone.

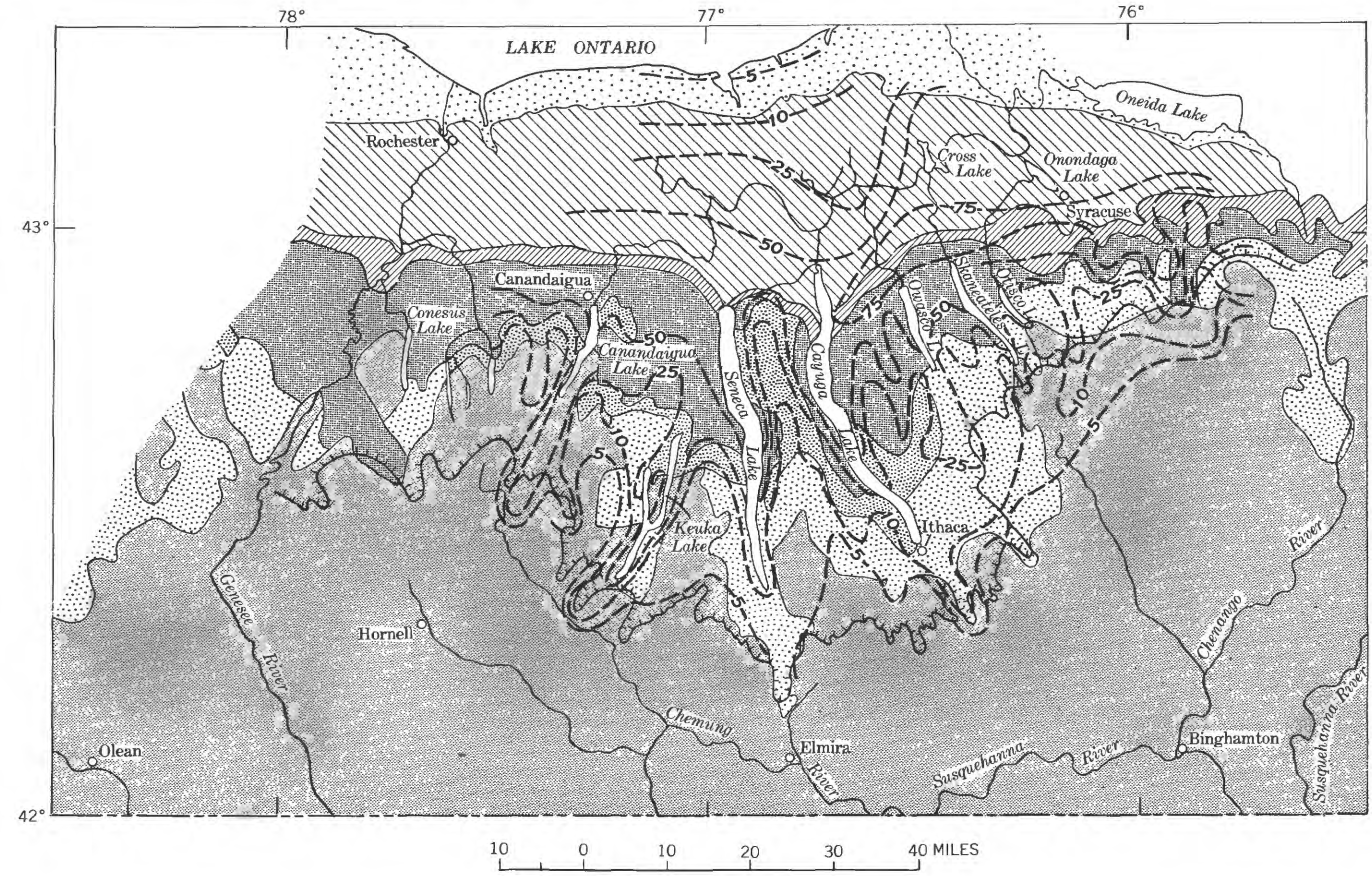
For comparison, Holmes' isopleths showing percentage distribution of limestone and dolomite fragments in unweathered till were added to the map. Some inconsistencies are at once apparent. Near Keuka and Canandaigua Lakes, for example, the till contains more than 25 percent carbonate fragments where the till matrix is mapped as slightly calcareous to noncalcareous. Such a comparison suggests that the till matrix may be derived dominantly from local bedrock, whereas the included fragments are far traveled. However, such apparent inconsistencies may only reflect insufficient data.

The map also shows the depth to free carbonates; that is, the depth to which the till has been leached. The depth of leaching increases southward as the content of free lime decreases. Thus the depth of leaching seems to be primarily dependent on the carbonate content of the till rather than on its age, whether Olean or Valley Heads. On the basis of more complete data for the area surrounding Cayuga Lake, Merritt and Muller (1959) reached a similar conclusion.

Sols Bruns Acides and Low Humic-Gley soils are the soils commonly developed on till and are mapped on plate 5 as members of the following associations: Lordstown–Bath–Mardin–Volusia, Lordstown, Lackawanna-Wellsboro–Morris, and Oquaga–Lackawanna (p. 37).

GLACIOFLUVIAL DEPOSITS

Glaciofluvial deposits of gravel and sand occur throughout most of the region and rest on till or bedrock; at a few points along the Chemung and Susquehanna Rivers they overlie lake sediments. The glaciofluvial deposits are divided into kame deposits and valley-train deposits, which implies a difference in origin of the sediments (pl. 1). Relatively broad, flat-topped terraces (pl. 4) in the large through valleys parallel present stream grades at heights ranging from 10 to 90 feet above the flood plain. These terraces are the dissected remnants of alluvial plains built by melt-water streams (valley-train deposits, pl. 1). Because these terraces are indented by only a few kettle holes, the melt-water streams probably flowed down the valley from the melting glacier rather than between masses of stagnant ice in the center of a valley and the adjacent valley wall. These terraces occur at many different heights and cannot be correlated from one end of a valley to the other; thus, they seem to be segments of not one but several river profiles. The differences in height are related to changes in such features as the position of the glacier terminus, the width of the bedrock valley, and the volume of melt water. Also, some of the terraces are erosional surfaces cut below the original top of the deposit. These terraces are underlain by relatively uniform-sized well-bedded pebble gravel and sand that include a relatively high proportion of limestone and chert pebbles. Such valley-train deposits are also found south of the Wisconsin drift border, but the only extensive remnant mapped was near Hughesville, about 15 miles east of Williamsport, Pa. The valley-train deposits at Wysox, near Towanda, Bradford County, Pa., are described in detail in the discussion of the Howard association (p. 46). The sands and gravels that make up the valley trains along the Cohocton, Chemung, and Susquehanna Rivers are uniform along reaches of as much as 100 miles, which suggests that their source was similar, probably the Valley Heads moraine.



EXPLANATION

Till

Content of calcareous material shown only in areas south of belt of limestone outcrop (based on Cline, 1955)

Calcareous

Calcium carbonate equivalent of matrix probably ranges from about 10 to 30 percent. Contains free lime at depths ranging from about 1½ to 2½ feet

Moderately calcareous

Calcium carbonate equivalent of a few samples of matrix ranges from about 2 to 15 percent. Contains free carbonates at depths commonly ranging from about 3 to 5 feet

Slightly calcareous

Calcium carbonate equivalent of matrix from a few localities ranges from 2 to 5 percent. Depth to free carbonates ranges from 6 to about 10 feet

Slightly calcareous to noncalcareous

Calcium carbonate equivalent of matrix from a few localities ranges from less than 1 to about 3 percent. Depth to free carbonates ranges from 6 to about 10 feet

Bedrock

Shown only in northern part of area

Limestone

Helderberg, Oriskany, and Onondaga formations of Merrill (1901)

Limestone and dolomite

Niagara and Salina formations of Merrill (1901)

Sandstone, limestone, and shale

Medina, Oneida, and Clinton formations of Merrill (1901)

Bedrock of area south of limestone belt is chiefly sandstone, shale, and limestone. Hamilton, Tully, Genesee, Ithaca, Portage, and Chemung formations of Merrill (1901)

— — — 10 — — —

Isopleth

Percentage of limestone and dolomite fragments in till; fragments range from ¼ to ½ inch in diameter (Holmes, 1952, fig. 7)

Southern limit of Valley Heads moraine of Fairchild (1932)

FIGURE 4—Generalized map showing content of calcareous material in the unweathered till of south-central New York. Map shows (1) by isopleths the distribution of limestone and dolomite fragments within a selected size range (Holmes, 1952, fig. 7), and (2) by patterns the content of calcareous material in the till matrix based on an interpretation of the soil-association map of New York (Cline, 1955).

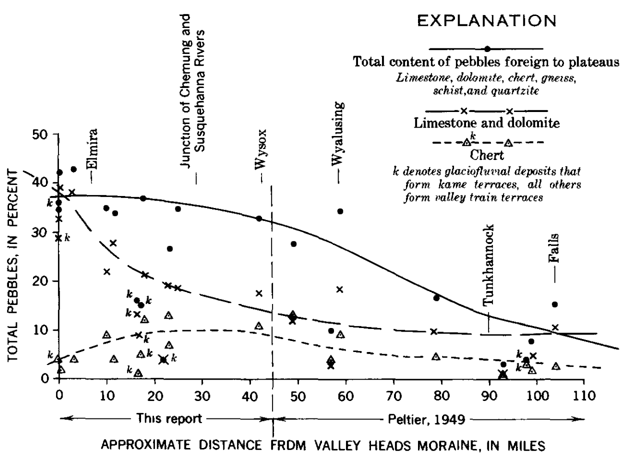


FIGURE 5.—Graph showing change in content of erratic pebbles in glaciofluvial deposits along a through valley southward from the Valley Heads moraine. The zero point of traverse is on the south edge of the moraine north of Horseheads, Chemung County, N.Y. The traverse runs southward to Elmira, eastward down Chemung River valley to Athens, and southeastward down the Susquehanna River valley almost to the Wyoming Valley at Pittstown (pl. 3). Compiled from data shown on figure 7 and on table 3 in Peltier (1949).

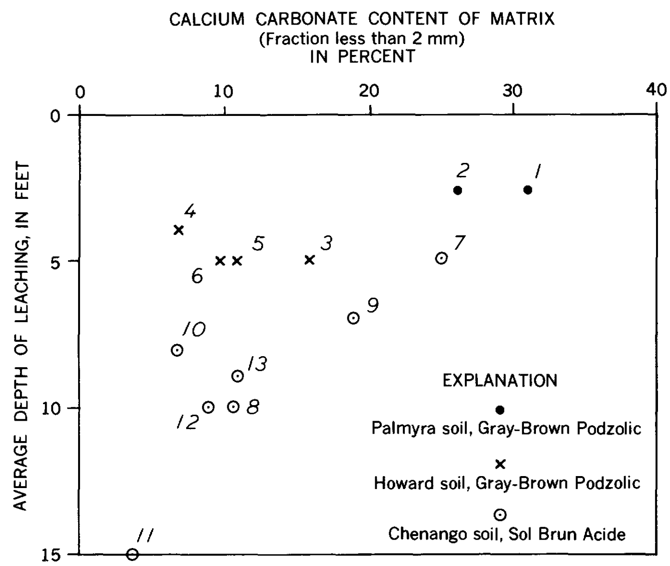
A systematic change in the erratics in the valley-train deposits is illustrated by figure 5, which shows the change in content of erratic pebbles along a through valley southward from the Valley Heads moraine for about 100 miles. The graph includes data gathered by Peltier (1949) that may not be entirely comparable to that of figure 7. The total content of erratic pebbles decreases from about 40 percent near the moraine to about 16 percent near Falls, Pa., about 100 miles away. Although the amount of limestone near the moraine is several times greater than the amount of chert, the limestone rapidly decreases in abundance downstream, probably because it is less durable.

In many of the smaller valleys, and in some places even on the uplands, are narrow terraces, ridges, or knolls of gravel and sand that commonly surround kettles. These kames, composed of pebbly to bouldery gravel and coarse and fine sand, occur at heights of 30 to 300 feet above adjacent floodplains (pl. 4). Stratification is variable: some kame deposits are well bedded, and others are irregularly stratified. The internal and external character of the deposits indicates deposition in association with wasting glacial ice; commonly kames were built by melt-water streams flowing between the ice and the valley walls.

The maximum exposed thickness of glaciofluvial deposits is about 50 feet, but topographic relations suggest a thickness of perhaps 100 feet in a few places, a figure supported by well records (Wetterhall, 1958). The deposits rest on bedrock, till, or lake deposits and are in places overlain by Recent alluvium and by colluvium of Wisconsin or younger age.

In the region as a whole, the carbonate content of the fine fraction of the glaciofluvial deposits decreases southward and depth of leaching increases. However, the relations within any one area are more complex. For example, the calcium carbonate content of the matrix in about a dozen samples of unweathered gravel ranges from 4 to 31 percent, while the depth of leaching ranges from 2½ to 15 feet. But in spite of a wide scattering of points, there is a rough increase in depth of leaching with a decrease in carbonate content of the matrix (fig. 6).

The content of limestone pebbles in the glaciofluvial deposits also ranges from zero throughout much of Pennsylvania, where the depth of leaching may be more than 20 feet, to nearly 40 percent in parts of New



[Carbonate content (calcium carbonate equivalent) determined by Soil Survey Laboratory, Soil Conservation Service, Beltsville, Md., using acid neutralization method; and by Paul Blackmon, U.S. Geological Survey. Samples 4, 5, 10, and 12 were determined by Blackmon in the field using an oil displacement method]

Sample	*Location*	*Soil type*
1,2	Near Manchester, Ontario County, N.Y. (pl. 3, loc. 1).	Palmyra gravelly loam.
3	Shiner gravel pit, Wysox, Bradford County, Pa. (pl. 1, loc. 27).	Howard gravelly loam.
4	Gravel pit in large delta, ½ mile southeast of Hammondsport, Steuben County, N.Y. (pl. 1, loc. 5).	Do.
5	Gravel pit, ½ mile northwest of Breesport, Chemung County, N.Y. (pl. 1, loc. 14).	Do.
6	One-half mile west of Weston, Schuyler County, N.Y. (pl. 1, loc. 3).	Do.
7	One mile east of Howard, Steuben County, N.Y. (pl. 1, loc. 6).	Chenango gravelly loam.
8	Gravel pit, Mitchellsville, Steuben County, N.Y. (pl. 1, loc. 4).	Do.
9	Pipeline trench, 3 miles north of Owego, Tioga County, N.Y. (pl. 1, loc. 15).	Do.
10	Gravel pit, 1½ miles north of Troupsburg, Steuben County, N.Y. (pl. 3, loc. 10).	Do.
11	Gravel pit, 2 miles west of Roseville, Tioga County, Pa. (pl. 1, loc. 24).	Do.
12	Gravel pit, mouth of Jackson Creek, Schuyler County, N.Y. (pl. 1, loc. 10).	Do.
13	One-half mile west of Stephens Mills, Steuben County, N.Y. (pl. 3, loc. 4).	Do.

FIGURE 6.—Graph showing relation between the carbonate content of the matrix of some glaciofluvial deposits, depth of leaching, and soil type.

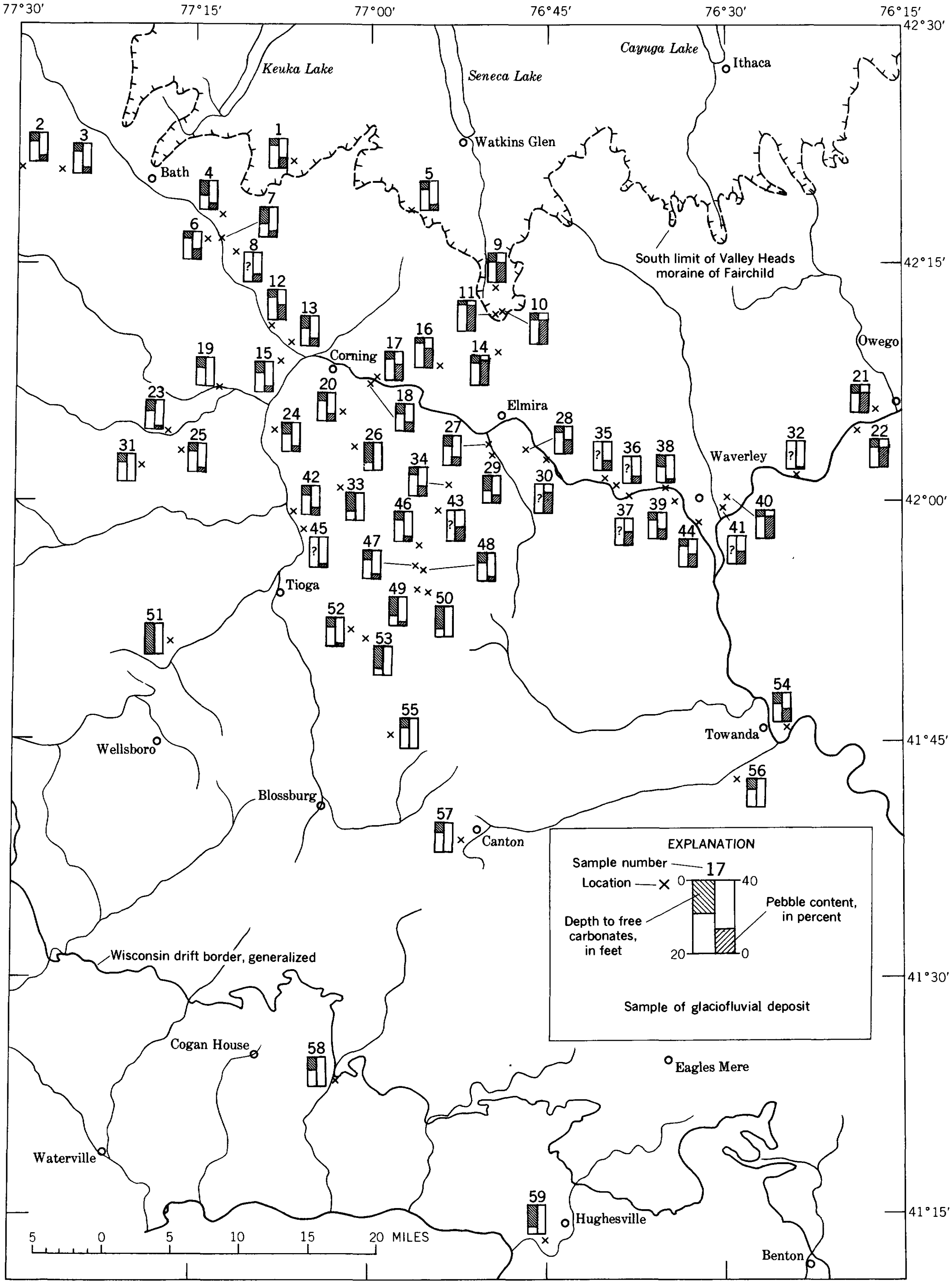


FIGURE 7.—Map showing depth to free carbonates and percentage of limestone and dolomite pebbles in glaciofluvial deposits at selected localities in the Elmira-Williamsport region, New York and Pennsylvania. The percentage is of the total number of pebbles (200–300 pebbles) passing through a 1-inch sieve and retained on a ½-inch sieve. (See figure 8 for range of values at selected localities.)

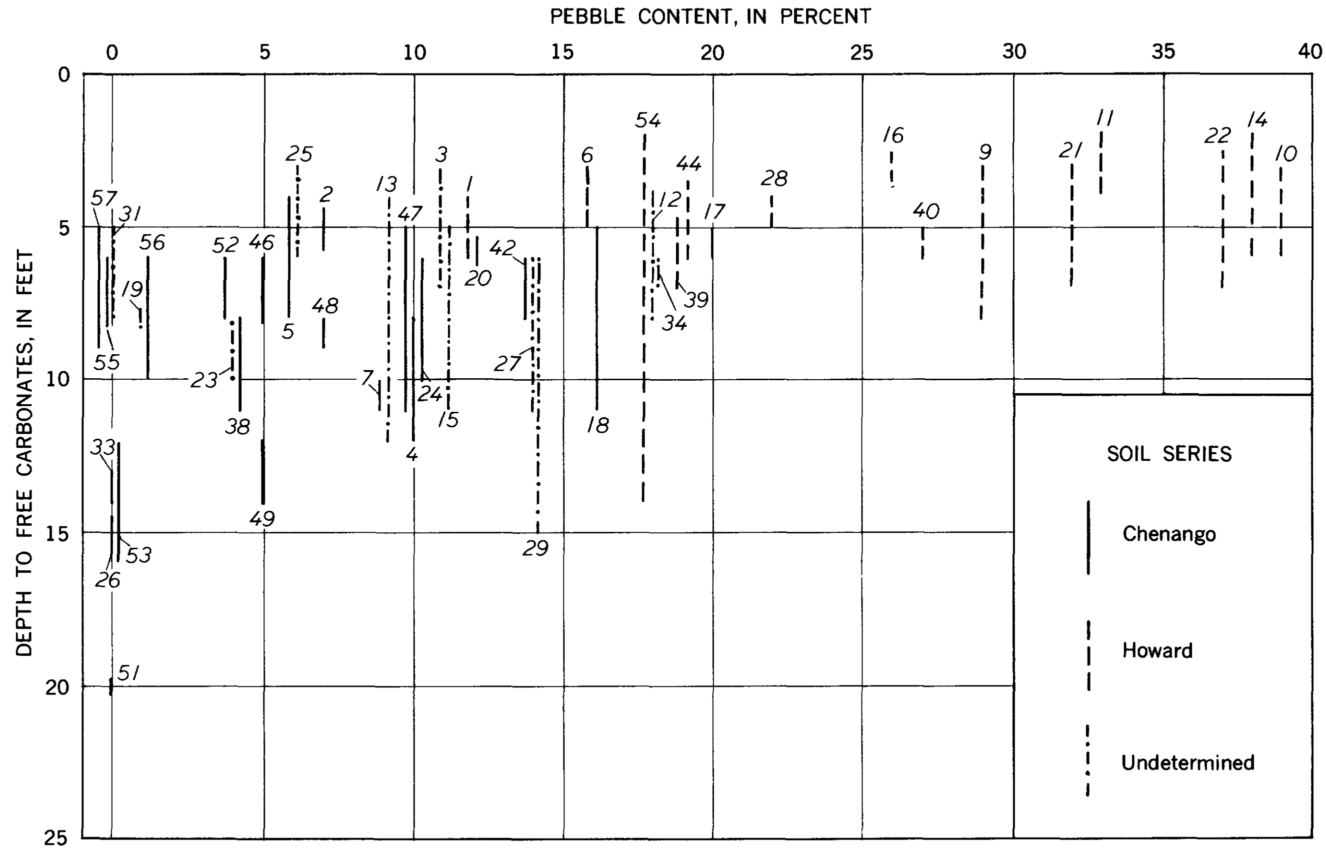


FIGURE 8.—Graph showing relation between depth to free carbonates and abundance of pebbles of limestone and dolomite in glaciofluvial deposits. Numbers refer to localities shown on figure 7. Vertical lines show range in depth to free carbonates and soil series developed in the deposits at each locality sampled.

York (fig. 7), where calcareous pebbles may be present at depths of only 2½ feet. When plotted on a graph (fig. 8), the data suggest a slight increase in depth of leaching with a decrease in the content of limestone pebbles.

MacClintock (1954) gathered data on the depth of leaching and the limestone content of glaciofluvial deposits throughout the northeastern United States. The data, when plotted as in figure 8, fell into three groups, each was restricted to a limited range of depth of leaching while extending over a wide range in content of limestone pebbles (MacClintock, 1954, fig. 1). Plotted on a map, his 3 groups fell into 3 geographic belts which, MacClintock believed, mark the deposits of 3 Wisconsin substages. Our graph for the Elmira-Williamsport region (fig. 8) does not show distinct grouping by depth of leaching. It is true that some observations are within the range from 2 to 7 feet, others from 5 to 9 feet, and still others 10 feet or more. However, no overall grouping such as was obtained by MacClintock is possible.

Also, there is no grouping by depth of leaching, like that made by MacClintock, that has geographic continuity (fig. 7). For example, gravels in the through valleys in New York, such as the valleys of the Susquehanna, Chemung, and Cohocton Rivers, range in average depth of leaching from 3 to 10 feet, but in Pennsylvania some gravels are leached to a depth of 15 or 20 feet, while others in the vicinity are leached to depths of as little as 4 or 5 feet. The depth of leaching of the glaciofluvial deposits does increase southward as their content of calcareous material decreases, but the change is gradual and cannot be used to subdivide the glaciofluvial deposits.

LAKE SEDIMENTS

In the valley of the Chemung River from Elmira to Sayre, lake beds underlie the glaciofluvial deposits. The lake sediments accumulated in the narrow bedrock valley of the river and its principal tributaries, and they are older than the Valley Heads moraine of Fairchild, perhaps antedating the Olean substage (MacClintock and Apfel, 1944). Lake beds are exposed at the places listed below.

Locality	*Material exposed*
West bank of Chemung River, west of Chemung, N.Y., about 1,500 feet north of State line (pl. 1, loc. 20; fig. 7, sample 37).	Silt and clay, bedded; overlain by pebble gravel forming valley-train terrace. About 2 feet of lake beds exposed above river level at low water.
West bank of Chemung River, west of Sayre, Pa., about 0.8 mile south of State line (pl. 1, loc. 21).	Silty clay, calcareous; forms varves overlain by pebble gravel forming valley-train terrace about 30 feet above river. About 6 feet of lake beds exposed near river level.
East bank of Chemung River west of Sayre, about 1,000 feet north of Chemung River bridge, State Route 427 (pl. 1, loc. 22).	Clay, calcareous, bedded; forms varves overlain by gravel forming terrace about 40 feet above river. (See section below.)

Local inhabitants reported that sand and clay underlying glaciofluvial deposits are exposed in borrow pits along the Susquehanna River near Owego, N.Y.; and clay underlying gravel has been reported in the Chenango River valley near Binghamton (Brigham, 1897).

Section of gravel overlying lake sediments in east bank of Chemung River near Sayre, Bradford County, Pa. (pl. 1, loc. 22). Exposure is about 1,000 ft north of Chemung River bridge, State Route 427.

	Thickness (feet)
Top: Valley-train terrace, about 40 ft above river:	
1. Gravel, pebbly; not well exposed, resembles unit 2 below; noncalcareous near top, calcareous at depths ranging from 3 to 6 ft	22
2. Gravel, cobbly and bouldery, coarse sandy matrix, calcareous, dark grayish-brown (2.5*Y* 4/2—10*YR* 4/2), faintly stratified to massive. Lower contact sharp, essentially horizontal for exposed distance of 200 ft; local relief less than 1 ft	8
3. Lake beds; silt, clayey, calcareous, light olive-brown (2.5*Y* 5/4), massive. Lower contact sharp, wavy; local relief ranges from 2 to 3 inches. About 200 ft to the south this unit changes to calcareous medium to fine sand, about 2 ft thick that rests disconformably on the lake beds of unit 4	¾
4. Lake beds; clay, silty, calcareous, gray (5*Y* 5/1), stratified; form varves ranging from 2 to 4 inches in thickness and consisting of a relatively thick layer of silty clay that grades upward into a thin layer of clay; the contact between two varves is sharper than that within a varve	13
Base: Chemung River, low-water stage.	

Wetterhall (1958) in his study of the ground-water resources of Chemung County found blue clayey silt underlying gravel in many valleys. Silt also crops out on the west side of the valley at Elmira Heights, in the lowlands between Horseheads and Big Flats, and in the Valley Heads moraine north of Horseheads. Near Elmira Heights, Wetterhall found that the depth to bedrock ranges from 30 feet in many places to more than 400 feet in a narrow channel cut into the relatively flat buried bedrock floor of the valley. The lower part of the channel is filled with gravel. Above this gravel is silt that fills the channel and mantles the adjacent bedrock floor of the valley. Wetterhall believes that before the last glaciation, a lake filled the larger bedrock valleys of the Elmira area and that the sediments deposited in this lake were extensively eroded before their burial by drift. The lake could have formed during retreat of a pre-Olean, possibly Illinoian, ice sheet, or the lake may have been dammed by a part of the Olean ice sheet before being overridden.

Although the Tioga River drains northward and appears to be favorably located for the development of a large melt-water lake, no extensive lake sediments were found there. The deposits of glacial Lake Cowanesque (Willard, 1932) and the lake sediments along North Elk Run near Mansfield, Pa. (pl. 1, loc. 26), apparently represent only small proglacial lakes.

DRIFT BORDER

No conspicuous terminal moraine marks the limit of Wisconsin glaciation. In a few places there are subdued knolls and ridges but, commonly, no topographic break is visible. The south border of Wisconsin drift crosses the Elmira-Williamsport region in a southeasterly direction (pl. 1). From Muncy Creek northwestward to Pine Creek, a distance of about 40 miles, the drift border trends about N. 66° W., following a winding course in a belt about 6 miles wide and changing in altitude from about 650 feet along Muncy Creek to about 2,250 feet on Laurel Mountain. Although the location of the drift border is based largely on reconnaissance, it was precisely identified at a number of points which were used to determine the slope of the surface of the ice sheet (fig. 9). All these points are along roads or trails where the limit of till can be defined within a distance no greater than a quarter of a mile. Assuming that these points mark the position of the front of the ice sheet and that the ice reached its southernmost limit at about the same time, contours on the restored ice front can be drawn by using the three-point method. Thus, between the accurately located points, the drift border corresponds to the intersection of these restored contours with the existing land surface.

Although for simplicity the contours are drawn as straight lines across the narrow valleys, it is probable that the ice tongues were highest in the center of the valleys and sloped outward to the adjacent walls. The restored contours suggest that the slope of the surface of the ice, ranging from 100 to 500 feet per mile, increased slightly as the drift border is approached.

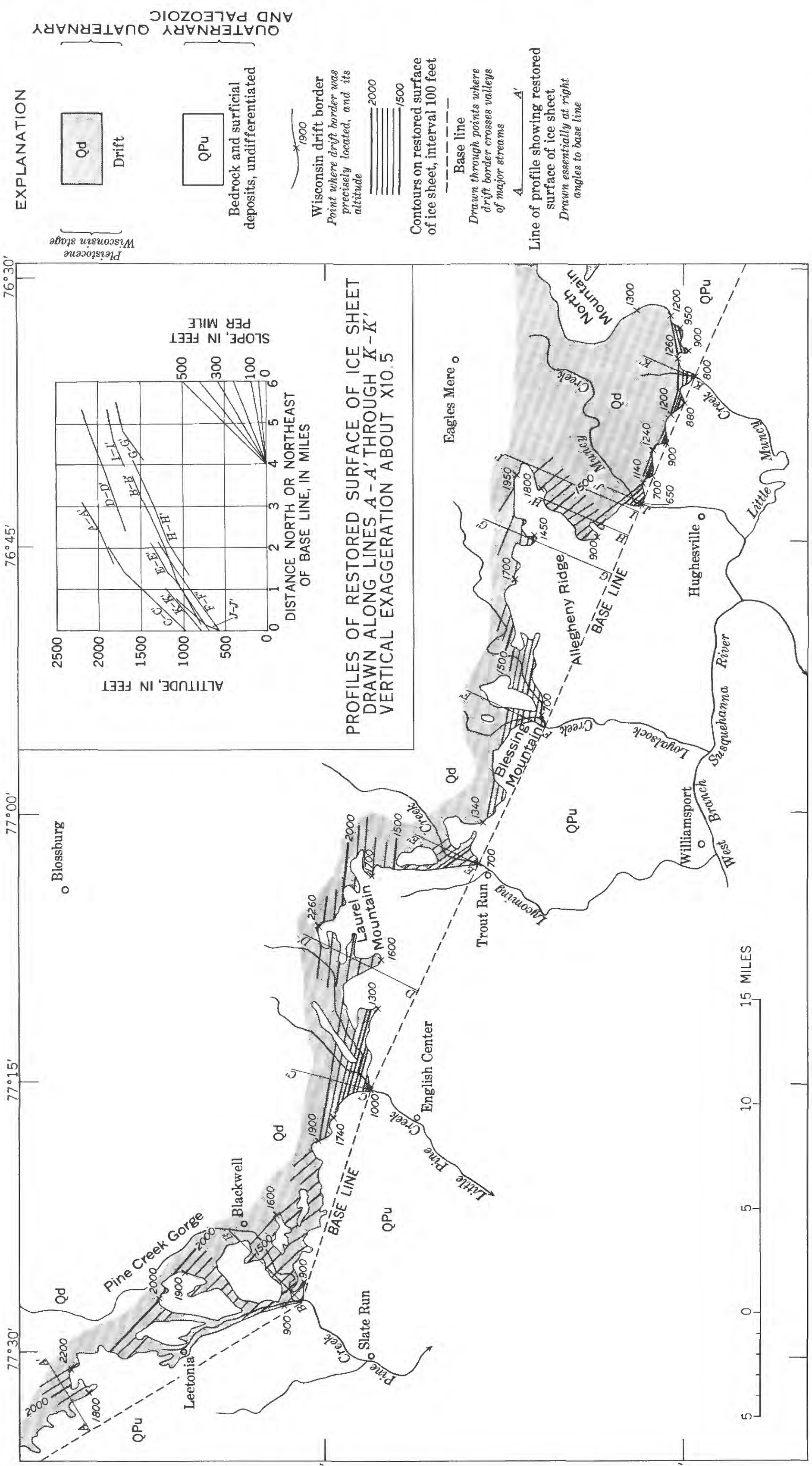


FIGURE 9.—Map of Wisconsin drift border in the Elmira-Williamsport region, New York and Pennsylvania, showing one interpretation of the slope of the surface of the ice sheet at its maximum extent.

Figure 9 includes several profiles of the restored surface of the ice sheet plotted according to their respective distances from a line connecting the points where the ice front crossed valleys of major streams. This method permits comparison of slope differences at various points. Such a comparison shows that the values given here are greater than those reported by Peltier (1949, p. 25–26), who listed a slope of 128 feet per mile for the front of the Wisconsin (Olean) ice sheet along Loyalsock Creek.

VALLEY HEADS MORAINE

The Valley Heads moraine of Fairchild consists of thick deposits of drift in the southern end of the valleys containing the Finger Lakes and of discontinuous patches of moraine, commonly at the base of northward-facing escarpments, on the adjacent uplands. The moraine is close to the divide between the Susquehanna River and the Ontario drainage basins and includes a large volume of water-laid drift, both fluvial and lacustrine. Similar materials are widespread north of the moraine and also form a valley train that extends southward for nearly 100 miles. The moraine and its valley train are larger and more conspicuous than any similar features at the Wisconsin drift border.

The Valley Heads moraine was first decsribed by Chamberlin in 1883 as part of the terminal moraine of the second glacial epoch. Tarr (Williams, Tarr, and Kindle, 1909) interpreted it as a recessional moraine formed during a pause in the general retreat of the ice sheet from the Wisconsin drift border. In 1932, Fairchild applied the name "Valley Heads moraine" to the deposits, and the term has been used extensively since that time (MacClintock and Apfel, 1944; Peltier, 1949; Holmes, 1952; Flint, 1953; MacClintock, 1954; Denny, 1956a). There has been, however, no agreement as to which deposits should be included or whether the moraine is terminal or recessional.

The moraine extends north and south for several miles and may be several hundred feet thick in the larger valleys, where it forms steep-sided hills as much as 100 feet high that are separated by ponds and swamps. In most of the larger through valleys, the moraine lies many hundreds of feet above the Finger Lakes. To the south, however, the surface of the moraine generally decends only a few tens of feet, loses its prominence, and merges with valley-train terraces underlain by glaciofluvial deposits (pl. 4).

In the larger valleys, the moraine is composed of till and stratified gravel, sand, silt, and clay of both fluvial and lacustrine origin. Water-laid drift is more voluminous than till, suggesting that water was impounded in the Finger Lakes valleys during the building of the moraine. In the valley of Catherine Creek from Pine Valley northward, red silt regarded as lake sediment and red silty till apparently reworked from the lake beds are present. Similar silt and silty till form low hills near Horseheads. The morainal deposits vary widely in lithology, texture, and color within short distances, but in general they are mostly calcareous.

Steep-sided abandoned stream channels cut in bedrock and found on the sides of some valleys adjacent to the moraine (pl. 1) suggest erosion by ice-marginal streams that also may have come from ponded water to the north (Williams, Tarr, and Kindle, 1909; Von Engeln, 1945; see also U.S. Geol. Survey Alpine 7½-minute quadrangle map).

On the uplands, the moraine is a discontinuous belt of complex topography—small knolls or ridges and shallow depressions—ranging from a few hundred yards to several miles in width and clearly distinguishable from adjacent areas of smooth and more uniform slopes. This belt of moraine is not shown on plate 1, but its approximate south limit is outlined. The belt commonly lies at the base of a northward-facing escarpment; for example, on the uplands south and southwest of Ithaca (pl. 1), the belt skirts the base of Connecticut Hill and the northeast side of Bull Hill.

Erratics of metamorphic rock (gneiss) are conspicuous within the moraine but are rare farther south. Holmes' study (1952) of the lithology of the till in the Valley Heads drift did not extend south of the moraine.

The common soils on the better drained part of the moraine are Gray-Brown Podzolic and are members of the Howard association and the Lansing-Nunda association. (See pl. 5 and p. 45).

COLLUVIUM OF WISCONSIN OR YOUNGER AGE

Colluvium is widespread throughout the Elmira-Williamsport region and occurs on ridgetops, slopes, and valley bottoms, but it is perhaps most common near the base of steep-sided hills. Athough some of the material on ridgetops has probably formed in place and is strictly a residual deposit, such deposits are grouped with colluvium in the present discussion. Essentially unsorted and unstratified, the colluvium reflects the local bedrock and is dominantly gray, brown, and red mixtures of sandstone, siltstone, and shale. Textures range from rubble (a mixture of angular fragments of rock with little matrix) to silty clay loam containing only a few fragments of rock. Flagstones arranged in imbricate structure are common. Rubbly colluvium is found especially in areas with considerable relief and with relatively massive coarse-grained sandstone or conglomerate bedrock (chiefly rocks of Mississippian and of Pennsylvania age, pl. 2). Colluvium in some areas underlain by shale or by thin-bedded siltstone is composed almost exclusively of small chips of rock with little or no matrix. The colluvium rests on older deposits—drift, colluvium, alluvium, residuum—and also on bedrock. It is not commonly overlain by other material. The soils developed on colluvium are the same as those developed on Wisconsin till of similar lithology and drainage (see p. 37–51).

Much of the colluvium is of Wisconsin age, because no evidence of weathering of Wisconsin drift before colluvial deposition has been found and because colluvium seems to be more extensive south of the Valley Heads moraine than north of it. This evidence indicates that much of the colluvium antedates the emplacement of the moraine. Similar colluvial materials in Potter County, Pa., just west of the region have been called periglacial deposits (Denny, 1956b) and are attributed to mass movement during Wisconsin time, probably during deglaciation. Some colluvium is unquestionably of Recent age, such as that near Daggett, Pa. (p. 17). Thick colluvium of modern date on a small flood plain in the Allegheny Plateau of eastern Pennsylvania has been described by Lattmann (1959).

COLLUVIUM NEAR THE WISCONSIN DRIFT BORDER

A common feature near the Wisconsin drift border is channery or flaggy colluvium along the sides of valleys. This material is derived from extensive areas underlain chiefly by the Chemung formation, of Late Devonian age, a thin-bedded gray siltstone and sandstone together with some shale, and partly by the Catskill formation, red beds also of Late Devonian age (pl. 2). The uplands east of Hughesville, about 15 miles east of Williamsport, Pa., for example, are largely mantled by colluvium made up almost exclusively of shale and thin-bedded sandstone fragments as much as 3 inches in diameter. These porous deposits are the "shale-fragment slopes" of Peltier (1949, p. 64–67). The slabby fragments lie parallel to the slope, similar to shingles on a roof, and the deposits are at least 8 feet thick. In general, the amount of rock fragments increases with depth. Most of the colluvium near the drift border is of Wisconsin or of Recent age, but locally it contains traces of strongly weathered material, either as soft, strongly weathered fragments mixed with less weathered and firmer rock particles or as traces of the characteristic red color of the pre-Wisconsin deposits. The soils on colluvium are dominantly Sol Brun Acide and Gray-Brown Podzolic. Near the Wisconsin drift border the soils are commonly members of the Weikert-Hartleton-Allenwood association (pl. 5). A detailed description of such colluvium and of a Weikert soil developed on it at a locality near Hughesville, Pa., is given on page 34.

Steep slopes underlain by coarse-grained sandstone and conglomerate (the younger Mississippian and Pennsylvanian rocks, pl. 2) result in the formation of rubble, such as is found in parts of all the major valleys that cross the drift border. Rubbly colluvium formed by Wisconsin or younger mass movement overlying at least 10 feet of strongly weathered pre Wisconsin gravel was seen near English Center, Lycoming County, Pa. (Denny, 1956b, p. 38–39, pl. 3F). Coarse-textured and rubbly colluvium commonly are parent materials of Podzols or Sols Bruns Acides that are mapped in the Leetonia-Dekalb association (pl. 5).

Masses of bouldery rubble occur in some of the small valleys in the higher plateaus. Although most are concealed beneath a forest cover, some deposits are nearly free of vegetation and have been called block fields (Peltier, 1949; Denny, 1951; Smith, 1953).

COLLUVIUM OVERLYING STRATIFIED DRIFT

The time of formation of the colluvium cannot be precisely determined, but several lines of evidence suggest that much of it formed during deglaciation. At several localities colluvium rests on bedded fluvial or lacustrine sediments in such a way that it must have moved downslope to mantle the older deposits. Because there is no evidence of weathering of these bedded materials before emplacement of the colluvium, it was probably laid down shortly after the underlying sediments. For example, rubbly colluvium overlying glaciofluvial deposits was seen in borrow pits near Tioga, about 10 miles north of Wellsboro, Pa., and in the Canisteo River valley near Cameron, about 15 miles west of Corning, N.Y. (fig. 10, sections *A* and *B*). The colluvium exposed in the pit near Tioga is a red channery and flaggy silt loam derived by weathering of bedrock on the adjacent steep slope. Between the colluvium and the underlying glaciofluvial gravel and sand are transitional beds, 5 to 10 feet thick, that record a change from fluvial deposition of sorted material to colluvial deposition of unsorted debris. Similar stratigraphic relations are shown in a borrow pit at the base of a bedrock hill near Cameron (fig. 10, sec. *B*), where gravel and and sand were eroded or perhaps modified by mass-wasting before or during accumulation of the overlying colluvium. The tongues of colluvium that project downward into the sand may mark the location of ancient gullies. Presumably, the ice which caused the accumulation of the underlying glaciofluvial sediments was largely melted when mass movement took place. But at neither of these pits is there evidence of weathering between alluvial and colluvial deposition.

Similar stratigraphic relations are exposed near Troy, about 17 miles west of Towanda, Pa. (fig. 10, sec. *C*), where the base of the colluvium has a relief (at right angles to sec. *C*) of as much as 14 feet. This relief indicates erosion of the underlying gravel and sand

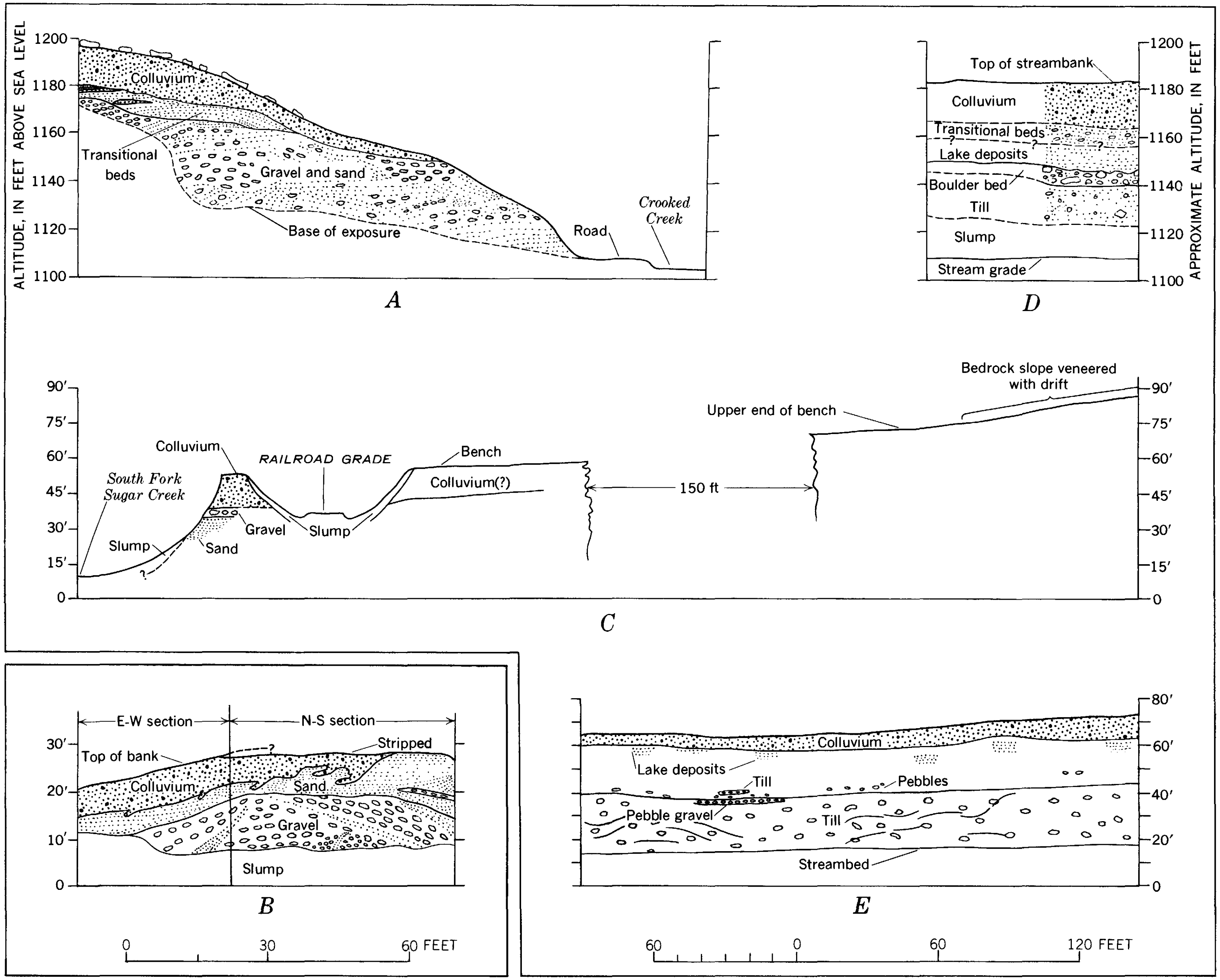


FIGURE 10.—Colluvium overlying stratified drift. *A:* Borrow pit on west side of Crooked Creek about 6 miles southwest of Tioga, Tioga County, Pa. (pl. 1, loc. 23); pit is on northwest side of State Route 84, about 1 mile northeast of village of Crooked Creek (Crooked Creek 7½-minute quadrangle). *B:* Borrow pit in Canisteo River valley near Cameron, Steuben County, N.Y. (pl. 1, loc. 12). Pit is on west side of road along Helmer Creek, about 0.6 mile north of Canisteo River Road (Rathbone 7½-minute quadrangle). *C:* Exposure in south bank of South Fork Sugar Creek near Troy, Bradford County, Pa. (pl. 1, loc. 25). Colluvium underlies a gently sloping bench at base of steeper valley wall. Exposure is about 400 feet above mouth of South Fork. *D:* Exposure in west bank of South Branch Towanda Creek at Stevenson, about 1½ miles north of New Albany, Bradford County, Pa. (pl. 1, loc. 28). *E:* Exposure in valley of Elk Run about 3 miles southwest of Mansfield, Tioga County, Pa. (pl. 1, loc. 26). Steambank on south side of North Elk Run about 0.3 mile above mouth (Mansfield 7½-minute quadrangle).

before or during colluvial deposition. The colluvium was probably derived from material on the adjacent bedrock slope, but its dissection leaves no doubt that it is not accumulating at the present time.

North of Owego, N.Y., colluvium resting on glaciofluvial deposits was observed in a 5-foot-deep pipeline trench that crossed the valley of Owego Creek (fig. 14). The sediments and associated soils exposed in this trench are described on page 37.

Colluvium has been observed resting on lake beds. Near New Albany, about 12 miles south of Towanda, Pa. (fig. 10, sec. *D*), a channery and flaggy colluvium overlies lake sediments, with transition beds of sandy material between. The boulder bed beneath the lake deposit is perhaps a lag concentrate derived by erosion of the till before formation of the lake. Here again, there is no evidence of weathering of the deposits beneath the colluvium; rather, the relations suggest that it was emplaced shortly after the lake deposits. The colluvium that rests on lake deposits exposed along Elk Run near Mansfield, about 9 miles east of Wellsboro, Pa. (fig. 10, sec. *E*), contains a few rounded and striated rock fragments and resembles till. However, the presence of striated stones is misleading because the other constituents and the topographic relations demonstrate local derivation by mass movement from the adjacent drift-covered hillside. Since the colluvium is leached to a depth of only 3½ feet, whereas the till nearby is leached down to depths of 10 feet, the colluvium may have been undergoing leaching for only a compartively short time and may be Recent. On the other hand, since carbonate could have been brought in by downslope seepage of ground water, the colluvium could be as old as the till.

At Daggett, Pa., on the west bank of Seeley Creek, about 12 miles south of Elmira, N.Y., a loose faintly stratified channery and flaggy colluvium overlies sandy lake beds and forms the toe of a small fan. The colluvium lies at the mouth of a small gulch and probably was carried from nearby slopes by streams incapable of doing much sorting. The toe of the fan is dissected by Seeley Creek, and a small stream flows in a shallow gully down the fan, showing that it is not being actively built at present; however, the colluvium may be only a few hundred years old.

DEPOSITS OF RECENT AGE

Little is known about the geologic history of the region in Recent time, nor can the Pleistocene-Recent boundary be defined in terms of any deposits. The record is largely erosional rather than depositional. The glacial drift has been dissected, but when the dissection took place is unknown. Alluvium is the principal Recent sediment, forming flood plains, low terraces, and alluvial fans, but some colluvium is also Recent. The flood plains are underlain by well-stratified sand, silt, clay, and swamp deposits and are, in general, finer grained near the surface and reflect local source rócks. Some of the alluvium may have been deposited when glacier ice was nearby, but most alluvium is now in transit down the valley. In a few places alluvium shows cut-and-fill relations. Near Sayre, Pa., for example, in the east bank of the Chemung River, gravel and silt forming a low terrace about 15 feet above low water rest unconformably on and against glacial-lake and stream deposits (described on p. 12). This relation indicates dissection of the valley-train deposits to depths below present river level, followed by deposition of alluvium up to a height of about 15 feet above river level. Renewed dissection exposed this Recent(?) fill. Along the Chemung River and the upper Susquehanna River, the gravelly alluvium contains many pebbles of limestone, dolomite, and chert and resembles the adjacent glaciofluvial deposits. In small valleys and in the southern part of the region the alluvium is commonly flaggy and contains many angular slabs of thin-bedded sandstone and siltstone (Denny, 1956b, fig. 18).

The alluvial fans are small, commonly only a few hundred feet long, but large fans have developed in a few places. For example, near Big Flats, northwest of Elmira, N.Y., short southward-flowing streams such as Guthrie Run head in the uplands north of Big Flats and flow out over a broad terrace north of the Chemung River. These streams maintain large fans where they leave the adjacent uplands. Most other streams decending from the uplands end on active flood plains, where their load is removed as fast as it is deposited.

The Recent deposits range in thickness from a few to perhaps several tens of feet. They probably overlie Pleistocene deposits in many places. Alluvial soils and Sols Bruns Acides are the dominant soils developed on the Recent deposits; the soils are commonly members of the Tioga-Barbour-Chenango-Tunkhannock association (pl. 5).

DISCUSSION AND INTERPRETATION OF THE GEOLOGIC HISTORY

DEVELOPMENT OF PLEISTOCENE LANDSCAPE

The landscape of the Elmira-Williamsport region conforms to the bedrock lithology and its structure, rather than to any ancient peneplain. The postulation of such an ancient erosion cycle is unnecessary to explain any topographic feature. Tarr (1898), who was critical of Davis' peneplain hypothesis, did not reconize peneplains in this region (Williams, Tarr, and Kindle, 1909), but most others have (Campbell, 1903; Fridley, 1929; Von Engeln, 1932; Cole, 1941). The apparent accordance of summits in some areas reflects the bedrock geology and results from long continued erosion of rocks of different resistance; it is essentially unrelated to the activity of larger streams that flow in narrow valleys many hundreds of feet deep (Denny, 1956b, p. 43-51). Of course, many prominent topographic features such as the through valleys containing the Finger Lakes and their hanging tributary valleys are commonly attributed to glaciation, but such features are outside the scope of this paper.

Any reconstruction of the landscape as it existed in early Pleistocene time is speculative, but the region in pre-Sangamon time was probably at least as rugged as it is today. Thus, in Potter County, the major valleys were as deep then as now (Denny, 1956b, p. 19). Similarly, in the Elmira-Williamsport region, some of the streams have cut through high areas that seem to be drainage divides dating from pre-Sangamon time. For example, from Ansonia, about 6 miles west of Wellsboro, Pa., Pine Creek flows southward for many miles in a deep gorge known locally as Pennsylvania's "Grand Canyon." Pine Creek rises in central Potter County and flows eastward to Ansonia, where it turns abruptly southward (pl. 3). However, a broad, open valley extends eastward from Ansonia into the northward-draining valley of the Tioga River. The divide between the Pine Creek and Tioga drainages is a swamp on the floor of this broad valley, just north of Wellsboro. The gorge probably originated in the following manner (Fuller, 1903a).

The headwaters of Pine Creek were probably once part of the Tioga drainage, entering it by way of the broad valley east of Ansonia. However, ponded water in the headwaters, dammed by ice to the north, overflowed southward across the lowest available point on the drainage divide, southwest of Wellsboro near Harrison Lookout on the east side of the present gorge. The overflow cut down the divide, and subsequent erosion of both glacial and nonglacial origin has produced the present canyon. Since gravel dating from pre-Wisconsin time occurs in the valley of Pine Creek south of the Wisconsin drift border, the cutting of the gorge probably antedates the Illinoian stage (Denny, 1956b, p. 51). The Canisteo River gorge, west of Corning, N.Y., the gorge of the Chemung River, just west of Elmira, and other drainage features described by Tarr (Williams, Tarr, and Kindle, 1909) also contain Wisconsin drift and are of pre-Wisconsin age; presumably their origin is also due to glaciation. These large gorges probably date from early Pleistocene time (Muller, 1957).

ORIGIN OF PRE-WISCONSIN DRIFT

Little is known about the extent, the age, or the origin of the pre-Wisconsin drift in the Elmira-Williamsport region. In fact, the positive identification of any of the strongly weathered materials as drift is difficult. We did not map the extent of pre-Wisconsin drift in any part of the region. Although two or more pre-Wisconsin drifts (Illinoian and Jerseyan) have been recognized in Pennsylvania and in New Jersey (Salisbury, 1902; Leverett, 1934, MacClintock, 1940), we could not find a suitable basis for such a distinction in this region (see also Peltier, 1949, p. 30; Denny, 1956b, p. 18–19). There is no stratigraphic evidence nor any difference in weathering indicative of more than one pre-Wisconsin drift. Although the depth of weathering of the pre-Wisconsin drift, more than 30 feet at one exposure (p. 30), is much greater than that of Illinoian drift in the Middle West, the authors believe that the old drift in the Elmira-Williamsport region is probably of Illinoian age, as the greater depth of weathering is probably related to the gravelly, porous nature of the drift and the hilly to mountainous region in which it occurs.

Little is known about the ice sheet that laid down the pre-Wisconsin drift. The pre-Wisconsin ice near Williamsport, Pa., extended about 30 to 40 miles farther south than the Wisconsin ice sheet (Leverett, 1934, pl. 1) but farther west, in north-central Pennsylvania, the pre-Wisconsin drift was apparently completely overridden by Wisconsin ice. With so few facts, we can only speculate that the area of nourishment of the pre-Wisconsin ice sheet was perhaps in a different location than during Wisconsin time. But it is known that the pre-Wisconsin ice encroached on a landscape rather like that of today, filling valleys with outwash now largely removed. In Potter County there was a pre-Wisconsin valley fill more than 100 feet thick (Denny, 1956b, p. 19).

SANGAMON INTERGLACIAL STAGE

The pre-Wisconsin drift and associated deposits doubtless were extensively eroded and greatly weathered during Sangamon time. Although we believe that all the soils in the region are of Recent age, some of them, especially the Red-Yellow Podzolic soils, have some features inherited from such pre-Wisconsin weathering. The nature of these inherited characteristics and their significance is discussed on pages 25–33 and 51–53.

ADVANCE AND DISAPPEARANCE OF THE WISCONSIN ICE SHEET

Little is known about the advance of the Wisconsin ice sheet to its maximum extent. Because the drift in the southern part of the region contains a few fragments of red, strongly weathered rock, the ice probably advanced over remnants of a reddish weathered zone of Sangamon age. When the ice reached its maximum extent in Pennsylvania, it had a relatively straight and steep front, the slopes ranged from 100 to 500 feet per mile, and the ice was 1,000 feet thick about 5 miles north of its terminus. Although the ice front was relatively straight, it curved around small irregularities in the bedrock surface, apparently where its thickness was little more than 200 feet (fig. 9).

The northwestward trend of the Wisconsin drift border suggests that the ice sheet moved southwestward, and this is the attitude of most of the striae in northeastern Pennsylvania and adjacent New York (pl. 3). Since the striae run athwart many of the major valleys, at any point except those close to the drift border, the last movement of the ice sheet—that which formed the striae—must have taken place when its thickness was sufficient to permit it to flow without regard for the local topography, that is many hundred feet, and, locally, more than 1,000 feet.

The Wisconsin ice sheet did not build a prominent moraine at its drift border, nor are there extensive moraines in any part of the region south of the Valley Heads moraine of Fairchild. Perhaps the ice sheet stood at its line of maximum extent for only a short time, and wastage was dominant over nourishment continuously thereafter until the building of the Valley Heads moraine. Exposures of till on water-laid drift are rare.

Glaciofluvial deposits are relatively scarce within 15 to 20 miles north of the drift border. Kame deposits are present farther north, especially in areas that drain northward or eastward. These deposits accumulated in association with wasting glacial ice, presumable stagnant, but the location and extent of such stagnant ice is conjectural (Goldthwait, 1938; Antevs, 1939; Lougee, 1940; Flint and Demorest, 1942; Rich, 1943; Jahns, 1953). For example, the streams that built the kames in the valley of Seeley Creek near Jobs Corners, south of Elmira, probably flowed northward toward the Chemung River valley along the edge of a body of ice that was about 10 miles long. The east-west dimension may have been only a few miles, especially if the ice edge was wasting back northeastward. There is no evidence with which to tie this local event to what was happening elsewhere in the area at the same time. The large kames on the uplands west of Bath, N.Y., near the border of the Binghamton drift of MacClintock and Apfel (1944) between the Canisteo and Cohocton Rivers (pls. 1, 3) can be ascribed to either active or to stagnant ice.

Rather extensive kame deposits were emplaced during deglaciation. However, lake deposits are scarce except for those in the Elmira region, which apparently antedate the last glaciation, and those north of the Valley Heads moraine, which are outside the region considered here.

The problem of dating the colluvium reflects the difficulty of appraising the rates of erosion and deposition during Recent time. In Virginia, for example, far south of the drift border, Hack (oral communication) has found colluvium almost identical with that found at the base of steep slopes in the shale uplands near Hughesville, Pa., along the Wisconsin drift border. The colluvium in Virginia is essentially unweathered, apparently accumulated where a stream undercut the base of a shale hill, and seems unrelated to Pleistocene events. However, in Potter County, Pa., west of the region considered here, Denny (1956b) decribed periglacial deposits that are essentially the same as the colluvium of the present report. In this county the surficial mantle is relatively thick and continuous within about 10 miles of the drift border. Bedrock outcrops are scarce even along streams. However, farther south of the drift border, bedrock outcrops are more numerous and the surficial mantle seems to be thinner. The extent and thickness of the periglacial deposits in Potter County suggest that they are related to the presence of an ice sheet at or near the border of the Wisconsin drift and are not the result of processes active during Recent time. By the same token, rather numerous outcrops of pre-Wisconsin paleosol suggest that a weathered mantle almost completely covered the region as late as Sangamon time and has since been largely removed by colluvial processes.

The colluvium in the Elmira-Williamsport region is probably in large part of Wisconsin age. Much of the colluvium is now being dissected, the underlying drift is unweathered, and the colluvium is apparently more extensive south of the Valley Heads moraine than north of it. The colluvium is dominantly the result of mass movement during deglaciation. The almost complete absence of involutions, ice-wedge structures, or similar features in stratified drift beneath or adjacent to the colluvium indicates that permafrost was not present. The only exception is a 5-foot layer of contorted beds of gravel and sand occurring within a sequence of horizontally bedded sand and gravel exposed in a borrow pit on the north side of the Chemung River about 3½ miles east of Corning (pl. 1, loc. 17). These contortions could have been caused either by overriding glacial ice or slumping when an adjacent mass of ice melted, rather than by permafrost.

The bedrock clearly influences the distribution and character of the colluvium. For example, bouldery rubble (block fields), are restricted to areas of massive sandstone or quartzite. Block fields are commonly attributed to a glacial environment of vigorous frost action and sparse vegetation. Some block fields, however, include strongly weathered, rounded and irregular blocks (Smith, 1953) which rest on strongly weathered mantle. Such block fields probably have a long and complex history.

The origin of the Valley Heads moraine is not completely understood. The moraine and its associated valley train seem to be closely related to the bedrock topography. The prominent segments of the moraine (pl. 1) lie near the south ends of straight, narrow valleys near the presumed location of a buried bedrock divide, and on the adjacent uplands the moraine commonly lies against or at the base of northward-facing escarpments. Probably the deep Finger Lakes valleys, reaching below sea level and extending from the Ontario plains southward into Pennsylvania, were at one time occupied by tongues of actively moving ice that extended many miles south of the places where the ice sheet crossed the adjacent uplands. Relatively rapid movement and rapid melting of the ice in the Finger Lakes valleys might cause deposition of thick drift in these valleys. In addition where the ice sheet rode up over the escarpments on the uplands between the lakes it may have deposited more drift than north or south. Hence, under this hypothesis which we favor, the Valley Heads moraine is a concentration of drift but does not necessarily mark a long-occupied terminus of the ice sheet. Lake sediments, north of the moraine outside the region here considered, accumulated in lakes dammed between the moraine and an ice sheet to the north. Deep bedrock gorges on the sides of some of the through valleys near the moraine were cut by ice-marginal streams from the adjacent ice sheet. But streams draining the lakes north of the moraine may have cut some of the bedrock gorges as well as drift-walled channels through the moraine. The valley train, now dissected, that heads in the moraine and extends southward for many miles could have been built by overflow from the lakes north of the moraine, and the sediments could have been derived by erosion in stream channels. However, it is perhaps more likely that melting ice in the moraine was the major source of abundant debris-laden water that built the valley-train deposits. If this is true, it is the best argument for the hypothesis that the moraine does mark an ice terminus that was maintained for some time.

The abundance of valley-train deposits derived from the Valley Heads moraine as compared to their paucity at the Wisconsin drift border may reflect differences in the durability of the rocks of which the deposits were composed. The pebbles in the Valley Heads moraine, for example, include resistant quartzite, gneiss, and chert, as well as dense limestone, whereas the rocks in the drift farther south are soft sandstone, siltstone, and conglomerate that do not easily survive transport. In addition, by no means all the glaciofluvial deposits in the through valleys that drain from the Valley Heads moraine were derived from it. Kame deposits, laid down adjacent to glacial ice, are mapped in the Susquehanna Valley in New York and along the Chemung River (pl. 1). The valley-train terraces near Chemung, N.Y., rise steeply upstream (pl. 4) and may have been laid down when the edge of an ice sheet was nearby, an interpretation essentially the same as Peltier's for the terraces near the New York State line (Peltier, 1949, figs. 30, 31, and table 35).

We believe that the disappearance of the Wisconsin ice sheet from the Elmira-Williamsport region may have proceeded at a gradually increasing rate. At first, wastage was relatively slow along a nearly straight ice front; only small volumes of water-laid drift were left behind, and mass movement and other weathering processes were actively producing colluvium. As time went on, more and more glaciofluvial deposits were formed, possibly because of more rapid melting. By the time most of the area south of the line of the Valley Heads moraine was uncovered, the ice sheet had a more sinuous margin, tongues of ice extended down the larger valleys from which large streams of melt water emerged, and the rate of formation of colluvium showed a marked decrease.

POSSIBLE SUBDIVISIONS OF THE WISCONSIN STAGE

The Wisconsin drift border as mapped by us is similar to the terminal moraine mapped by H.C. Lewis and G. F. Wright (Lewis, 1884), who were the first to systematically trace the limit of the glaciated area across Pennsylvania. The only other detailed study of the Wisconsin drift border is by Frank Leverett, whose report published in 1934 includes a summary of previous work. While Lewis and Wright were mapping the terminal moraine, T. C. Chamberlin (1883) was engaged in tracing another belt of moraine across the Eastern United States, a belt that he called the "terminal moraine of the second glacial epoch." R. S. Tarr and co-workers studied this moraine in the vicinity of the Finger Lakes about 50 years ago (Williams, Tarr, and Kindle, 1909); and H. L. Fairchild in 1932 named it the Valley Heads moraine.

During the first half of the present century the glacial deposits of Wisconsin age in central United States were divided into substages by various geologists, and there was some agreement among them as to the correlation of the deposits from place to place (Flint, 1947, p. 210–214). In Northeastern United States, however, the deposits of Wisconsin age were not readily divisible into stratigraphic units, and the few attempts at correlation with Central United States were of questionable value (Taylor, 1925; Goldthwait, 1922). The moraines in the Erie basin and in the western part of the Ontario basin were described by Frank Leverett (1902), but his mapping did not extend east of the Genesee River. In 1941, Paul MacClintock and E. T. Apfel (1944) studied the drifts near Salamanca, Cattaraugus County, N.Y., and on the basis of lithologic, stratigraphic, and topographic evidence, they recognized three drifts of Wisconsin age: Olean, Binghamton, and Valley Heads, in order of decreasing age. These stratigraphic subdivisions of the Wisconsin stage have been recognized in Potter County and in other parts of Pennsylvania, in New York, and in New Jersey (table 1).

We believe that all the drift in the Elmira-Williamsport region south of the Valley Heads moraine is of Olean subage. The Olean drift is early Wisconsin, possibly a pre-Farmdale and post-Sangamon substage. The Binghamton and Valley Heads drifts are thought to be of post-Farmdale age; perhaps the Binghamton drift border marks the maximum advance of the ice sheet that built the Valley Heads moraine.

OLEAN SUBSTAGE OF MacCLINTOCK AND APFEL

The drift at the limit of the Wisconsin stage in the area north and east of Salamanca, Cattaraugus County, N.Y. (pl. 3), was designated Olean by MacClintock and Apfel (1944). Their reasons for distinguishing Olean drift from a younger Wisconsin drift west of Salamanca, which they named Binghamton, are summarized on page 22. The Olean drift, believed by them to be the oldest drift of Wisconsin age in the Salamanca area, was traced southeastward to Potter County, Pa., and Denny (1956b) mapped it to the west edge of the Elmira-Williamsport region. Peltier (1949) correlated the oldest Wisconsin drift he recognized in the Susquehanna Valley with the Olean of MacClintock and Apfel, and MacClintock (1954), recognized Olean drift overlain by younger drift in the Delaware Valley.

Olean drift is composed chiefly of material derived from the local bedrock; accordingly, its content of calcareous material or crystalline rocks from Precambrian terrane is low. The drift is thin, and the landscape shows slight evidence of glaciation. The depth of leaching ranges from 10 to 20 feet.

The Olean drift is older than any other Wisconsin deposit in the region, but its correlation with other areas is uncertain. It has been variously assigned an early Wisconsin, Iowan, or Tazewell age by various authors, as shown in table 1. The depths to which Olean drift has been leached are generally greater than in the Wisconsin drift of the Middle West; yet Olean drift lacks the strongly weathered aspect characteristic of pre-Wisconsin drift in the Susquehanna Valley previously described on page 5 (Denny, 1956b, p. 19).

The deposits exposed in a streambank at Otto, Cattaraugus County, N.Y., in the Olean drift north of Salamanca (fig. 11 and section of surficial deposits, p. 22), contain a layer of peat that has a radiocarbon age of more than 35,000 years (Suess, 1954, sample W-87). The peat (fig. 11, unit 3) rests on till (1) and on silt, sand, and gravel (2) that MacClintock and Apfel (1944) believe were deeply weathered before deposition of the peat. They assign the till and associated sediments (1, 2) to Illinoian age, and the weathering and deposition of peat (3) to Sangamon time. We failed to find evidence of weathering of the upper part of the till (1) beneath the peat, and we found a thin layer of peaty silt in the Olean gravel (4) about 8 feet above its base. We believe that the Illinoian till of MacClintock and Apfel (1) is of Olean subage. The peat (3) was formed in a bog in front of the Olean ice

TABLE. 1—*Correlation of drifts of Wisconsin age recognized by various workers in parts of New York and Pennsylvania*

MacClintock and Apfel (1944)	Peltier (1949)	Flint (1953)	MacClintock (1954)	Denny (1956a)	Denny (1956b)	Denny and Lyford (this report)
Region near Salamanca, N.Y.	Susquehanna Valley	Northeastern United States	Northeastern United States	Elmira, N.Y., region	Potter County, Pa.	Elmira-Williamsport region, New York and Pennsylvania
Valley Heads-Cary	Valley Heads	Cary(?)	Cary	Later Wisconsin	Absent	Wisconsin; possibly a post-Farmdale substage. MacClintock's and Apfel's Binghamton drift border may be the maximum advance of the ice that built the Valley Heads moraine.
Binghamton-Cary	Binghamton	Cary(?)	Cary	Later Wisconsin	Absent	
Olean-Tazewell	Olean	Iowan-Tazewell complex(?)	Tazewell	Early Wisconsin	Olean-Iowan(?)	Early Wisconsin(?); possibly a pre-Farmdale-post-Sangamon substage.

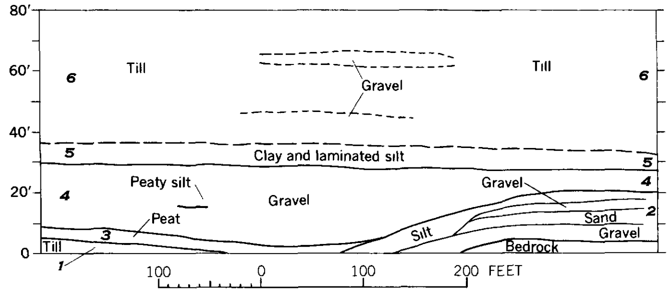


FIGURE 11.—Exposure at Otto, Cattaraugus County, N.Y. (pl. 3, loc. 5). Stratigraphic units are described on this page. MacClintock and Apfel interpret the section as follows: Binghamton till (6) overlying Olean gravel (4) separated by clay and silt (5) deposited in a lake in front of advancing Binghamton ice sheet. Gravel (4) overlies peat (3) of Sangamon(?) age that rests on till (1) and on silt, sand, and gravel (2) of Illinoian age. The peat (3) has a radiocarbon age of more than 35,000 years (Suess, 1954, sample W-87). Diagram modified from MacClintock and Apfel (1944, fig. 3). Vertical exaggeration about 3 times.

sheet shortly after it had deposited the underlying till (1). The bog was then buried by outwash from the Olean ice sheet. If the drift below the peat is Olean and if the radiocarbon age is correct, the Olean drift may be a pre-Farmdale and post-Sangamon drift, perhaps related to that which may be present at Sidney in Shelby County, Ohio (Flint and Rubin, 1955; Forsyth and LaRocque, 1956; Forsyth, 1957; Muller, 1957).

BINGHAMTON SUBSTAGE OF MacCLINTOCK AND APFEL

MacClintock and Apfel (1944, p. 1152–1153) based their distinction between the Binghamton and Olean drifts on a lithologic contrast west and east, respectively, of Salamanca, N.Y. West of Salamanca, the drift contains 12 to 20 percent pebbles of limestone and many pebbles of igneous rock; east of Salamanca, the drift contains only a few such pebbles. This change indicates that the source of the two drifts was different. The difference in age of the two drifts was suggested by the exposure at Otto, north of Salamanca, where typical Olean drift is overlain by typical Binghamton drift (fig. 11).

MacClintock and Apfel suggested the following interpretation: The Olean ice approached Salamanca from the northeast and deposited drift containing many sandstone pebbles and only a few pebbles of limestone or igneous rock. After the Olean ice had largely disappeared, the Binghamton ice sheet advanced into the region from the north and northwest and deposited drift that contained many fragments of limestone and igneous rock in addition to sandstone pebbles. "This notable withdrawal, rearrangement, and readvance of ice lobes is sufficient evidence to constitute an important demacation within the Wisconsin" (MacClintock and Apfel, 1944, p. 1162). The Binghamton drift border was mapped by MacClintock and Apfel (1944, pl. 1) from Salamanca to the Genesee River valley and was traced by them in reconnaissance eastward to Binghamton, N.Y. Thus, these authors, recognized three Wisconsin drifts in the Elmira-Williamsport region.

Section of surficial deposits exposed at Otto, Cattaraugus County, N.Y. Exposure in east bank of South Branch Cattaraugus Creek, Cattaraugus 15-minute quadrangle, about 0.2 mile south of Otto (pl. 3, loc. 5). Stratigraphic relations shown in figure 11.

[After MacClintock and Apfel, 1944]

	Thickness (feet)
6. Till, gray, calcareous; includes several beds of gravel; contains many pebbles of limestone and of igneous rock	50–60
5. Clay, red, laminated; contains calcareous gray silt	5–8
4. Gravel, medium- to coarse-grained, horizontal stratification; contains lens of peaty silt and very few pebbles of limestone or igneous rock	8–25
3. Peat and peaty silt, brown, dense, compact	3–4
2. Silt, sand, and gravel, in part calcareous, in part noncalcareous; contains boulders of igneous rock, but no fragments of limestone	12–16
1. Till, blue-gray, noncalcareous; includes many fragments of igneous rock; base not exposed	4

We believe that only two Wisconsin drifts are present in the Elmira-Williamsport region—that the Binghamton drift is absent. Our interpretation, given on plate 3, places the drift that is south of the Valley Heads moraine in the Olean substage. The Binghamton drift border mapped by MacClintock and Apfel (1944) appears to us to be a gradational change. If Binghamton drift is present in the region, it lies buried beneath or incorporated in the Valley Heads drift.

The southward change in drift lithology is illustrated by data from kames containing many erratics of limestone and igneous rock that occur near Jobs Corner, Tioga County, Pa., and to the north along Seeley Creek. To the west, in the Tioga River valley, kames with abundant erratics are also found as far south as Tioga Junction (fig. 7). In both valleys most of these kames were called Binghamton drift by MacClintock and Apfel (1944). The gradual change is illustrated by the graphs of figure 12, where the content of erratic pebbles in these kames is plotted against the distance southwest from the Chemung Valley. In addition, all the till on the uplands south of the Chemung River is composed chiefly of locally derived material deficient in erratics. Even farther north, between the Chemung River and the Valley Heads moraine, most of the drift on the uplands is thin and erratics are scarce, a fact noted by Tarr 50 years ago (Williams, Tarr, and Kindle, 1909). Such drift is indistinguishable from Olean drift farther south. Large areas east of Cayuta Creek, Tioga County, N.Y., are also mantled by drift essentially free of erratic pebbles.

Using depth of leaching as a criterion of age, MacClintock (1954) recognized a southern area where gravel

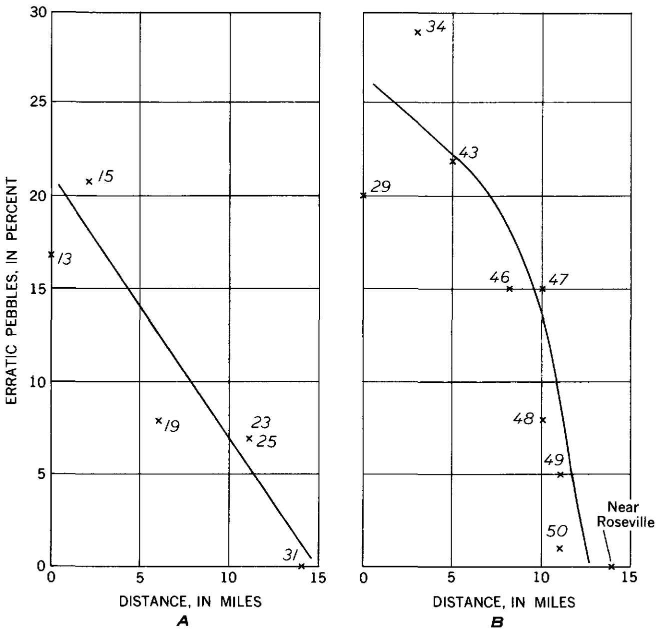


FIGURE 12.—Graphs showing change in content of erratic pebbles in kame deposits southward from the Chemung Valley. Graph A runs southwest from near Corning, N.Y. (fig. 7, loc. 13), and graph B from near Elmira, N.Y. (fig. 7, loc. 29). Numbers refer to localities shown on figure 7.

is leached 11 to 13 feet (Olean substage) and a middle area where gravel is leached 5 to 8 feet (Binghamton and Valley Heads substages). We do not believe that the distinction of MacClintock can be made in this region. Instead we find that the depth of leaching in the glaciofluvial deposits ranges from about 2 to more than 20 feet. Although there is a gradual increase in depth of leaching from north to south (fig. 7), the increase is not uniform nor can a line marking an abrupt change be drawn. Rather there seems to be a slight increase in the average depth of leaching with a decrease in the content of pebbles of limestone and dolomite (fig. 8). Figure 13 illustrates the changes that take place along a traverse southward from the Valley Heads moraine near Elmira. The traverse includes gravels of the three substages, Valley Heads, Binghamton, and Olean, recognized by MacClintock and Apfel in 1944. The average depth of leaching of the Binghamton is no different than the Olean, although the amount of limestone varies considerably. The division of these kame deposits into substages on the basis of depth to free carbonates yields results that are inconsistent with a division based on lithology, such as was used by MacClintock and Apfel, and requires a geographic distribution of the drift that is unlikely. Other similar examples could be cited. Depth of leaching is not a valid basis for assigning more than one age to these gravels.

The differences in the soils throughout the entire region, excluding those on strongly weathered parent materials of pre-Wisconsin age, are slight and are due to differences in lithology and in drainage, rather than to age of parent material. Most of the soils seem to be in equilibrium with the present environment and do not contain features inherited from the Pleistocene.

A greater contrast in topographic expression of the drift exists north and south of the Valley Heads moraine than is found on either side of the Binghamton drift border mapped by MacClintock and Apfel (1944, fig. 1). South of the moraine, topographic expression of glaciation is unobtrusive and morainal topography is scarce, while to the north they are obvious. Thus, the topography on either side of the Binghamton drift border, which lies south of the moraine, is about the same, except for a few large kames at or near the border. Topography is not a means of subdividing the drift south of the Valley Heads moraine in this region

In Potter and Tioga Counties, Pa. which are both within and outside the glaciated area, a characteristic landform consists of hills with long, smooth slopes that meet narrow flood plains (Denny, 1951). Such a smooth landscape is not so well developed in the region east of the Susquehanna River, where there are also numerous small lakes, chiefly on the uplands. Because of this contrast, it was once thought that perhaps the Olean drift of MacClintock and Apfel might be divisible

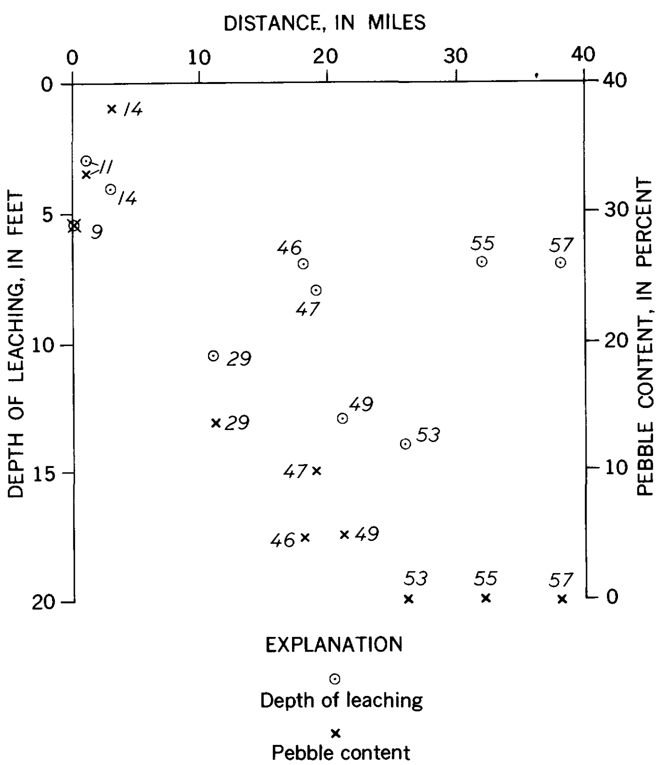


FIGURE 13.—Graph showing change in depth of leaching and in content of calcareous pebbles in glaciofluvial deposits along a traverse southward from the Valley Heads moraine north of Elmira. Numbers refer to samples of glaciofluvial deposits shown in figure 7.

into an eastern Olean drift and a somewhat older western Olean drift, but fieldwork has failed to demonstrate this supposition. Many of the small lakes appear to be in rock basins and do not have conspicuous drift dams (MacClintock, oral communication). The topographic differences between Tioga County, Pa., and the area to the east may be the result of differences in bedrock.

In the Susquehanna Valley in New York west of Binghamton, MacClintock and Apfel (1944) placed the Binghamton drift border along the south side of the valley, nearly parallel to the trend of the striae in that part of the region (pl. 3). Because a drift border generally crosses rather than parallels striae, we believe that the last ice to move across this part of the region was the Olean, whose drift border crosses northeastern Pennsylvania in a southeasterly direction.

Binghamton drift is not present in the Elmira-Williamsport region. We suggest that the Binghamton drift recognized in the Salamanca area was laid down by the same ice sheet that built the Valley Heads moraine. East of the region, the moraine turns northward around the southeast edge of the Finger Lakes area (pl. 3) and passes north of Cortland and thence eastward to at least a few miles south of Utica. Between Cortland and Oneonta, N.Y., at the west edge of the Catskill Mountains, there is a large area of drift, identified as Binghamton by MacClintock and Apfel (1944), where there are many large kames, some with a considerable amount of limestone and dolomite pebbles. We have not attempted to draw any boundary between this drift and the Olean drift of the Elmira-Williamsport region. Subsequent work by Moss and Ritter (1962) in the region between the Finger Lakes and the Catskill Mountains demonstrate that there is no compelling evidence in that region for a separate Binghamton drift.

Till and kame deposits in the Susquehanna and Chemung Valleys lithologically resemble the Binghamton of MacClintock and Apfel and demand an explanation. The following hypothesis has been offered by Denny (1956a). Valley-train deposits (pls. 1, 3) in the present through valleys contain abundant erratics that were carried more than 100 miles from their source; therefore, similar deposits may have been present in front of the Olean ice sheet as it advanced. The Olean ice sheet moved westward down the Susquehanna River Valley and across the adjacent uplands, picking up material from the earlier valley train that contained many erratics of limestone, dolomite, and metamorphic rock. Thus, the till and kame gravel in the westward-trending Susquehanna River valley contain many erratics because there the ice moved parallel to the earlier valley train. Elsewhere, the westward-moving ice crossed northward-trending valleys that are deeply incised below the uplands, and the ice was not able to pick up and carry forward many pebbles from the earlier valley fill. Therefore, the drift on the uplands adjacent to the southward-trending through valleys north of the Susquehanna River in New York does not contain as many as erratics as the drift on the uplands adjacent to the westward-flowing river.

VALLEY HEADS SUBSTAGE OF FAIRCHILD

The Valley Heads moraine (Fairchild, 1932) is a relatively distinct topographic feature composed of material whose lithology is slightly different from that of the drift south of the moraine. The base is nowhere exposed, and the origin and significance of the moraine are not clear. Tarr (Williams, Tarr, and Kindle, 1909) and Von Engeln (1921, 1929) believed that the moraine was built by a minor readvance of the ice sheet during its retreat from the Wisconsin drift border. The fact that it occurs near the south end of the Finger Lakes valleys, near the Ontario-Susquehanna bedrock divide, and adjacent to northward-facing escarpments on the neighboring uplands suggests that its location is at least partly controlled by the bedrock topography.

Most geologists who have studied the moraine have concluded that it marks a significant retreat and readvance of the Wisconsin ice sheet (MacClintock and Apfel, 1944; Peltier, 1949; Holmes, 1952; Flint, 1953; MacClintock, 1954; Denny, 1956a), but the field relations are not compelling. The abundance of colluvium and scarcity of glaciofuvial deposits south of the moraine and the reverse situation north of it indicate a change in the conditions of erosion and deposition between Olean time and Valley Heads time. The Valley Heads drift is probably younger than the Farmdale substage (table 1), but its precise position in the Wisconsin section is as yet unknown.

SOILS

In this study, particular emphasis was given to the relation between surficial geology and soil formation. Although detailed descriptions of many soil series were made, only a few, illustrating some particular geology-soil relation, are presented in the following pages. Most of the discussion is in terms of great soil groups rather than series.

The soil map (pl. 5) shows the soil series grouped into associations which include one or more great soil groups. The great soil groups, defined in the glossary, conform to the classification used in the 1938 Yearbook of Agriculture (U.S. Dept. Agriculture, 1938), and amplified by Thorp and Smith (1949) and Baur and Lyford (1957). Some of the soils in the Elmira-Williamsport region, called intergrades, have properties intermediate between two great soil groups and are given a dual name, the first being that of the great soil group which they most nearly resemble. The soils that are most common in the area south of the Wisconsin drift border are described first, followed by the description of those found chiefly north of it.

Soils of the most extensive great soil group, Sol Brun Acide, occur principally on unweathered or weakly weathered parent material of all ages, including Recent alluvium. The parent material is generally acid or has a low carbonate content. Red-Yellow Podzolic soils are found only south of the Wisconsin drift border and are developed on deposits that contain a considerable proportion of strongly weathered material. Sols Bruns Acides are associated with them. Podzols are most common in the Appalachian Plateaus province on coarse-grained sandy deposits containing abundant quartz. Gray-Brown Podzolic soils occur chiefly on highly calcareous parent materials that are part of, or adjacent to, the Valley Heads moraine, but they also intergrade to Red-Yellow Podzolic soils south of the Wisconsin drift border, where the parent material consists of colluvial mixtures of weakly and strongly weathered materials. Low Humic-Gley and Humic-Gley soils develop where the water table is relatively near the surface throughout a large part of the year, as on long, smooth slopes. Organic soils occur in only a few areas and are of small extent.

In this region, most Sols Bruns Acides, Podzols, and Low Humic-Gley soils on silty deposits have B horizons that are conspicuously brittle and firm; such a horizon is called a fragipan (Carlisle, Knox, and Grossman, 1957). This feature is especially marked in the periodically water-saturated and mottled parts of moderately well, somewhat poorly, and poorly drained soils.

Table 2 is a key to most of the soil series found in the Elmira-Williamsport region. This key is based principally on three characteristics: soil parent material, great soil group, and natural drainage class. The fluctuation, duration, and height of the water table have a marked effect on soil development. Water-table variations cause conspicuous local differences in soils and account for the rather intricate soil patterns shown on some detailed soil maps (Cline, 1953).

RED-YELLOW PODZOLIC SOILS

Strongly weathered drift, colluvium, or residuum of pre-Wisconsin age, whether well, moderately well, or somewhat poorly drained, are the parent materials of the Red-Yellow Podzolic soils of the Allenwood association (pl. 5). The principal soils of this association—the Allenwood series—are developed on pre-Wisconsin drift. The soils on pre-Wisconsin residuum or colluvium are like the Allenwood series in many respects, but they are coarser textured throughout and are more friable in the lower part. Gray-Brown Podzolic soils intergrading to Red-Yellow Podzolic soils occur on mixtures of strongly weathered (pre-Wisconsin) and weakly weathered (Wisconsin or Recent) materials.

TABLE 2.—*Key to soil series of Elmira-Williamsport region, New York and Pennsylvania*

[Includes only those mentioned in text, and some related series]

Parent material	Great soil group (excessive to somewhat poor natural-drainage classes)	Natural-drainage class				
		Good or excessive	Moderately good	Somewhat poor	Poor (Low Humic-Gley or Humic-Gley soils)	Very poor (Humic-Gley soils)
Alluvium of Recent age						
Flood plains underlain by medium to moderately coarse textured deposits derived chiefly from fine-grained sandstone or siltstone:						
Grayish deposits:						
Acid throughout	Alluvial [1]	Tioga	Middlebury		Holly	Papakating.
Acid over nearly neutral substratum.	do	Chagrin	Lobdell		Wayland	Sloan.
Reddish deposits:						
Acid throughout	do	Basher	Barbour		Holly	Papakating.
Gravelly or channery deposits forming low terraces or alluvial fans:						
Grayish deposits, acid to depths of 5 or 10 feet, alkaline or weakly calcareous below.	Sol Brun Acide	Chenango	Braceville	Redhook		Atherton.
Reddish deposits, acid throughout.	do	Tunkhannock		do		Do.
	Podzol	Portage				

See footnote at end of table.

TABLE 2.—*Key to soil series of Elmira-Williamsport region, New York and Pennsylvania*—Continued

Parent material	Great soil group (excessive to somewhat poor natural-drainage classes)	Natural-drainage class: Good or excessive	Moderately good	Somewhat poor	Poor (Low Humic-Gley or Humic-Gley soils)	Very poor (Humic-Gley soils)
Glaciofluvial deposits of Wisconsin age						
Grayish deposits:						
Acid solum, alkaline or calcareous at depths of about 5 to 10 feet:						
Gravelly throughout	Sol Brun Acide	Chenango	Braceville	Redhook		Atherton.
Silt over gravel or other coarse-textured material.	do	Unadilla	Scio	do		Do.
Acid solum, gravelly throughout, calcareous at depths of 3 to 5 feet (tongues of leached material extend down into calcareous material below).	Gray-Brown Podzolic.	Howard	Phelps			
Nearly neutral or alkaline solum, gravelly throughout, calcareous at depths of 2 to 3 feet.	do	Palmyra	do			
Reddish deposits, generally acid to depths of more than 5 feet:						
Gravelly throughout	Sol Brun Acide	Tunkhannock		do		Do.
Silt over gravel or other coarse-textured material.	do	Vrooman				
Prominent segments of Valley Heads moraine of Fairchild [Only the dominant soils are keyed]						
Glaciofluvial deposits, grayish, gravelly throughout:						
Acid solum, calcareous at depths of 3 to 5 feet (tongues of leached material extend down into calcareous material below).	Gray-Brown Podzolic.	Howard	Phelps	Homer		Westland.
Nearly neutral or alkaline solum, calcareous at depths of 2 to 5 feet.	do	Palmyra	do	do		Do.
Lacustrine deposits:						
Very fine sand and silt, grayish:						
Acid throughout	Sol Brun Acide	Amboy	Williamson	Wallington		Birdsall.
Acid solum, calcareous at depths of 3 to 5 feet.	Gray-Brown Podzolic.	Dunkirk	Collamer	Canandaigua.		Colwood.
Silt and clay:						
Grayish:						
Strongly calcareous at depths of 2 to 3 feet.	do	Lucas		Fulton	Madalin	Toledo.
Moderately calcareous at depths of 2 to 3 feet.	do		Caneadea		Canadice	Lorain.
Reddish, strongly calcareous at depths of 2 to 3 feet.	do	Schoharie	Odessa		Lakemont	Poygan.
Till and lacustrine deposits, interstratified:						
Silt loam to silty clay, grayish, strongly acid near surface, calcareous at depths of 2 to 3 feet.	do	Nunda		Burdett	Romulus	Fonda.
	Sol Brun Acide	Canaseraga		Dalton		
Till and colluvium or both:						
Strongly acid near surface, grayish, medium textured, moderately calcareous at depths of 3 or 4 feet.	Gray-Brown Podzolic.	Lansing	Conesus	Kendaia		Lyons.

TABLE 2.—*Key to soil series of Elmira-Williamsport region, New York and Pennsylvania*—Continued

Parent material	Great soil group (excessive to somewhat poor natural-drainage classes)	Natural-drainage class				
		Good or excessive	Moderately good	Somewhat poor	Poor (Low Humic-Gley or Humic-Gley soils)	Very poor (Humic-Gley soils)
Till and colluvium of Wisconsin Age; north of Wisconsin drift border [Excludes soils listed previously under prominent segments of Valley Heads moraine]						
Chiefly from fine-grained sandstone and siltstone; medium to moderately fine texture, gravelly orchannery:						
No or slight textural change in deposits with depth; with brittle very firm (fragipan) horizons:						
Grayish deposits, strongly acid to depths of 3 or 4 feet, neutral or slightly acid to depths of 6 to 10 feet, calcareous below.	Sol Brun Acide	Bath	Mardin	Volusia	Cuyler	Chippewa.
Grayish deposits, strongly acid to depths of 2 or 3 feet, neutral or slightly acid to depths of 5 or 6 feet, calcareous below.	do	Valois	Langford	Erie	Ellery	Alden.
Reddish deposits, strongly acid to depths of several feet:						
Reddish sola	do	Lackawanna	Wellsboro	Morris		Norwich.
Yellowish-brown sola.	do	Cattaraugus	Culvers	do		Do.
With depth, increasingly channery, flaggy or stony, friable or firm, acid throughout, bedrock commonly at shallow depth:						
Grayish deposits	do	Lordstown	Arnot	Tuller		
Reddish deposits	do	Oquaga				
With depth, changes into gravelly, loose, stratified or nonstratified deposits (underlying material may be glaciofluvial deposits):						
Grayish deposits	do	Chenango				
Reddish deposits	do	Tunkhannock				
Chiefly from coarse-grained sandstone or conglomerate:						
Coarse texture, channery, flaggy, or stony, bedrock commonly at shallow depth:						
Yellowish-brown deposits	do	Dekalb				
Reddish deposits	Podzol	Dilldown				
Very coarse texture, channery, flaggy or stony, bedrock commonly at shallow depth:						
Grayish or yellowish deposits.	do	Leetonia				

TABLE 2.—*Key to soil series of Elmira-Williamsport region, New York and Pennsylvania*—Continued

Parent material	Great soil group (excessive to somewhat poor natural-drainage classes)	Natural-drainage class				
		Good or excessive	Moderately good	Somewhat poor	Poor (Low Humic-Gley or Humic-Gley soils)	Very poor (Humic-Gley soils)
Drift, colluvium, and residuum of pre-Wisconsin age; south of Wisconsin drift border						
Drift, colluvium, or alluvium of pre-Wisconsin age, unmixed or only slightly mixed with younger material:						
Yellowish-red deposits, moderately fine texture, with brittle very firm (fragipan) horizons.	Red-Yellow Podzolic.	Allenwood	Watson	Alvira	Shelmadine	Chippewa.
	do	(Dewart) [2]	(Warrior) [2]			
Drift, colluvium or alluvium mixed with younger material (chiefly colluvium):						
Medium to moderately fine texture, acid throughout:						
Yellowish or grayish deposits, friable to firm.	Gray-Brown Podzolic.	Hartleton				
Reddish deposits (color chiefly inherited from red bedrock), friable to firm.	Sol Brun Acide	Germania				
	Gray-Brown Podzolic.	Weatherly	Drums			
Residuum or colluvium:						
Relatively unmodified by mixing with younger deposits:						
Moderately coarse or coarse:						
Yellowish-red deposits, friable or firm throughout.	Red-Yellow Podzolic.	Undetermined [3]				
Yellowish-brown or brown deposits, friable or firm throughout.	Sol Brun Acide	Dekalb [4]				
	Gray-Brown Podzolic.	Clymer				
Reddish deposits, friable or firm throughout.	Podzol	Dilldown [4]				
	Sol Brun Acide	Lehew				
Yellowish-brown or brown deposits, with very firm brittle horizons.	Gray-Brown Podzolic.	----------	Cookport	----------	Nolo	
Very coarse textured, channery, flaggy or stony, bedrock commonly at shallow depth:						
Grayish or yellowish deposits, friable throughout.	Podzol	Leetonia [4]				
With 2 to 3 feet overburden of sandy colluvium of Wisconsin age.	do	Sweden				
Residuum or colluvium of Wisconsin or younger age; south of Wisconsin drift border						
Yellowish-brown channery deposits, friable throughout.	Sol Brun Acide	Weikert				
Reddish channery deposits, friable throughout.	do	Klinesville				

[1] These soils generally show some development and perhaps should be classed as Sols Bruns Acides.

[2] The Dewart and Warrior soils mapped in Union, Montour, and Northumberland Counties, Pa., seem to be identical with the Allenwood and Watson soils.

[3] These soils were not studied in detail. They bear some resemblance to the Allenwood series.

[4] These soils also occur on till or colluvium of Wisconsin age north of the Wisconsin drift border.

A soil survey of Lycoming County, Pa. (Stevens and others, 1928), completed in 1923, classified all freely drained soils on pre-Wisconsin drift as members of the Lycoming series, whereas the surveys of adjacent Union County (Bacon and others, 1946) and Montour and Northumberland Counties (Taylor and others, 1955), made in the late 1930's, established several new soil series that were thought to be related to the Illinoian and pre-Illinoian drifts described by Leverett (1934). The pre-Illinoian till, for example, was presumed to be the parent material of the Allenwood soil and the Illinoian till of essentially the same lithology that of the Dewart soil. Subsequent work has shown no consistent difference between these Red-Yellow Podzolic soils: the depth and degree of solum developed are the same, and the parent materials are strogly weathered to depths of as much as 30 feet, judging by the decay of coarse fragments. This similarity between soils developed on all drift of pre-Wisconsin age in the region is, of course, not independent evidence for the presence of only one pre-Wisconsin drift, because soil development depends on many factors besides the geologic age of its parent material.

Two profiles of Allenwood soil developed on till are described and discussed on the following pages; one profile is from a forested area on the uplands near Hughesville, Pa., the other is from a deep road bank along Route 15 at Penny Hill, near Montgomery, Pa.

ALLENWOOD SOIL ON UPLANDS NEAR HUGHESVILLE, LYCOMING COUNTY, PA.

Allenwood stony silt loam, a Red-Yellow Podzolic soil developed on pre-Wisconsin till, is typically yellowish red to dark red and occurs in small areas on the uplands east of Hughesville between Muncy and Little Muncy Creeks (pl. 1, loc. 33), just south of the Wisconsin drift border. In the particular area studied, the top of a broad ridge, the soil covers about one-half acre within an oak forest consisting predominantly of chestnut oak. The till, a dark-red gravelly loam, contains subrounded striated rock fragments, mostly siltstone weathered throughout and mottled red, yellowish red, brown, or gray brown (*10R* 4/6, *5YR* 5/6, 7.5*YR* 5/6, and 2.5*Y* 5/2). Many of the fragments can be broken by hand. The pebbles of red sandstone (9–12 percent) and of conglomerate and very coarse grained sandstone (5–13 percent) in the till may be erratics derived from the Catskill and Pocono formations to the north (pl. 2).

In the soil-profile description which follows, a prime (′) used with a horizon letter designates a micropodzol horizon (for example, A'_2).

Allenwood stony silt loam

Horizon	*Depth (inches)*	*Profile description*
A_0	0–1½	Forest floor, consisting of leaves and needles in various stages of decay. A_{00}, A_{01}, A_{02}, and A_{03} horizons can be distinguished. Casts and tunnel excavations of arthropod fauna occur as discontinuous A_1 horizons.
A'_2, B'_2	0–1	These are the very thin horizons of a micropodzol. The A'_2 horizon is gray (10*YR* 6/1, moist) gravelly silt loam or loam about ¼ inch thick consisting of a mass of intertwined grayish fibrous fungal hyphae mixed with yellowish-brown and gray sandy material. The B'_{21} horizon is dark yellowish-brown (10*YR* 4/4, moist) channery silt loam; weak, very fine, granular structure; matted with fungal hyphae.
A_2	1–3	Reddish-brown (2.5*YR* 4/4, moist) gravelly silt loam; very weak, granular structure; friable; horizontal roots numerous; many fine pores; matted with fungal hyphae.
A_3	3–4	Dark-yellowish-brown (10*YR* 5/4, moist) gravelly silt loam; otherwise like the A_2 horizon.
B_{11}	4–6	Strong-brown (7.5*YR* 5/6, moist) gravelly silt loam, weak, coarse, subangular blocky structure; very firm when dry; roots common, few fine pores.
B_{12}	6–10	Yellowish-red (5*YR* 5/6, moist) silt loam; otherwise like the B_{11} horizon.
B_{21}	10–16	Yellowish-red (5*YR* 4/8, moist) loam or clay loam; strong, medium, subangular blocky structure; very firm; few discontinuous clay skins, exterior of peds duller colored than interior; abrupt boundary.
B_{22}	16–22	Intermediate between yellowish-red (5*YR* 4/8) and dark-red (2.5*YR* 3/6, moist) clay loam; otherwise like B_{21} horizon. Material cut with a knife exhibits a few soft clayey strongly weathered fragments from sand size up to ¼ inch in diameter.
B_{23}	22–36	Yellowish-red (5*YR* 4/6, moist) and dark-red (2.5*YR* 3/6) gravelly clay loam; strong, very coarse, blocky and prismatic structure; extremely firm; roots common between peds; many fine pores; interior of peds is dark red, exterior is yellowish red; very coarse blocks are made up of moderate or weak, medium, angular blocks; discontinuous clay skins on ped surfaces; pores are glazed with clay, many soft clayey ⅛- to ½-inch pale-yellow fragments inside of peds; coarse skeleton about 10–20 percent by volume; gradual boundary.

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Allenwood stony silt loam—Continued

Horizon	*Depth (inches)*	*Profile description*
B_{31}	36–46	Dark-red (2.5*YR* 3/6, moist) gravelly loam; massive; extremely firm and dense; a few very fine pores lined with clay; black, finely pitted manganese dioxide(?) skins are conspicuous, particularly bordering pebbles and stones; soft, dark yellowish-brown (10*YR* 4/4), strongly weathered fine channers and pebbles are also conspicuous when the material is cut or broken, much less so when crushed; subrounded, hard pebbles larger than ½ inch diameter make up 20 percent of the soil volume.
B_{32}	46–60	Same as B_{31} horizon except for greater depth.
C_1	60–70	Dark-red (2.5*YR* 3/6, moist) gravelly loam; very firm; clay skins rare and discontinuous; black streaks of manganese dioxide(?) are common, also some yellowish streaks; coarse skeleton 50–60 percent of volume consisting of angular, blocky fragments 3–4 inches in diameter; few, soft, weathered, clayey fragments.
C_2	70–88	Same as C_1 horizon except that texture is gravelly sandy loam.

This profile has several characteristics, such as color, texture, low base saturation, and strong weathering, which in combination are characteristic of Red-Yellow Podzolic soils. The B and C horizons are yellowish red and dark red with relatively high chromas of 6 or 8 and thus are somewhat more intensely colored than usual Gray-Brown Podzolic soils. The B_2 horizons are noticeably finer textured than the A_2 or C horizons, indicating accumulation of silicate clay, and base saturation is very low in all horizons (table 3). Strong weathering of the soil parent material is indicated by the high chromas, the reddish hues, the friable condition of most rock fragments, the relatively high content of kaolinite, and the presence of gibbsite in the clay fraction (table 4).

The thin micropodzol horizons are unrelated to the development of a Red-Yellow Podzolic soil. They occur on many soils in the Northeast, where they develop within 50 to 100 years under certain kinds of forest floors. Their development seems to be related to a lack of disturbance of the surficial inch or two of mineral soil.

The dark-red color of the lower B and C horizons, the occurrence on a gentle slope, and the strongly weathered coarse skeleton indicate that this particular remnant of pre-Wisconsin drift has not been modified by colluvial deposition in Wisconsin or younger time. A coarse-grained channery and flaggy colluvium mantles the adjacent slopes, but it does not extend down to this area. Although the abundant silt in the upper 16 inches of the profile might be aeolian or colluvial, it more likely was derived from weathering of siltstone fragments, which is most intense at or near the surface of the soil.

Because only remnants remain of the pre-Wisconsin drift that once covered the surrounding area, much material has probably been removed and, at the study area, an older (Sangamon stage?) weathering profile has been truncated. The presence of 22 percent kaolinite and 1 percent gibbsite in the clay fraction of the C_2 horizon (table 4) indicates that this horizon is in an older strongly weathered deposit. The Allenwood soil profile has been disturbed in some places by tree throw during recent years, but probably not below a depth of about 22 inches, because soft strongly weathered fragments of rock in the B and C horizons would have been destroyed by such mechanical disturbance. The Red-Yellow Podzolic soil itself gives no evidence as to the original thickness of the old drift.

On the ground surface are a few boulders of coarse-grained sandstone or conglomerate 1 to 2 feet in diameter and spaced about 50 feet apart that may be remnants of a once thicker cover of drift. These weathered boulders have a nearly white (8/0 or 9/0) rind as much as one-half an inch thick underlain by a red (2.5*YR* 5/8) layer. The weathered exteriors may have developed when the boulders were encased in the drift, perhaps in the solum of an ancient soil. The Allenwood soil developed after the boulders were concentrated on the surface. Present-day soil development is not the cause of the yellowish-red color of the till; the weathering of the parent material is older than the present soil.

ALLENWOOD SOIL ON PENNY HILL, LYCOMING COUNTY, PA.

Gray moderately calcareous pre-Wisconsin till—strongly weathered to a depth of about 30 feet— is found on top of Penny Hill, near Montgomery, Lycoming County, Pa. (pl. 1, loc. 35). On the crest of a broad eastward-trending ridge underlain by sandstone and siltstone, drift is exposed on part of the west side of a deep highway cut (along U.S. Highway 15) that runs northward through the ridge. The east bank of this cut and the northern part of the west bank are bedrock. The drift apparently fills a narrow gorge cut across the top of the bedrock ridge; the trend of this gorge is at a slight angle to the highway. Most of the weathered zone consists of strongly weathered reddish loam containing about 5 to 10 percent by volume of pebbles that are weathered siltstone, sandstone, and shale. Peltier (1949, fig. 8) showed that the weathered

TABLE 3.—*Partial chemical analysis and particle-size distribution of Allenwood stony silt loam near Hughesville, Lycoming County, Pa.*

[Analyses by U.S. Department of Agriculture, Soil Survey Laboratory, Beltsville, Md.]

Depth (inches)	Horizon	Particle-size distribution (percent by weight): Material <2 mm in diameter: Sand: Very coarse (2–1 mm)	Coarse (1–0.5 mm)	Medium (0.5–0.25 mm)	Fine (0.25–0.10 mm)	Very fine (0.10–0.05 mm)	Silt (0.05–0.002 mm)	(Clay <0.002 mm)	Other classes: (0.2–0.02 mm)	Other classes: (0.02–0.002 mm)	Whole soil: Gravel (>2 mm)	Textural class
0–¼	A′₂	----	----	----	----	----					----	
¼–1	B′₂	2.3	3.9	3.8	8.7	8.8	58.5	14.0	33.9	38.7	53	Gravelly silt loam.
1–3	A₂	1.6	3.2	3.6	8.0	8.3	61.6	13.7	35.4	39.2	30	Do.
3–4	A₃	2.6	3.0	3.4	7.3	7.8	59.6	16.3	33.4	38.5	35	Do.
4–6	B₁₁	3.6	3.4	3.4	6.8	7.7	57.1	18.0	31.8	37.1	21	Do.
6–10	B₁₂	3.4	3.7	3.5	6.8	7.2	53.6	21.8	29.6	35.2	16	Silt loam.
10–16	B₂₁	3.6	3.7	4.0	7.6	7.6	47.4	26.1	28.9	30.3	12	Loam.[1]
16–22	B₂₂	2.7	3.8	3.7	7.2	7.2	38.1	37.3	24.1	25.6	20	Clay loam.
22–36	B₂₃	3.2	4.8	4.7	9.1	8.8	37.7	31.7	28.4	23.5	34	Gravelly clay loam.
36–46	B₃₁	6.7	7.1	6.0	11.4	10.0	37.2	21.6	30.4	23.3	28	Gravelly loam.
46–60	B₃₂	6.3	6.8	5.5	10.6	9.5	39.8	21.5	32.1	23.4	28	Do.
60–70	C₁	7.2	8.3	7.0	13.4	12.0	36.4	15.7	35.8	20.7	57	Do.
70–88	C₂	9.4	10.4	8.2	15.5	12.9	32.1	11.5	37.4	16.9	47	Gravelly sandy loam.

Depth (inches)	Horizon	Extractable cations (milliequivalents per 100 g of soil <2 mm): Ca	Mg	H	Na	K	Cation exchange capacity[2]	Base saturation (percent)	pH	Organic carbon (percent)	Free iron oxides (percent)
0–¼	A′₂	0.5	0.8	24.6	0.1	0.3	26.3	6	3.9	11.20	----
¼–1	B′₂	.2	1.0	23.0	<.1	.2	24.4	6	3.9	4.42	2.3
1–3	A₂	.1	.5	10.8	.1	.2	11.7	8	4.4	2.26	1.8
3–4	A₃	.2	.2	8.1	<.1	.1	8.6	6	4.4	1.17	2.1
4–6	B₁₁	.1	.3	7.9	<.1	.1	8.4	6	4.3	1.20	2.4
6–10	B₁₂	.1	.3	7.9	.1	.1	8.5	7	4.4	.34	3.0
10–16	B₂₁	.1	<.1	9.7	<.1	.1	9.9	2	4.4	.17	3.7
16–22	B₂₂	<.1	.1	11.1	<.1	.2	11.4	3	4.8	.20	5.8
22–36	B₂₃	<.1	<.1	10.2	.1	.1	10.4	2	4.5	.18	5.5
36–46	B₃₁	<.1	<.1	6.9	<.1	.1	7.0	1	4.6	.04	4.8
46–60	B₃₂	<.1	<.1	6.9	.1	.1	7.1	3	4.7	.11	4.7
60–70	C₁	.1	.2	6.0	<.1	.1	6.4	6	4.8	.02	4.1
70–88	C₂	.1	.3	5.6	.1	.1	6.2	10	4.8	.01	4.2

[1] Close to clay loam boundary.
[2] The sum of the extractable cations is an estimate of the cation-exchange capacity.

zones in the drift extend laterally northward into the adjacent bedrock.

This drift has been considerably modified since it was strongly weathered, because when first visited in 1949 the strongly weathered loam till was overlain by a rubbly colluvium that was a mixture of weakly and strongly weathered rock fragments in a silt loam matrix. This colluvium apparently was derived from the bedrock that forms the top of the ridge and, without doubt, was emplaced after the underlying drift was strongly weathered. The rounded form of the ridge through which the highway is cut also clearly indicates that there has been considerable modification of slopes since the till was deposited (Peltier, 1949, p. 28).

The drift at Penny Hill has three weathering zones and is probably of Illinoian age. The unweathered till is an olive calcareous loam resembling in general appearance and lithology the calcareous till of Wisconsin age in central New York. The reddish strongly weathered till is like the parent material of the Red-Yellow Podzolic soils of the Allenwood series elsewhere in the region.

Size analyses of two samples of weathered till are given in table 5. The mineral composition of the clay fraction of selected horizons is included in table 4.

The profile description which follows was made in 1952 after the colluvium had been largely removed during highway construction and the top of the bank

TABLE 4.—*Mineral composition of clay fraction of selected horizons of Allenwood, Weikert, and Mardin soils*[1]

[Analyses by U.S. Dept. of Agriculture, Soil Survey Staff, Beltsville, Md. X, detected; M, moderate; A, abundant]

Depth sampled (inches)	Horizon	Mica (illite)	Vermiculite	Vermiculite and montmorillonite (interlayered)	Chlorite	Kaolinite (percent)	Gibbsite (percent)
Allenwood stony silt loam near Hughesville, Lycoming County, Pa.							
1–3	A_2	M	D			12	
16–22	B_{22}	M	A			22	Tr.
70–88	C_2	A	M			22	1
Allenwood silt loam at Penny Hill, Lycoming County, Pa.							
5–6	B_2 [2]	A	A			20	3
7–8	C_1	A	A			20	3
15–16	C_2	D				18	
16–17	C_3	D	M			15	
37–38	C_5	D			M	<10	
Weikert very channery silt loam near Hughesville, Lycoming County, Pa.							
3–12	A_2	M	A			12	
24–36	B_{21}	A	M	X		8	
56–66	B_{24m}	D	X			11	
66–78	CD	D	X			8	
Mardin channery silt loam, Mount Pleasant, Tompkins County, N.Y.							
½–¾	A_{12}	A	M [3]				
¾–1	A_{12}–A_2	A	A [3]				
1–2	A_2	A	A [3]				
2–16	B_{21}	A	A [4]				
2–16 [5]	B_{22}	A	A [6]		M		
16–20	A'_{2mg}	D	M [6]		M		
34–42	B'_{22mg}	D	M [6]		M		
42–52+	C	D	X		M		

[1] Vermiculite, mica, and chlorite data based on X-ray diffraction. Kaolinite and gibbsite data based on differential thermal analysis.
[2] Lower part of horizon.
[3] 14A spacing collapses with K saturation at room temperature. 14A is broad, indicating much interstratified (mica-vermiculite) material.
[4] 14A spacing does not collapse at room temperature, nearly collapses completely at 110° C, and collapses fully at 500° C.
[5] Discontinuous.
[6] 14A spacing does not collapse at 110° C; collapses between 110° C and 500° C.

had been cut westward a few feet to the bedrock forming the west wall of the buried gorge.

Allenwood silt loam

Horizon	*Depth (feet)*	*Profile description*
A_1, A_2, B, B_2 (upper).	0–5	Depth estimated on basis of description made at this same cut in 1949. Horizons removed before present study.
B_2 (lower).	5–6	Red (2.5*YR* 4/8, moist) silty clay loam; strongly developed, thin, platy structure; very firm, sticky and plastic when moist; few roots; very few pores; prominent red clay skins on ped surfaces; 5–10 percent by volume of weathered red siltstone, sandstone and shale pebbles; very strongly acid; abrupt, smooth boundary. This is the lower party of the B_2 horizon. The very firm consistence and lack of pores in part may be due to compaction of this material by a bulldozer when the upper part of the soil was removed.

Allenwood silt loam—Continued

Horizon	*Depth (feet)*	*Profile description*
C_1	6–13	Red (2.5*YR* 4/8, moist) and strong-brown (7.5*YR* 6/8 and 7/6, moist) reticulately mottled loam; strongly developed, medium, platy structure; very firm, nonsticky, nonplastic; no roots; few to many clay-coated discontinuous pores to depth of about 8 feet, none below; discontinuous red clay skins on some peds, also a few, discontinuous light-gray silty and sandy coats; 5 to 10 percent strongly weathered sandstone, siltstone, and shale pebbles commonly as much as 2 inches in diameter: many in the ¼- to ½-inch diameter range cut easily with a knife and are red or strong brown throughout, some have dark-gray interiors; very strongly acid; gradual smooth boundary. The mottles occur as more of less continuous, distinct, horizontal, ¼- to ½-inch strong-brown bands.

Allenwood silt loam—Continued

Horizon	*Depth (feet)*	*Profile description*
C_2	13–16	Red (2.5*YR* 4/8 and 10*YR* 4/8, moist) reticulately mottled loam; moderately developed, medium, platy structure in the upper part, weak, thick, platy or massive in the lower part; very firm; no pores; few, discontinuous red clay skins on some pebbles and peds; distinct and common, black, finely pitted coats on peds; 5 to 10 percent strongly weathered sandstone, siltstone, and shale pebbles, many small soft yellowish-brown or strong-brown (10*YR* or 7.5*YR* 5/6) spheroidal, strongly weathered siltstone pebbles or concretions which have silty clay loam to clay texture, distinct when material is cut with a knife; very strongly acid; abrupt, smooth boundary.
C_3	16–26	Yellowish-brown (10*YR* 5/8, moist) loam, moderate to weak, thick, platy structure; very firm; discontinuous red clay skins on peds in upper part, none in lower part, black skins prominent except in lower part; 5–10 percent sandstone, siltstone, and shale pebbles and stones, many yellowish brown throughout, others with only a yellowish-brown rind and relatively unweathered within; very strongly acid; abrupt, smooth boundary.
C_4	26–33	Dark-grayish-brown (2.5*Y* 4/2, moist) loam; weak, thick, platy structure; extremely firm; very small white specks on many pebbles and peds; very strongly acid; abrupt, smooth boundary. In overall appearance the material in this horizon is exactly like the calcareous material in the C_5 horizon. The very small specks of white material (gypsum?) are neither salty to the taste nor rapidly soluble in water. They are hardly noticeable to the eye but can be seen readily with a 10-power lens.
C_5	33–38±	Dark-grayish-brown (2.5*Y* 4/2, moist) or light-gray (2.5*Y* 7/2, dry) loam; weak, thick, platy structure; extremely firm, dense, brittle; nonporous, 5–15 percent by volume of nearly black, subangular, fine-grained limestone, sandstone, and siltstone pebbles and stones, many with distinct glacial striae, and a few fragments of coarse-grained gray sandstone ranging from a few to as much as 12 inches in diameter; slightly calcareous (judged to have about 2- to 5-percent calcium carbonate equivalent), effervesces freely when dilute hydrochloric acid is applied.

A notable feature of this calcareous till, horizons C_4 and C_5, is what appears to be strongly weathered small rock fragments which constitute as much as one-fourth of the total particles in the 1- to 2-millimeter size range. The fragments crush easily to a silty or clayey material. Such fragments may represent strongly weathered material which existed in the area before glaciation and was incorporated in the calcareous till when the glacier advanced. Such strongly weathered material might be the source of the kaolinite found in the sample from the horizon at the 37–38-foot depth. (table 4)

Mechanical analyses (table 5) show that the B_2 horizon (depth, 5 feet) has a markedly higher clay content than does the C_1 horizon (depth, 12 feet). This is, of course, characteristic of Red-Yellow Podzolic soils. The estimated mineral composition of the clay fraction (table 4), based on X-ray diffraction and differential thermal analysis, shows a relatively high kaolinite content in the B_2 horizon and a gradual decrease downward. A small percentage of gibbsite also occurs in the B_2 horizon and is absent below. These results indicate strong weathering in the B_2 horizon and a gradual decrease in intensity downward, as would be expected if the profile is part of a Red-Yellow Podzolic soil.

The presence of a moderate concentration of vermiculite in the C_3 horizon (depth 16–17 feet), and the essential absence of this mineral in the horizons immediately above and below, suggest a break in the profile. Such a break could be the result of two episodes of weathering, the first before deposition of the material above the C_3 horizon the second following deposition of the upper 16 feet of material.

The heavy-mineral content of the sand fraction of selected samples from the cut was studied by J. G. Cady in the hope that such data would be informative. Unfortunately, the percentage of sand in the horizons sampled is very small, but the analysis did show a concentration of 22 percent amphibole in the C_3 horizon (depth 16–17 feet), versus 9 percent in the C_2 horizon (depth 15–16) and 2 percent in the C_5 horizon (depth 37–38 feet). Such a varying distribution of an easily weathered mineral suggests a complex history of weathering and deposition, but the data are insufficient.

The authors conclude that the Red-Yellow Podzolic soils in this region have developed since early Wisconsin time, perhaps in Recent time, on strongly weathered parent material. In favorable places, such as the buried gorge on Penny Hill, some of the features of the modern soil, for example, the presence of gibbsite and the distinctive red color especially in the lower B and C horizons, may be largely inherited from older pre-Wisconsin weathering. But even at Penny Hill the presence of relatively weakly weathered colluvium on top of strongly weathered till demonstrates truncation of an older weathering profile, and the mineralogical

TABLE 5.—*Mechanical analysis of Allenwood silt loam at Penny Hill, Lycoming County, Pa.*[1]

[Analysis by U.S. Department of Agriculture, Soil Survey Laboratory, Beltsville, Md.]

Sample	Depth (feet)	Particle-size distribution (percent by weight)								
		Material <2 mm								Whole soil
		Sand					Silt (0.05–0.002 mm)	Clay (<0.002 mm)	Other classes (0.02–0.002 mm)	
		Very coarse (2–1 mm)	Coarse (1–0.5 mm)	Medium (0.5–0.25 mm)	Fine (0.25–0.1 mm)	Very fine (0.1–0.05 mm)				Gravel (> 2 mm)
51177	5	2.1	2.2	1.8	3.9	4.8	47.8	37.4	30.6	6
51178	12	4.3	5.4	6.1	14.7	10.3	42.8	16.4	28.0	36

[1] Samples collected by J. G. Cady and C. S. Denny.

data, although incomplete, suggest a complex history. The origin of these soils is considered in more detail in the concluding section of this paper.

SOLS BRUNS ACIDES, GRAY-BROWN PODZOLIC, AND RED-YELLOW PODZOLIC SOILS

Sols Bruns Acides, Gray-Brown Podzolic and Red-Yellow Podzolic soils (pl. 5) are soils developed principally on weakly to moderately weathered parent materials of colluvial origin found south of the Wisconsin drift border. The area is hilly, and much of the surficial mantle is thin. Most of the material is of Wisconsin age, derived in large part by the physical breakdown of the underlying bedrock. In general, even on hilltops the surface materials show evidence of lateral movement. In many places, remnants of pre-Wisconsin drift or other strongly weathered material were incorporated into the colluvium either as distinct strata or as strongly weathered coarse fragments, many of them rounded, occurring in intimate mixture with weakly weathered channers.

Two associations have been mapped (pl. 5). The Weikert-Harleton-Allenwood association includes the members of the Weikert series, which are Sols Bruns Acides, developed on yellowish-brown weakly weathered colluvium of Wisconsin age (fig. 1) that contains some yellowish or reddish strongly weathered material. The soils are accordingly yellowish brown throughout. Most of the rock fragments in the Weikert soils are relatively unweathered. A profile of the Weikert soil is described and discussed below. The Gray-Brown Podzolic–Red-Yellow Podzolic intergrade soils of the Hartleton series, associated with the Weikert and Allenwood soils (fig. 1), probably developed on mixtures of weakly weathered colluvium with rather large amounts of strongly weathered material. The B horizons have a definite accumulation of silicate clay minerals. The Hartleton soils resemble the Allenwood soils except that the solum colors are yellow rather than red.

The Klinesville-Weatherly association includes the Klinesville soils that are developed on red, weakly weathered colluvium of Wisconsin age. These are Sols Bruns Acides and are like the Weikert soils except for the red colors inherited from the parent material. The Weatherly soils are comparable to the Hartleton soils except for inherited red colors.

WEIKERT SOIL NEAR HUGHESVILLE, LYCOMING COUNTY, PA.

A Weikert soil developed in colluvium of Wisconsin or younger age was described and sampled in a pit 500 feet above the valley floor on a 20- to 30-percent slope about 2 miles east of Hughesville, Lycoming County, Pa. (pl. 1, loc. 32). The vegetation is an oak forest of predominantly black birch, red maple, sugar maple, hemlock, red oak, chestnut oak, and flowering dogwood. Tree-throw mounds spaced about 50 feet apart form a 2- to 3-foot microrelief.

In the following description a prime (′) with horizon letter designates a micropodzol horizon (for example A'_2).

Weikert very channery silt loam

Horizon	*Depth (inches)*	*Profile description*
A_{00}	½–¼	Surface litter of whole red oak, chestnut oak, black birch, and red maple leaves tied together weakly with fungal hyphae.
A_0	¼–0	Matted, partially decomposed leaves and needles firmly fastened to each other and to the A_1 below by fungal hyphae; many animals including beetle larvae, ants, thrips, and millipedes.
A_1	0–¼	Black (10*YR* 2/2, moist) silt or silt loam; weak, fine, granular structure; very friable; many rootlets; very high organic-matter content; possibly should be considered an A_0 rather than an A_1 horizon.

Weikert very channery silt loam—Continued

Horizon	*Depth (inches)*	*Profile description*
A'_2–B'_{21}	¼–1	Dark-gray (5*YR* 4/1, moist) very channery silt loam, a very thin bleicherde, A_2, underlain by a dark-reddish-brown (5*YR* 3/3, moist) orterde, B'_{21}; fibrous, spongy, and tied together with fungal hyphae; contains 50 percent or more fine channers, with a few larger ones; pH 5.2; abrupt, smooth boundary. In many places these horizons are absent and in their place is a very dark grayish-brown (10*YR* 3/2, moist) very channery silt loam.
B'_{22}	1–3	Yellowish-brown (10*YR* 5/4, moist) very channery silt loam; weak, very fine, granular structure; very friable; pH 5.1; abrupt, smooth boundary.
A_2	3–12	Light-olive-brown (2.5*Y* 5/4, moist) very channery sill loam; very weak, medium, subangular blocky clods with no visible ped faces; very friable; many roots; many pores; no clay skins, channers have silt caps and do not separate cleanly from surrounding material; pH 4.8; abrupt, wavy boundary. This horizon is distinctly paler in color than the B_1 horizon.
B_1	12–24	Light-olive-brown (2.5*Y* 5/4 toward 10*YR*, moist) very channery loam, very weak, medium, subangular blocky structure; friable; many fine pores; no clay skins; contains 50–70 percent by volume fine and coarse channers with very fine sand packed in around them; clear, wavy boundary.
B_{21}	24–36	Dark-yellowish-brown (10*YR* 4/4, moist) very channery loam which feels finer textured than B_1 horizon; massive or very weak, medium, platy structure; firm, slightly sticky and plastic; many fine pores, less than in B_1 horizon; shiny clay skins are common, some have yellowish-red color (5*YR* 4/6); 50–60 percent coarse skeleton, chiefly fine channers; pH less than 5.0; abrupt, wavy boundary.
B_{22m}	36–54	Dark-yellowish-brown (10*YR* 4/4, moist) very channery loam; massive; very firm in place; 80–90 percent coarse skeleton consists mostly of coarse channers, includes as much as 5 percent of subrounded pebbles, the latter conspicuous because of their absence in horizons above; channers have silt caps, lie horizontal to the surface, and are firmly wedged one against another; abrupt, smooth boundary.
B_{23m}	54–56	Yellowish-brown (10*YR* 5/4, moist) and brown (7.5*YR* 4/4) coarse distinctly mottled channery silt loam; massive; very firm, nonsticky; 20–30 percent coarse skeleton mostly weathered hard angular siltstone; abrupt smooth boundary. This material caps the prisms of the B_{24m} horizon.

Weikert very channery silt loam—Continued

Horizon	*Depth (inches)*	*Profile description*
B_{24m}	56–66	Yellowish-red (5*YR* 4/6, moist) and brown (7.5*YR* 4/4) silt loam which feels finer textured than B_{23m} horizon; moderate, very coarse, prismatic structure, prisms 4 to 6 inches across, bordered with ⅛-inch-thick pale-brown (10*YR* 6/3) very fine sand, and break readily to very weak, medium, angular blocky structure; very firm, dense; few clay-coated pores; 5–10 percent coarse skeleton consisting of strongly weathered(?) but hard angular fragments of siltstone; no erratics or rounded pebbles observed.
CD	66–78+	Yellowish-brown (10*YR* 5/6, moist) very channery loam; massive; firm in place; 90 percent coarse skeleton, consists of angular blocks of siltstone capped with fine material. These coarse fragments appear to be strongly weathered and lie on weakly weathered channers and flags that appear to be part of the underlying bedrock. Clay skins and silty material occur on these less weathered fragments.

On the basis of texture, color, and free iron oxide content, this soil is classed as Sol Brun Acide. The clay content of the B_2 horizons is not significantly greater than that of the A_2 horizons (table 6), because the small variations from horizon to horizon that do exist are probably the result of slight differences in the parent material. The color of the individual horizons in the upper solum, aside from the micropodzol horizons, is the same throughout, and the free iron oxide content of the upper solum is essentially uniform. The B_{21} horizon appeared to be the horizon with maximum clay content when the soil was sampled, but this is not supported by the particle-size distribution analysis.

At the time of sampling it was thought that the horizons below 54 inches might be those of a buried Red-Yellow Podzolic soil. This hypothesis was based on the yellowish-red color and what appeared to be strong weathering. The laboratory data (tables 4, 6) do not support this, and the lower horizons are now interpreted as weakly developed fragipan horizons because of their firmness and brittleness. There is no distinct clay accumulation in these horizons, and the increase in illite and in base saturation does not suggest strongly weathered material. The redder color may come from adjacent bedrock, and this would account for the higher free iron oxide content of the lower solum. The relatively high silt content in these lower horizons may be from decomposition of siltstone or from silt moving down through the solum. Many rock fragments

TABLE 6.—*Partial chemical analysis and particle-size distribution of Weikert very channery silt loam near Hughesville, Lycoming County, Pa.*

[Analysis by U.S. Department of Agriculture, Soil Survey Laboratory, Beltsville, Md.]

Depth (inches)	Horizon	Particle-size distribution (percent by weight)										Textural class
		Material <2 mm in diameter									Whole soil	
		Sand					Silt	Clay	Other classes			
		Very coarse (2–1 mm)	Coarse (1–0.5 mm)	Medium (0.5–0.25 mm)	Fine (0.25–0.10 mm)	Very fine (0.10–0.05 mm)	(0.05–0.002 mm)	(<0.002 mm)	0.2–0.02 mm	0.02–0.002 mm	Gravel (>2 mm)	
¼–1	A'_2–B'_{21}	11.2	3.5	1.2	2.4	3.6	62.8	15.3	22.2	45.6	64	Very channery silt loam.
1–3	B'_{22}	17.7	3.3	.6	.9	2.0	57.9	17.6	17.6	42.8	68	Do.
3–12	A_2	20.2	5.8	1.0	.8	1.6	56.5	14.1	16.9	41.7	70	Do.
12–24	B_1	25.0	9.7	1.9	1.4	1.8	45.6	14.6	15.0	33.0	74	Very channery loam.
24–36	B_{21}	27.4	11.1	2.3	1.8	2.3	37.9	17.2	14.8	26.2	70	Do.
36–54	B_{22m}	12.2	11.9	6.1	7.4	5.2	45.8	11.4	24.2	30.6	58	Channery loam.
54–56	B_{23m}	4.2	3.7	1.6	3.3	5.8	65.2	16.2	31.4	41.6	25	Channery silt loam.
56–66	B_{24m}	7.6	8.5	2.8	3.7	3.9	55.3	18.2	20.7	40.5	0	Silt loam.
66–78	CD	10.5	18.7	4.0	4.0	3.5	45.2	14.1	18.3	32.5	0	Loam.

Depth (inches)	Horizon	Extractable cations (milliequivalents per 100 g of soil <2 mm)					Cation exchange capacity [1]	Base saturation (percent)	pH	Organic carbon (percent)	Free iron oxides (percent)
		Ca	Mg	H	Na	K					
1/4–1	A'_2–B'_{21}	0.2	0.5	0.9	26.2	0.1	27.9	6	4.0	7.90	2.2
1–3	B'_{22}	.5	.2	.6	18.8	.1	20.2	7	4.6	3.62	2.2
3–12	A_2	.1	.3	.2	10.2	<.1	10.8	6	4.6	1.26	1.8
12–24	B_1	.1	.2	.2	7.3	.1	7.9	8	4.7	.39	2.1
24–36	B_{21}	.3	.8	1.1	6.0	.1	8.9	32	5.0	.21	2.5
36–54	B_{22m}	.2	.5	1.1	4.7	.1	6.6	29	4.9	.16	2.7
54–56	B_{23m}	.2	.1	1.2	5.8	.1	7.4	22	4.6	.15	3.3
56–66	B_{24m}	.2	.1	1.5	5.6	.1	7.5	25	4.8	.16	4.3
66–78	CD	.3	.2	2.1	4.9	.1	7.5	35	5.0	.15	3.8

[1] The sum of the extractable cations is an estimate of the cation-exchange capacity.

in the lower solum have thick caps of silt, which indicate downward movement of silt.

Sols Bruns Acides (Weikert series) with little or no clay accumulation in the sola are closely associated with Red-Yellow Podzolic soils (Allenwood series) which have a distinct clay accumulation in their sola. Gray-Brown Podzolic–Red-Yellow Podzolic intergrade soils (Hartleton series) are found on colluvium of Wisconsin age which consist of mixtures of weakly weathered and strongly weathered materials. These soils have a distinct clay accumulation in the B horizon but are classed as intergrades primarily on the basis of less contrast in color between the A_2 and B horizons than in Red-Yellow Podzolic soils. Therefore some soils with clay accumulation have developed during and since Wisconsin time. We believe that the closely associated Weikert, Hartleton, and Allenwood soils are of equal age but differ principally because of dissimilar parent material.

PODZOLS AND SOLS BRUNS ACIDES

The Podzols and Sols Bruns Acides, which include only the Leetonia-Dekalb association, (pl. 5) consist primarily of soils developed on coarse- to medium-textured parent materials of Wisconsin age and largely derived from the adjacent bedrock. These soils occur both north and south of the Wisconsin drift border, a rather large part of their area having been covered by the Wisconsin ice sheet. Podzols develop generally in coarse-textured parent materials whose internal drainage is moderately good or better, chiefly in the Appalachian Plateaus at altitudes above 1,500 feet. Gray or yellow very coarse textured highly quartzose mantles derived chiefly from conglomerate and very coarse grained sandstone (Pottsville formation) are the parent materials of the Leetonia series (table 2). Red deposits of similar texture derived from red beds are the parent materials of the Dilldown series. These two soils are associated closely with Sols Bruns Acides of both the Dekalb and Lehew series that are developed on materials with a higher proportion of medium and fine sand. Podzols also develop on silty parent materials of limited extent that are similar to those of the Sols Bruns Acides of the Bath and Lackawanna series. Some Podzols intergrade toward Sols Bruns Acides. South of the drift border this association includes a few smaller areas, each a few acres in size, of Red-Yellow Podzolic soils and of Red Yellow Podzolic-Podzol intergrades.

These soils were not studied in detail. In the higher parts of the Appalachian Plateaus, strongly developed Podzols are found on highly quartzose parent materials, probably because there is little material to provide suitable amounts and kinds of silicate clay for accumulation in the solum. On the remnants of strongly weathered materials, Red-Yellow Podzolic soils commonly have thin Podzol sola in their upper parts. Such thin sola are probably a reflection of the cool climate. Vegetation in the area is both oak forest and northern hardwood (pl. 6) but this difference, so far as is known, has not had an appreciable influence on soil development. Thus, the local differences in the well-aerated soils are due principally to their parent materials.

SOLS BRUNS ACIDES AND LOW HUMIC-GLEY SOILS

Sol Brun Acide is the most extensive great soil group recognized in the region and is commonly associated with much smaller areas of Low Humic-Gley soils (pl. 5). Sols Bruns Acides occur on well, moderately well, and somewhat poorly drained parent material, while the Low Humic-Gley soils are found on poorly drained parent materials, their distribution being dependent largely on the slope. Thus, where there are extensive areas of 2- to 3-percent slopes, Low-Humic-Gley soils are dominant. Sols Bruns Acides may develop on all kinds of weakly or moderately weathered parent material of Wisconsin or younger age. Most have fragipan horizons and are periodically wet, with a perched or a high-water table during much of the year. Although most of the soils described in this paper are in the area north of the Wisconsin drift border, identical soils are also found to the south. For example, laboratory study of samples of some soils in Potter County, Pa., show identical chemical properties and particle-size distribution irrespective of location in relation to the drift border (Soil Conservation Service, written communication).

These two great soil groups, Sol Brun Acide and Low Humic Gley, are subdivided into five soil associations (pl. 5). Two of these, the Chenango-Tunkhannock association and the Lordstown-Bath-Mardin-Volusia association are described in detail. The remaining three associations are mentioned briefly only for completeness.

The Lordstown association is composed almost entirely of the Lordstown soils and occurs for the most part on steep slopes bordering the valleys of the larger streams. The soils in the Lackawanna-Wellsboro-Morris association are developed on reddish till or colluvium and have reddish colors throughout. The Lackawanna soils are well drained, and the Wellsboro soils are moderately well drained; both are Sols Bruns Acides. The Morris soils are members of the Low Humic-Gley great soil group. These three soils parallel the Bath, Mardin, and Volusia soils in all properties except for the red solum color that is inherited from the underlying bedrock. The Oquaga-Lackawanna association also includes soils with red colors inherited from the underlying bedrock. The Oquaga soils commonly overlie bedrock at a depth of less than 3 feet and lack fragipans. They occur principally on steep valley walls and ridgetops and parallel the Lordstown soils in all properties except solum color.

CHENANGO-TUNKHANNOCK ASSOCIATION

The Chenango and Tunkhannock soils are Sols Bruns Acides developed on stratified parent materials that are commonly gray glaciofluvial deposits of Wisconsin age. If the deposits are red, the soils are members of the Tunkhannock series. The Chenango soils, although resembling the Howard soils (p. 46) and in some places occurring on similar parent material, have a relatively low clay content in the B horizon, the horizons are not prominent, and the parent materials are deeply leached, commonly in excess of 5 feet. Some Chenango soils have developed on noncalcareous gravel or on gravel leached to depths of more than 20 feet. Because the calcium carbonate content of the gravel may vary widely, its presence is apparently not required for the formation of Sols Bruns Acides.

CHENANGO SOIL NEAR OWEGO, TIOGA COUNTY, N.Y.

A typical Chenango soil, developed on glaciofluvial deposits along Owego Creek about 3 miles north of Owego, Tioga County, N.Y. (pl. 1, loc. 15; fig. 14), was exposed for several hundred feet in a trench about 5 feet deep. The gravel resembles that at Wysox, Pa. where the Howard soil is developed (p. 46), but perhaps contains a higher proportion of cobbles. No count was made by lithologic types of the pebbles in the deposit, but it is probable that the gravel near Owego contains fewer pebbles of black or dark-gray fine-grained limestone than the deposit at Wysox. The gravel is leached to depths of about 6 or 7 feet. The base of the leached zone, in contrast to that at Wysox, is fairly horizontal, as no irregular pipes or tongues extend down into the calcareous material. A description of Chenango gravelly loam follows.

Chenango gravelly loam

Horizon	*Depth (inches)*	*Profile description*
A_p	0–7	Very-dark-grayish-brown (10*YR* 3/2, moist) gravelly silt loam; moderate, medium, granular structure; friable; 22 percent by weight coarse skeleton, mostly noncalcareous, grayish, fine-grained sandstone and siltstone with grains ¼ to 1 inch in diameter; pH 5.3; abrupt boundary.
A_2	7–12	Dark-grayish-brown (10*YR* 4/4, moist), slightly paler than the B_1 horizon; gravelly silt loam; weak, thin, platy structure; very friable; 20 percent by weight coarse skeleton; isolated, light-gray, very fine sand particles occur on the surfaces and interiors of peds; vertical earthworm tunnels contain a considerable amount of A_p horizon material; pH 5.1; abrupt boundary.
B_1	12–20	Dark-yellowish-brown (10*YR* 4/4, moist) gravelly silt loam; very weak, medium, subangular blocky structure; friable; 59 percent by weight coarse skeleton; pH 5.1; abrupt boundary.
B_{21}	20–30	Brown (7.5*YR* 4/4, moist) very gravelly loam; weak, coarse, subangular blocky structure; firm; surface of peds are darker than those in B_1 and have discontinuous clay skins about ⅛ inch in diameter; no ghosts of former calcareous pebbles; 65 percent by weight coarse skeleton; pH 5.1; clear, wavy boundary.
B_{22}	30–72	Dark-yellowish-brown (10*YR* 4/3, moist) very gravelly coarse sandy loam; massive; loose; roots common; ⅛- to ¼-inch-diameter cavities between pebbles; small pockets of clay loam, silty clay loam, and clay occur, probably fill pre-existing cavities; strong brown (7.5*YR* 5/6) and very dark grayish-brown (10*YR* 3/2), soft, weathered ghosts of former calcareous pebbles occupy up to 20 percent by volume of this horizon; 74 percent by weight coarse skeleton; pH 5.4; clear boundary.
B_3	72–90	Very dark grayish-brown (10*YR* 3/2, moist) very gravelly coarse sandy loam; massive; loose; sticky; carbonates occur on the underside of many pebbles; a few dark-colored clayey-surfaced 2- to 4-inch-diameter pebbles with calcareous interiors; cobbles 6–8 inches in diameter are common, but most coarse fragments are in the 1- to 6-inch range; 74 percent by weight of the soil material is 2 millimeters or greater in diameter; a few, soft, leached ghosts and some partially leached pebbles; calcareous, 20 percent calcium carbonate equivalent; clear, wavy boundary.
C_2	90–100+	Very dark grayish-brown (2.5*Y* 3/2, moist) very gravelly coarse sand, single grained, cemented by carbonate to a conglomerate in places; 19 percent calcium carbonate equivalent. Depth to carbonate varies in the terrace from about 6 to 10 feet, with an average of about 7 feet.

Like many other Sols Bruns Acides, the Chenango soil has an A_2 horizon with a weak thin platy structure and pale color, no appreciable clay accumulation in the B horizon, a strongly acid solum, and, unlike Podzols, rather uniform distribution of free iron oxide in the upper solum (table 7). The larger amounts of free iron oxide in the B_{21}, B_{22}, and C_1 horizons possibly are related to remnants of leached ferruginous or argillaceous limestone fragments, some of which are still present as small masses or pockets of clay in the B_{22} horizon. The accumulation of clay in the B_3 horizon is probably localized in the partially leached limestone fragments. The upper 20 inches of the profile has been enriched in silt, most likely by fluvial deposition, or possibly by colluvial or eolian processes.

The amount of limestone and dolomite pebbles in the parent material of the Chenango soils is usually less than in that of the Howard soils (fig. 8). Clay is released when the soluble calcium or magnesium carbonate is leached from the argillaceous limestone or dolomite pebbles. The smaller amount of clay released when the parent material of the Chenango soils is leached probably explains why the amount of clay accumulated in the B horizon of the Chenango soils is smaller than that in the Howard soils. This is discussed in the description of the Howard soils at Wysox, Pa. (p. 49).

Sols Bruns Acides are widespread in the Elmira-Williamsport region on weakly weathered parent materials of Wisconsin or Recent age. The exact time when any given material became stabilized sufficiently for soil development to begin is not known. For example, the colluvium near Hughesville, Pa., on which the Weikert soil, a Sol Brun Acide, developed (p. 34), could be younger than the gravel near Owego, N.Y., even though the former is in the area south of the Wisconsin drift border. The glaciofluvial deposits of the valley-train terraces offer the best opportunity for comparing the development of Sols Bruns Acides on parent materials of different age. The gravel terrace near Muncy, Lycoming County, Pa., about 15 miles

TABLE 7.—*Partial chemical analysis, particle-size distribution, and textural class of Chenango gravelly silt loam near Owego, Tioga County, N.Y.*

[Analyses by U.S. Department of Agriculture, Soil Survey Laboratory, Beltsville, Md.]

Depth (inches)	Horizon	Particle-size distribution (percent by weight)										Textural class
		Material <2 mm in diameter									Whole soil	
		Sand					Silt (0.05–0.002 mm)	Clay <0.002 mm)	Other classes		Gravel (>2 mm)	
		Very coarse (2–1 mm)	Coarse (1–0.5 mm)	Medium (0.5–0.25 mm)	Fine (0.25–0.10 mm)	Very fine (0.10–0.05 mm)			0.2–0.02 mm	0.02–0.002 mm		
0–7	A_p	0. 9	3. 5	3. 7	5. 4	10. 0	63. 8	12. 7	44. 0	32. 7	22	Gravelly silt loam.
7–12	A_2	. 7	2. 8	3. 5	4. 7	9. 4	67. 8	11. 1	46. 4	33. 3	20	Do.
12–20	B_1	1. 0	4. 6	4. 8	6. 0	10. 0	63. 3	10. 3	46. 2	30. 1	59	Do.
20–30	B_{21}	3. 7	11. 9	9. 1	8. 1	8. 7	46. 7	11. 8	35. 8	23. 4	65	Very gravelly loam.
30–72	B_{22}	4. 7	24. 3	23. 3	12. 0	3. 7	20. 9	11. 1	14. 3	14. 6	74	Very gravelly coarse sandy loam.
72–90	C_1	11. 5	31. 0	13. 0	7. 5	3. 3	16. 5	17. 2	11. 1	11. 5	74	Do.
90–120	C_2	3. 9	34. 2	29. 2	17. 5	4. 2	8. 0	3. 0	14. 2	4. 4	77	Very gravelly coarse sand.

Depth (inches)	Horizon	Extractable cations (milliequivalents per 100 g of soil <2 mm)					Cation exchange capacity[1]	Base saturation (percent)	pH	$CaCO_3$ equivalent (percent)	Organic carbon (percent)	Free iron oxides (percent)
		Ca	Mg	H	Na	K						
0–7	A_p	22. 1	5. 6	0. 8	15. 6	<0. 1	0. 1	29	5. 3	------	3. 14	1. 60
7–12	A_2	12. 7	1. 3	. 3	10. 8	. 2	. 1	15	5. 1	------	. 70	1. 60
12–20	B_1	10. 5	1. 3	. 3	8. 4	. 3	. 2	20	5. 1	------	. 46	1. 68
20–30	B_{21}	8. 7	1. 7	. 3	6. 2	. 3	. 2	29	5. 1	------	. 25	2. 32
30–72	B_{22}	11. 3	3. 3	. 7	6. 8	. 3	. 2	40	5. 4	------	. 17	1. 84
72–90	C_1	20. 7	12. 4	4. 7	3. 4	. 1	. 1	84	7. 0	2	. 05	2. 16
90–120	C_2	12. 6	12. 1	. 4	<. 1	<. 1	. 1	100	7. 6	19	. 10	. 72

[1] The sum of the extractable cations is an estimate of the cation-exchange capacity.

east of Williamsport (pl. 1, loc. 34), is located a few miles south of the Wisconsin drift border and was built by melt water when the Olean ice sheet was at or near the drift border. This gravel is certainly older than similar gravels in the Susquehanna Valley near Wysox or near Owego, which are in part outwash from the Valley Heads moraine. Both the gravels near Muncy and near Owego support Sols Bruns Acides. The Tunkhannock soil on the terrace near Muncy has much the same profile characteristics as the Chenango soil near Owego; the major difference is the inherited brown and red colors of the Tunkhannock soil and the lack of carbonate. Many Chenango soils, however, have no carbonate in their parent material. The similarity between these two profiles suggests that the difference in age between their parent materials has not influenced the course of soil development.

LORDSTOWN-BATH-MARDIN-VOLUSIA ASSOCIATION

The Lordstown-Bath-Mardin-Volusia association, the most extensive in the region, includes the well-drained Bath soils, the moderately well-drained Mardin soils, and the somewhat poorly drained Volusia soils; all three have brittle, very firm fragipan horizons. The gray or olive parent materials of these soils are till or colluvium of Wisconsin age that formerly were thought to be acid throughout. Deep exposures show, however, that most of the deposits actually are calcareous below depths of about 7 feet. Profiles of these soils were examined in many places, including a continuous pipeline trench, about 5 miles long and about 5 feet deep, across the uplands a few miles north of Owego, N.Y.

The Lordstown soils are well drained and occur on olive or gray till or colluvium, commonly on ridgetops or steep slopes where bedrock is at depths of less than 3 feet. They do not have fragipan horizons and in general have a higher proportion of channers throughout the profile than the Bath soils.

Bath and Mardin soils developed on both Olean and Valley Heads drifts were studied in detail, but no soil differences were observed which could be related to differences in age of parent material. The parent materials are similar except for a slightly greater content of crystalline rocks in the Valley Heads till. Likewise, no profile differences among these soils were found which could be related consistently to differences in the species composition of the present forest. (See p. 54.)

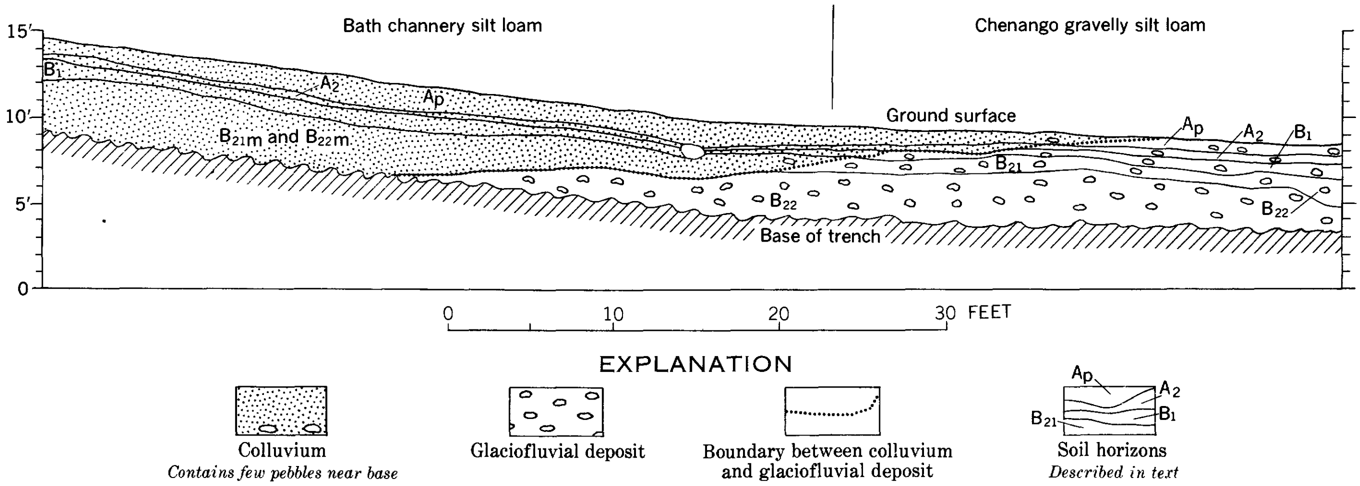

FIGURE 14.—Section of a valley wall showing colluvium overlying glaciofluvial deposits of Valley Heads subage. Bath soil on the colluvium adjoins Chenango soil on the adjacent sand and gravel. Exposure in 5-foot-deep pipeline trench that crosses the valley of Owego Creek about 3 miles north of Owego, Tioga County, N.Y.; examined July 1954 (pl. 1, loc. 15).

BATH SOIL NEAR OWEGO, TIOGA COUNTY, N.Y.

In the valley of Owego Creek about 3 miles north of its mouth, a gravel terrace of Valley Heads subage is overlain by locally derived olive-brown colluvium. There is no trace of a buried soil between the colluvium and the glaciofluvial deposits (fig. 14). Bath channery silt loam soil is developed on the colluvium, and Chenango gravelly loam is the soil on the adjacent gravel. (See p. 37.) Gray fine-grained sandstone which crops out upslope has contributed many small fragments to the colluvium, aggregating 55 percent by weight. The continuity of soil horizons across the geological boundary between colluvium and glaciofluvial deposits indicates that the same kind of development has gone on irrespective of differences in parent material or degree of slope. The analyses (tables 7, 8) show that, after leaching, the materials in which the two soils have developed are not greatly different either in lithology, in texture, or in chemical properties, even though the mode of origin of the parent materials is considerably different. The following is a description of Bath channery silt loam.

Bath channery silt loam

Horizon	*Depth (inches)*	*Profile description*
A_p	0–8	Very dark-grayish-brown (10*YR* 3/2, moist) channery silt loam; weak, fine granular structure, platy in some places where heavy trench-digging machinery has compressed the soil; friable; 43 percent by weight coarse skeleton, mostly angular siltstone or fine-grained sandstone fragments; pH 4.8; abrupt, smooth boundary.
A_2	8–12	Olive-brown (2.5*Y* 4/4, moist) channery silt loam; weak, thin, platy structure; friable; 50 percent by weight coarse skeleton, mostly ¼- to ½-inch-long channers; pH 5.1; abrupt, smooth boundary.
B_1	12–22	Essentially like the material in the A_2 horizon, but with weak, medium, blocky structure; 57 percent by weight coarse skeleton; pH 5.2; clear, smooth boundary.
B_{21m}	22–48	Olive-brown (2.5*Y* 4/4, moist) channery silt loam; very weak, very coarse, subangular blocky structure; very firm in place, friable when removed, moderately brittle; pores common; many obvious and continuous shiny clay skins; much unaggregated silt in pores and around pebbles; 48 percent by weight coarse skeleton; pH 5.2; gradual boundary.
B_{22m}	48–72	Similar to B_{21m} horizon above; very firm; 57 percent by weight coarse skeleton; pH 5.2; clear, smooth boundary.
C	72–84	Olive-brown (2.5*Y* 3/4, moist) channery loam, massive with perhaps a faint shinglelike arrangement of fragments; firm in place, much less firm than B_2 horizons; 1/16-inch-diameter pores common; clay skins rare, ½ inch apart, and discontinuous; 55 percent by weight coarse skeleton, mostly of ½- by ½- by ¼-inch channers of gray fine-grained sandstone; pH 5.3.

The soil is classified as Sol Brun Acide because it has an A_2 horizon, no clay accumulation in the B_2 horizons, no stronger color in the upper B horizon than below, a fairly uniform content of free iron oxide throughout the solum, and a strongly acid reaction (table 8). It is classed as a member of the Bath series mainly because of its very firm, brittle B_{2m} horizons. The clay content of the entire solum is less and the amount of coarse skeleton is somewhat greater than in the typical Bath soil. In these respects it is like the Lordstown soils. The particle-size data (table 8) indicate that about half the soil material is coarser than 2 millimeters and about a quarter is silt. Perhaps this distribution results from decomposition of the siltstone and sandstone bedrock.

A slightly higher silt content in the upper solum as compared with that of the lower solum parallels a corresponding higher silt content in the upper solum of the nearby Chenango soil (table 7). Clay skins on the surface of peds and in pores occur in the B_{2m} horizons, but the particle-size distribution (table 8) indicates clearly that even though these films of clay are distinct, they do not give a greater overall amount of clay to the horizon in which they occur. There is, in fact, less clay in these horizons (B_{21m} and B_{22m}).

The cause of the very firm, brittle consistence of the B_{2m} horizons is unknown. Although such firmness in till has been attributed to the weight of an overlying ice sheet, such an explanation is not applicable to colluvium. The association of clay skins with such consistence suggests that both may be due to the deposition of clay. Knox (1957) postulated for similar horizons in a Rockaway soil in Orange County, N.Y., that clay particles may act as the cementing agent or binder.

The extent to which the minerals in the solum have been modified by weathering has not been determined, but the increase in base saturation with depth (table 8), an increase in the amount of extractable calcium and magnesium ions with depth, and a fairly uniform free iron oxide content suggest that the minerals of the soil are in early states of chemical weathering (Jackson and Sherman, 1953). The data indicate that leaching rather than chemical alteration has been the chief soil-forming process. Aside from a more intense olive color in the B horizons, this Bath soil is strikingly similar, both chemically and morphologically, to the Weikert soil near Hughesville, Pa. (p. 34), which is also classed as Sol Brun Acide.

MARDIN AND BATH SOILS NEAR DRYDEN, TOMPKINS COUNTY, N.Y.

The Mardin and Bath soils developed on till of Valley Heads subage were studied on the Mt. Pleasant Farm of the Department of Agronomy, Cornell University, about 7 miles east of Ithaca, N.Y. (pl. 1, loc. 2). The soils on the farm, located north of the Valley Heads moraine of Fairchild, were compared with similar soils on Olean drift south of the moraine. Trenches were

TABLE 8.—*Partial chemical analysis and particle-size distribution of Bath channery silt loam near Owego, Tioga County, N.Y.*

[Analysis by U.S. Department of Agriculture, Soil Survey Laboratory, Beltsville, Md.]

Depth (inches)	Horizon	Particle-size distribution (percent by weight): Material <2 mm in diameter: Sand: Very coarse (2–1 mm)	Coarse (1–0.5 mm)	Medium (0.5–0.25 mm)	Fine (0.25–0.10 mm)	Very fine (0.10–0.05 mm)	Silt (0.05–0.002 mm)	Clay <0.002 mm)	Other classes: (0.2–0.02 mm)	(0.02–0.002 mm)	Whole soil: Gravel (<2 mm)	Textural class
0–8	A_p	14.7	6.7	1.8	2.1	5.3	56.0	13.4	28.5	33.8	43	Channery silt loam.
8–12	A_2	13.5	7.0	2.0	1.9	6.2	57.2	12.2	31.8	32.6	50	Do.
12–22	B_1	12.7	6.2	1.8	1.7	5.4	58.6	13.6	30.5	34.4	57	Do.
22–48	B_{21m}	15.5	8.3	2.6	2.9	7.0	54.1	9.6	35.2	27.4	48	Do.
48–72	B_{22m}	12.7	9.7	2.8	3.2	8.4	54.4	8.8	36.1	28.4	57	Do.
72–84	C	15.5	11.5	3.5	3.7	9.6	48.4	7.8	37.3	22.6	55	Channery loam.[1]

Depth (inches)	Horizon	Extractable cations (milliequivalents per 100 g of soil <2 mm): Ca	Mg	H	Na	K	Cation-exchange capacity[2]	Base saturation (percent)	pH	Organic carbon (percent)	Free iron oxides (percent)
0–8	A_p	19.8	1.7	0.5	17.4	0.1	0.1	12	4.8	2.64	1.44
8–12	A_2	9.8	.8	.3	8.4	.2	.1	14	5.1	.49	1.20
12–22	B_1	9.9	.8	.3	8.4	.2	.2	15	5.2	.33	1.44
22–48	B_{21m}	8.1	1.1	.3	6.4	.2	.1	20	5.2	.16	1.04
48–72	B_{22m}	6.4	1.3	.6	4.0	.3	.2	38	5.2	.03	1.20
72–84	C	7.5	1.9	1.0	4.2	.2	.2	44	5.3	.14	1.20

[1] Close to channery coarse sandy loam boundary.
[2] The sum of the extractable cations is an estimate of the cation-exchange capacity.

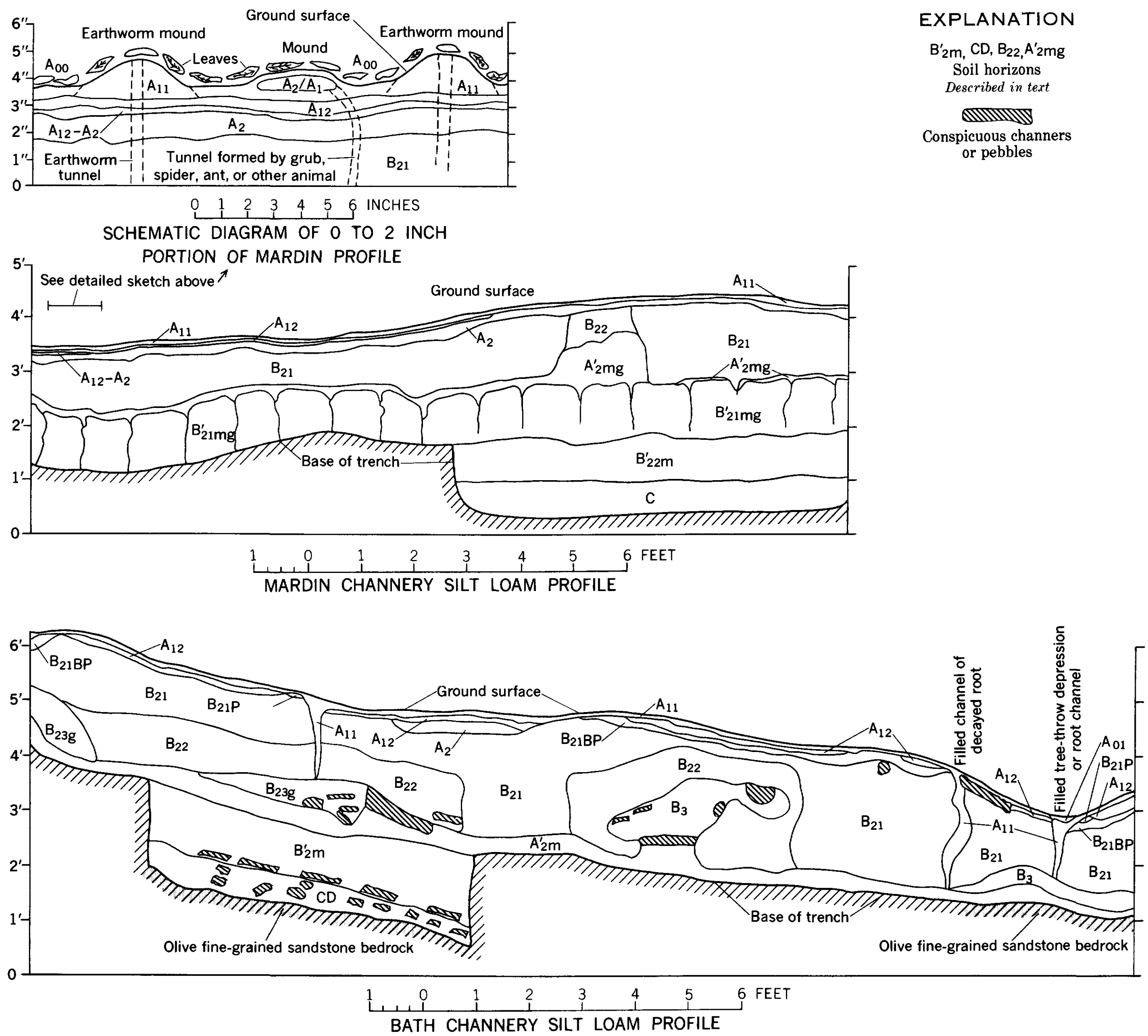

FIGURE 15.—Sections showing Bath and Mardin soils developed on till of Valley Heads subage. The Mardin soil has a fragipan and the Bath soil shows conspicuous evidence of tree throw. Exposure in trenches on Mt. Pleasant Farm, Department of Agronomy, Cornell University, near Dryden, about 7 miles east of Ithaca, Tompkins County, N.Y. (pl. 1, loc. 2).

dug to expose the soil, and scale diagrams of the profiles were prepared (fig. 15). The fragipan horizons of the soils at this same locality have been studied by Carlisle.[1] Laboratory data based on samples collected in the trenches and data from Carlisle are given in table 9 and figure 16. The sample area is at an altitude of about 1,750 to 1,800 feet and in northern hardwood forest. The present vegetation consists principally of beech, red oak, red maple, and sugar maple. Stumps of chestnut are common, and well-decayed stumps of hemlock or white pine are present also.

[1] Carlisle, F. J. Jr., 1954, Characteristics of soils with fragipans in a Podzol region: Cornell Univ., Ithaca, N.Y., PhD thesis.

The till of Valley Heads subage is olive, massive, dense, and very firm; soil scientists classify it as channery silt loam. Angular and rounded rock fragments up to 6 inches in diameter constitute about 35 percent of the mass. Most are olive fine-grained sandstone and siltstone that resemble the underlying bedrock; a few—perhaps 5 or 10 percent—are granitic rock and coarse-grained sandstone. The Mardin soil has developed where the till is more than 4 feet thick, and the Bath soil where olive sandstone and siltstone bedrock lie at a depth of not more than 4 feet. In the Bath soil the size and number of small fragments and flagstones increase with depth.

TABLE 9.—*Selected properties of three profiles of Mardin channery silt loam*

Horizon	Depth (inches)	Extractable cations (milliequivalents per 100 g of soil<2 mm)			Cation exchange capacity [1]	Base saturation (percent)	pH	Location, source of data, age of parent material
		Ca	Mg	K				
A_p	0–6	4. 2	0. 3	0. 10	11. 7	39	5. 0	Mt. Pleasant Farm, Dryden, Tompkins County, N.Y. The M_2 profile of Carlisle. Parent material is till of Valley Heads subage.
B_2	6–9	1. 1	. 1	. 07	7. 2	18	5. 3	
A'_2	9–11½	. 6	. 1	. 05	3. 2	25	5. 5	
B'_2	11½–29	2. 3	. 7	. 13	7. 2	44	5. 4	
B'_3	29–53	3. 3	1. 1	. 13	8. 4	54	5. 6–6. 0	
C_1	53–59	3. 6	1. 4	. 08	9. 6	53	6. 1	
A_p	0–6	1. 8	0. 2	0. 07	12. 6	17	5. 0	Mt. Pleasant Farm, Dryden, Tompkins County, N.Y. The M_3 profile of Carlisle. Parent material is till of Valley Heads subage.
B_2	6–12	1. 3	. 2	. 07	10. 5	15	5. 2	
A'_2	12–16	. 7	. 1	. 05	5. 5	16	5. 0	
B'_2	16–32	2. 1	. 2	. 07	6. 0	40	5. 0–5. 4	
B'_3	32–55	4. 2	1. 7	. 12	8. 2	73	5. 4	
C_1	55–61	5. 3	1. 7	. 10	8. 1	88	6. 5	
A_1	0–4	7. 6	0. 4	0. 6	37	23	4. 9	Pipeline trench on uplands about 4 miles northeast of Owego, Tioga County, N.Y. Analysis by U.S. Department of Agriculture, Soil Survey Laboratory, Beltsville, Md. Parent material is till of Olean subage.
A_2	4–6	1. 4	. 4	. 2	16. 6	12	4. 8	
B_1	6–10	1. 3	. 3	. 2	14. 2	14	4. 7	
B_{21}	10–16	1. 2	. 4	. 1	11. 8	17	4. 7	
B_{22mg}	16–24	1. 2	. 7	. 1	13. 1	18	4. 8	
B_{23}	24–48	3. 1	2. 2	. 1	14. 4	39	5. 2	
B_{24}	48–54	5. 1	3. 3	. 1	16. 7	52	5. 7	

[1] The sum of the extractable cations is an estimate of the cation-exchange capacity.

Mardin channery silt loam is described below and diagrammed in figure 15. This soil has conspicuous fragipan horizons, and in the soil-profile descriptions they are designated by a prime (′) with horizon letter (for example B'_{2mg}).

Mardin channery silt loam

Horizon	*Depth (inches)*	*Profile description*
A_{00}	1–0	Loose leaves.
A_{11}	0–½	Black (10*YR* 2/2, moist) silt loam; weak and moderate, medium, granular structure; very friable; horizontal, fine roots are numerous and occupy about one-half the volume; low bulk density, fluffy, high content of organic matter; earthworms common, their mounds numerous; abrupt, smooth boundary; continuous horizon.
A_{12}	½–¾	Dark-brown (10*YR* 3/3, moist), gray when dry (10*YR* 5/1), silt loam; weak, fine, granular structure; very friable; matted with rootlets; 6 percent coarse skeleton. The gray dry soil resembles the A_2 horizon of a Podzol.
A_{12}–A_2	¾–1	Dark-brown (10*YR* 4/3, moist) silt loam; very weak, thin, platy structure; weakly matted with mycelium; 9 percent coarse skeleton. This is a transitional horizon.
A_2	1–2	Brown (10*YR* 5/3, moist) channery silt loam; weak, very thin, platy structure; friable; many rootlets; discontinuous silt coats on some peds; 23 percent coarse skeleton; abrupt, smooth boundary; continuous horizon.
B_{21}	2–16	Dark yellowish-brown (10*YR* 4/4, moist) channery silt loam, yellowish brown (10*YR* 5/4 and 5/6) in a few places; moderate, coarse and medium, subangular blocky structure which crushes to weak fine granular structure; friable to firm; roots numerous; namy fine pores; 30 percent coarse skeleton; abrupt boundary; continuous horizon.

Mardin channery silt loam—Continued

Horizon	*Depth (inches)*	*Profile description*
B_{22}	2–16	Light-olive-brown (2.5*Y* 5/4, moist) channery silt loam; weak, coarse subangular blocky structure, peds crush readily to weak, fine, subangular blocks and fine granules; friable; 27 percent coarse skeleton; discontinuous horizon, discontinuity undoubtedly the result of a fallen tree.
A'_{2mg}	16–20	Olive (5*Y* 5/3 and 2.5*Y* 5/3, moist) channery silt loam which feels like a fine sandy loam, with common, fine, faint mottles of olive brown (2.5*Y* 4/4); weak, coarse, platy structure; very firm, weakly brittle; abrupt wavy boundary; 34 percent coarse skeleton; continuous horizon. About ½ inch thick over the underlying prism tops but deeper between the domes.
B'_{21mg}	20–34	Olive-brown (2.5*Y* 4/4, moist) channery silt loam with common, coarse, prominent and faint mottles of dark yellowish brown, strong brown, and olive; moderate, very coarse, prismatic structure; extremely firm; brittle; few or no roots; prominent mottles border the prisms, faint mottles are inside the domed prisms; 33 percent coarse skeleton; abrupt, smooth boundary.

Mardin channery silt loam—Continued

Horizon	*Depth (inches)*	*Profile description*
B'_{22m}	34–42	Olive-brown (2.5*Y* 4/4, moist) channery silt loam; weak, coarse, prismatic structure; extremely firm; roots only between prisms; few, coarse (1 mm), clay-coated pores; prisms are about 12 inches in diameter; outsides are olive (5*Y* 5/3) but under the surface is a thin layer of strong brown which, in section, gives appearance of streaks vertically or horizontally; 46 percent coarse skeleton; clear, smooth boundary.
C	42–52	Olive (5*Y* 4/3, moist) channery silt loam till; massive; very firm, dense, not brittle, nonporous; 36 percent coarse skeleton, mostly angular and rounded fragments of unweathered, olive, fine-grained sandstone or siltstone. Up to 10 percent of the coarse skeleton is pebbles of granitic rock or coarse-grained sandstone.

About 150 feet distant from the profile just discussed, a second trench was dug in an area of Bath channery silt loam (fig. 15). This Sol Brun Acide has a discontinuous B_{21} horizon which in some places resembles that of a Podzol soil and is designated B_{21P}; in other places the B_{21} horizon resembles that of a Brown-Podzolic soil and is designated B_{21BP}. The soil profile is described below, except that the horizons in the upper solum are not mentioned if they are similar to the corresponding horizons of the Mardin soil.

Bath channery silt loam

Horizon	*Depth (inches)*	*Profile description*
A_{01}	2–0	Matted leaves, softened, partially broken and decayed; discontinuous horizon, present only in tree-throw depression or root channel.
A_{11}, A_{12}, A_2.	------	Similar to those of Mardin soil in same area.
B_{21BP}	1½–3	Dark-yellowish-brown (10*YR* 4/4, moist) channery silt loam; very weak, fine and very fine, granular structure; gradational boundary; discontinuous horizon.
B_{21P}	1½–2	Dark-reddish-brown (5*YR* 2/2, moist) silt loam; very weak, fine granular structure; gradational boundary; discontinuous horizon.
B_{21}, B_{22}	------	Similar to those of Mardin soil in same area.
B_{23g}	12–26	Dark-yellowish-brown (10*YR* 4/4, moist) or olive-brown (2.5*Y* 4/4) channery silt loam with common, medium, distinct mottles of light olive brown (2.5*Y* 5/4) and olive (5*Y* 5/3); moderate to weak, medium, angular and subangular blocky structure; firm; very weakly brittle; abrupt, smooth boundary; discontinuous horizon.

Bath channery silt loam—Continued

Horizon	*Depth (inches)*	*Profile description*
B_3	12–26	Olive (4*Y* 4/3, moist) channery silt loam; weak, fine and medium, subangular blocky structure; firm in place, friable when removed; 10–20 percent coarse skeleton; abrupt boundary; discontinuous horizon.
A'_{2m}	26–30	Light-olive-brown (2.5*Y* 5/4, moist) channery sandy loam with common, medium, faint mottles of grayish brown (2.5*Y* 5/2) and dark yellowish brown (10*YR* 4/4); medium, subangular blocky, and weak, medium, platy structure; peds separate readily into weak, thin plates; firm in place, friable when removed, weakly brittle; 40–60 percent coarse skeleton, mostly of 2- by 4- by ½-inch channers with about 10 percent ½- to 2-inch pebbles; abrupt, smooth boundary; continuous horizon.
B'_{2m}	30–40	Olive-brown (2.5*Y* 4/3, moist) very channery sandy loam; massive; very firm; many fine pores; clay skins in some of the pores, grayish silt flour fairly well disseminated throughout the material; high proportion of angular channers of siltstone and sandstone.
CD	40–48	Fractured olive siltstone and sandstone bedrock consisting of 1- to 3-inch channers with olive-brown (2.5*Y* 4/3, moist) loam between the fragments; silt flour and pores with clay skins present in places.

A Mardin soil on till of Olean subage was sampled for comparison with Mardin soil on till of Valley Heads subage at Mt. Pleasant Farm. The results are included in tables 4, 9, 10, and 11, but a detailed profile description is not given. The Olean site was in a 5-foot-deep trench on the uplands about 4 miles northeast of Owego, Tioga County, N.Y. (pl. 3, loc. 6), where the land slopes 5 to 8 percent. The overall appearance and horizon sequence of both soils are essentially the same except that an A'_{2m} horizon is not present at the site near Owego. Figure 16 shows a comparison of some of the properties of these two Mardin soils. The differences are no more than would be expected within a soil type sampled at several spots in the same field.

The Mardin soil at Dryden and near Owego are both classed as Sol Brun Acide because of the continuous brown A_2 horizon, which is paler than the horizons above and below; the blocky B horizons, which have the same texture as the A horizons; and the fairly uniform free iron oxide content throughout (tables 10, 11). Slight differences between these analyses and those of Carlisle probably represent local variations within one horizon.

The Mardin soils near Dryden and Owego have about

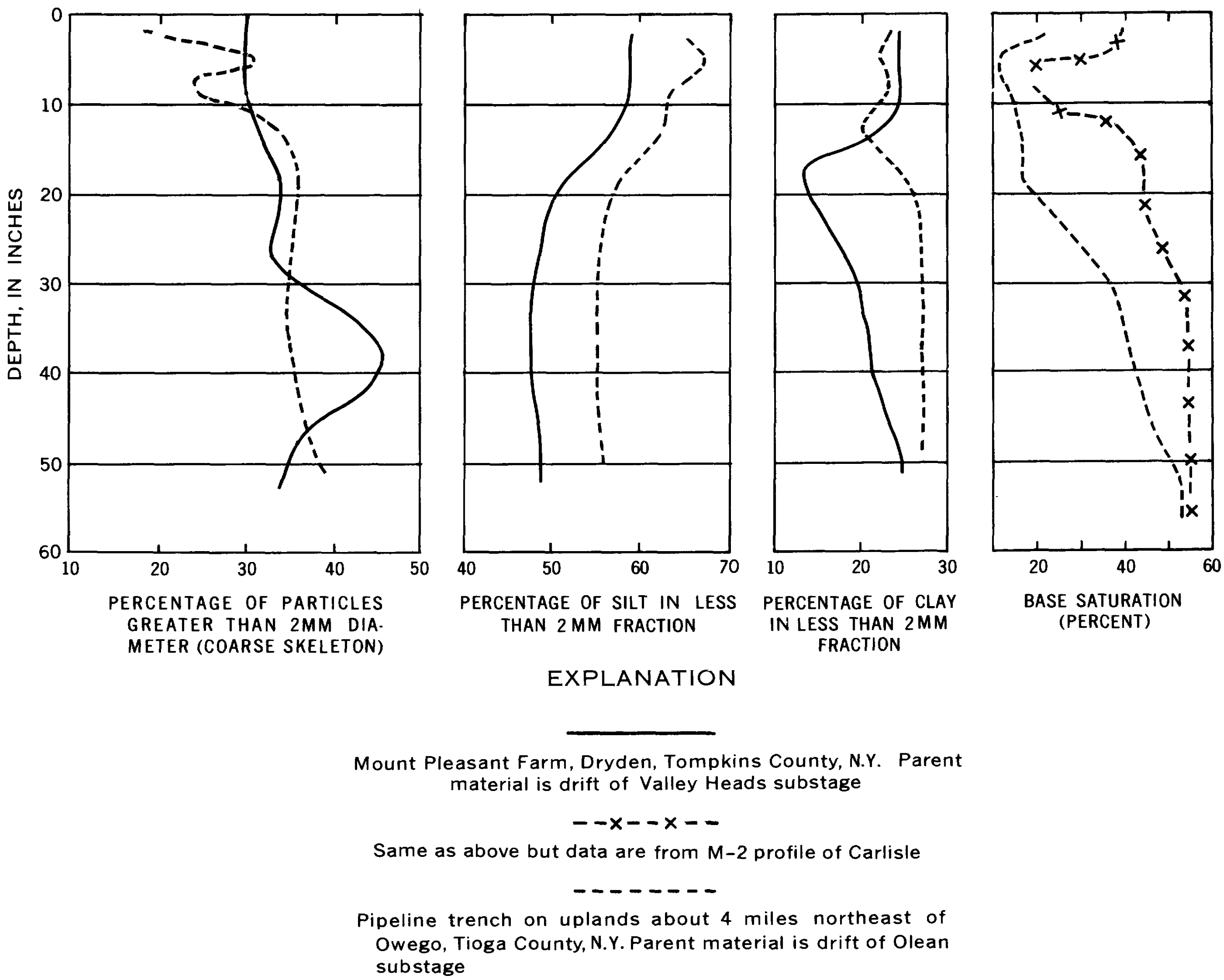

FIGURE 16.—Comparison of a Mardin soil developed on Olean drift with one developed on drift north of the Valley Heads moraine. For data of F. J. Carlisle, Jr., see footnote on p. 42.

one-fifth more silt in the upper 20 inches than in the horizons below (fig. 16) and have a correspondingly small amount of coarse skeleton. Although the silt is possibly a result of aeolian deposition, a more likely source is siltstone that was disaggregated by weathering. Carlisle (see footnote on p. 42) found numerous small soft weathered particles of rock in the solum of the Mardin soils.

The Bath soil at Dryden is also classed as Sol Brun Acide, although it has some morphological features characteristic of a Sol Brun Acide intergrading to a Podzol. Such an intergrade, however, should have appreciably more free iron oxide in the upper B horizon than in the lower; that is, more than is indicated in table 10. The soil has a discontinuous A_2 horizon and a very weak, subangular blocky structure in the B_{21} horizon.

Thin reddish-brown B_{21} horizons, like those characteristic of Podzols, occur in a few spots just under the A_{12} horizon of the Bath soil (fig. 15, B_{21P}) and may be remnants of once extensive horizons. In other spots, thin B_{21} horizons like those of Brown Podzolic soils of New England (Lyford, 1946) occur (fig. 15, B_{21BP}). These B_{21} horizons are not as red as corresponding horizons of the Podzols. In summary, the Bath soil has characteristics suggestive of incipient podzolization or of Podzol remnants.

GRAY-BROWN PODZOLIC SOILS

The Gray-Brown Podzolic soils are mapped in either of two associations. The Howard association is restricted to soils developed on calcareous gravel and occurs only in the northern part of the region on valley-train and kame deposits of Wisconsin age. Where

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TABLE 10.—*Organic carbon, free iron oxide content, and pH of Bath and Mardin soils near Dryden and Owego, N.Y.*

[Analyses by U.S. Department of Agriculture, Soil Survey Laboratory, Beltsville, Md.]

Horizon	Depth (inches)	Organic carbon (percent)	Free iron oxide (percent)	pH
Bath channery silt loam, Mt. Pleasant Farm, Dryden, N.Y.				
A_{11}	0–1	15.3	1.84	5.2
A_{12}	1–1½	3.06	2.16	4.6
A_2	1½–3	1.29	1.98	4.7
B_{21}	3–12	1.13	2.02	4.8
B_{22}	12–26	.52	2.27	5.1
Mardin channery silt loam, Mt. Pleasant Farm, Dryden, N.Y.				
A_{12}	½–¾	7.6	1.52	4.0
A_{12}–A_2	¾–1	3.01	1.56	4.0
A_2	1–2	1.30	1.52	4.2
B_{21}	2–16	.92	2.36	4.4
B_{22}	[1] 2–16	.67	1.76	4.8
A'_{2mg}	16–20	.26	1.28	4.7
B'_{21mg}	20–34	.24	1.60	4.8
B'_{22mg}	34–42	.14	-------	5.1
C	42–52+	.19	-------	5.8
Mardin channery silt loam, Owego, N.Y.				
A_1	0–4	7.3	1.60	4.9
A_2	4. 6	1.19	1.92	4.8
B_1	6–10	.63	1.84	4.7
B_{21}	10–16	.46	1.60	4.7
B_{22mg}	16–24	.16	1.84	4.8
B_{23m}	24–48	.15	1.84	5.2
B_{24m}	48–54+	.24	2.00	5.7

[1] Discontinuous.

the Howard soils occur, the gravel is commonly very dark grayish-brown (10*YR* or 2.5*Y* 3/2, moist) and calcareous below depths of 4 or 5 feet, but Sols Bruns Acides (Chenango series) are also formed on similar parent material. (See p. 37.) The B_2 horizons of the Howard soils are distinctly finer textured than the horizons above and below, and in most places they have an abrupt, intertongued, wavy boundary with the C horizon. Where the gravel is highly calcareous at depths of only 2 or 3 feet and the upper solum is neutral rather than acid, the soil is a member of the Palmyra series (fig. 6).

The common soils on the better drained parts of the Valley Heads moraine are also Gray-Brown Podzolic and are mapped in the Lansing-Nunda association (pl. 5). They have developed on thick deposits that are generally calcareous but range widely in lithology, texture, and color within short distances. The more extensive soils are the Howard soils on glaciofluvial deposits, the Lucas and Nunda soils on lacustrine deposits, and the Lansing soils on till.

HOWARD SOIL AT WYSOX, BRADFORD COUNTY, PA

PARENT MATERIAL

The valley-train terraces in the Cohocton, Chemung, and Susquehanna River valleys (pl. 4) are underlain by gravel and sand that is the parent material of the Howard soils. A typical exposure is the Shiner gravel

TABLE 11.—*Particle-size distribution and texture of two Mardin soils*

[Analyses by U.S. Department of Agriculture Soil Snrvey Laboratory, Beltsville, Md.]

Depth (inches)	Horizon	Particle-size distribution (percent by weight): Material <2 mm in diameter: Sand: Very coarse (2–1 mm)	Sand: Coarse (1–0.5 mm)	Sand: Medium (0.5–0.25 mm)	Sand: Fine (0.25–0.10 mm)	Sand: Very fine (0.10–0.05 mm)	Silt (0.05–0.002 mm)	Clay (<0.002 mm)	Other classes: 0.2–0.02 mm	Other classes: 0.02–0.002 mm	Whole soil: Gravel (>2 mm)	Textural class
Mt. Pleasant Farm, Dryden, Tompkins Co., N.Y. (Valley Heads drift)												
½–¾	A_{12}	9.3	5.8	3.4	7.3	8.3+	56.1	9.8	35.5	33.3	6	Silt loam.
¾–1	A_{12}–A_2	4.2	3.4	2.3	5.7	8.0+	62.2	14.2	32.9	40.0	9	Do.
1–2	A_2	3.4	2.4	1.8	4.4	6.8	65.6	15.6	32.9	42.2	23	Channery silt loam.
2–16	B_{21}	3.8	2.8	1.7	3.7	5.3	59.0	23.7	26.9	39.7	30	Do.
2–16 [1]	B_{22}	4.9	4.3	2.3	4.7	6.2	58.7	18.9	28.7	39.0	27	Do.
16–20	A'_{2mg}	9.1	7.2	3.8	7.8	6.6	52.2	13.3	32.1	31.5	34	Do.
20–34	B'_{21mg}	7.5	6.1	3.4	6.6	7.8	49.0	19.6	28.9	32.0	33	Do. [2]
34–42	B'_{22mg}	7.4	6.6	3.7	6.8	7.6	47.7	20.2	27.4	31.9	46	Do. [2]
42–52+	C	6.2	5.9	3.0	5.6	6.5	48.7	24.1	24.8	33.7	36	Do. [2]
Near Owego, Tioga Co., N.Y. (Olean drift)												
0–4	A_1	2.0	2.6	1.0	1.6	4.4	65.0	23.4	27.4	42.8	18	Silt loam.
4–6	A_2	3.4	2.7	.8	.9	3.4	66.9	21.9	25.7	45.1	31	Channery silt loam.
6–10	B_1	4.8	3.3	.9	1.0	3.3	64.1	22.6	24.2	43.7	24	Do.
10–16	B_{21}	6.2	3.9	1.2	1.2	3.9	63.1	20.5	24.1	43.5	34	Do.
16–24	B_{22mg}	6.5	4.9	1.4	1.6	4.4	55.3	25.9	24.4	36.1	36	Do.
24–48	B_{23m}	7.6	5.1	1.5	1.5	4.1	53.3	26.9	24.4	35.7	35	Do. [3]
48–54+	B_{24m}	7.8	4.8	1.4	1.4	3.3	54.1	27.2	20.8	37.3	39	Do. [3]

[1] Discontinuous. [2] Close to the silt loam-loam boundary. [3] Close to the silt loam-silty clay loam boundary.

pit at Wysox on the north bank of the Susquehanna River east of Towanda, Bradford County, Pa. (pl. 1, loc. 27). The pit is in a flat-topped terrace about 1 square mile in area and ranges in altitude from about 730 to 740 feet, or about 50 feet above low-water stage of the Susquehanna River. In September 1953 the pit measured roughly 1,300 feet long, 600 feet wide, and 20 feet deep; its south end was being actively worked.

The deposit is primarily pebble gravel in a coarse sandy matrix. Although most of the pebbles are not more than an inch in diameter and few are larger than 2 inches, a few boulders as much as 1 foot in diameter are present. Two boulders, several feet across, were seen on the floor of the pit. The size distribution of a 51-pound sample of gravel dug out of the face of the pit at a depth of 15 feet (fig. 17, loc. 2) was as follows:

Size, in inches	*Percent, by weight*
4	0
4–2	[1]1
2–1	27
1–0.5	30
0.5–0.079	42

[1] Only one pebble.

Most of the pebbles are well rounded—about half are disk shaped and some are nearly spherical. A few angular fragments, apparently broken since deposition, are found near the top of the deposit at depths ranging from 1 to 9 inches.

The lithology of the pebbles in the gravel exposed in the Shiner gravel pit, including the soil horizons, is presented in table 12. Pebbles of chert and black limestone, conspicuous in the gravel, are among those foreign to the region. Although the general aspect of the deposit is massive, faint stratification is present in some lenses of coarse-grained pebbly sand. The stratification in considerable measure reflects changes in the amount, shape, and size of pebbles rather than changes in texture of the matrix. Some of the more disk-shaped pebbles tend slightly toward imbrication, suggesting deposition by currents.

The deposit is leached to depths ranging from 2 to 14 feet, forming a highly irregular contact between calcareous and noncalcareous gravel. Pipes and irregular masses of leached gravel extend down into calcareous material (figs. 17, 18). These irregularities are probably related to the growth and decay of tree roots.

TABLE 12.—*Lithology of pebbles in gravel underlying valley-train terrace, Shiner gravel pit, Wysox, Bradford County, Pa.*

[In each sample the percentages are of the total number of pebbles passing a 1-inch sieve and retained on a ½-inch sieve]

Locality (see fig. 17)	Sample	Depth of sample below ground surface	Soil horizon	Lithologic types (percent): Sandstone and siltstone, olive-gray	Sandstone, red	Sandstone, white, quartzitic	Limestone, black	Limestone and dolomite, pale-gray	Limestone, leached	Chert	Metamorphic rock, gneiss, schist, quartzite	Groups of lithologic types (percent): Noncalcareous sedimentary rock (in part, slightly calcareous)	Calcareous sedimentary rock	Chert and metamorphic rock	Total number of pebbles
		Inches													
2	1	0–9	A_p	60	5	5	0	0	0	23	7	70	0	30	300
	2	15–17	B_1	53	3	12	0	0	5	18	9	73	0	27	271
	3	21–22	B_{21}	54	8	11	0	0	9	11	7	82	0	18	399
	4	44–48	B_{22}	62	4	7	0	0	5	15	7	78	0	22	404
	5	56–62	C	[1]33 / [2]27	[1]3 / [2]2	[1]3 / [2]4	14	2	1	7	4	73	16	11	366
		Feet													
	6	9½	C	55	5	10	8	5	0	14	3	70	13	17	311
	7	15	C	[1]28 / [2]19	[1]4 / [2]2	[1]5 / [2]7	13	4	0	14	4	65	17	18	304
1	8	14	C	46	8	7	19	6	0	10	4	61	25	14	300
5	9	15	C	53	4	7	14	5	0	11	6	64	19	17	373
Average for calcareous part of deposit (C horizon) (samples 5–9)				52.2	5.6	8.6	13.6	4.4	.2	11.2	4.2	66.6	18.0	15.4	
Range for calcareous part of deposit (C horizon) (samples 5–9):															
High				55	8	10	19	6	1	14	6	73	25	18	
Low				33	4	3	8	2	0	7	3	61	13	11	

[1] Slightly calcareous.
[2] Noncalcareous.

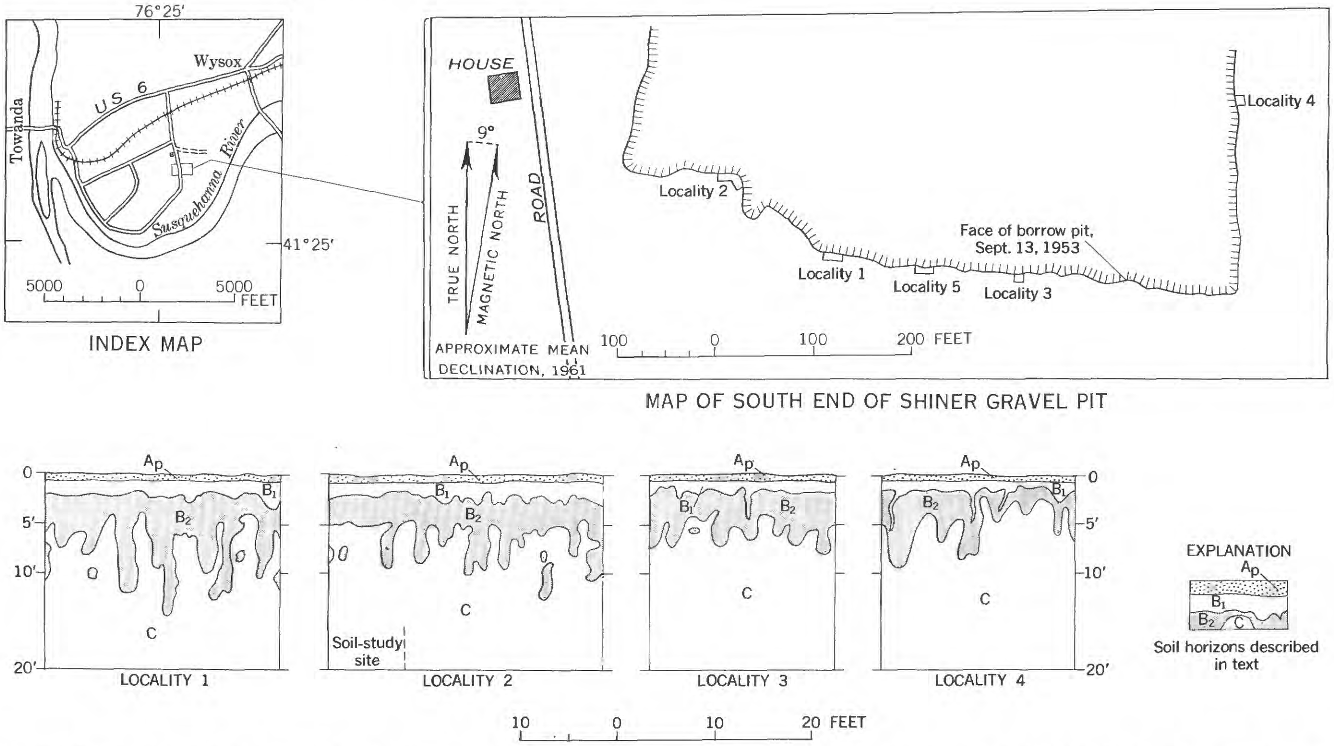


FIGURE 17.—The Howard soil, a member of the Gray-Brown Podzolic great soil group, developed on glaciofluvial deposits underlying a valley train terrace. Sections show soil profile and stratigraphic relations of calcareous and noncalcareous gravel and sand. Depth to free carbonates ranges from 2 to 14 feet. Noncalcareous material extends as tongues and pipes down into calcareous material. Exposure in Shiner gravel pit at Wysox, Bradford County, Pa. (pl. 1, loc. 27).

SOIL PROFILE

The Gray-Brown Podzolic soil developed on the gravel exposed in the Shiner gravel pit at locality 2 (fig. 17) is described here in detail. The kinds of rock that comprise the coarse skeleton are described in table 12.

Howard gravelly loam

Horizon	*Depth (inches)*	*Profile description*
A_p-----	0–9-----	Very-dark-grayish-brown (10*YR* 3/2, moist) gravelly loam; weak, fine, granular structure; very friable; 37 percent by weight pebbles and angular fragments 2 millimeters or greater in diameter; pH 6.5; abrupt, smooth boundary; thickness range 8 to 10 inches (plow layer).
B_1-----	9–20----	Dark-yellowish-brown (10*YR* 4/4, moist) very gravelly loam or sandy loam; very weak, fine, granular structure; very friable or loose; 64 percent by weight coarse skeleton; no clay skins; pebbles with no adhering fine material; vertical earthworm channels filled with A_p horizon material are spaced 5 or 6 inches apart and penetrate 3 or 4 inches; pH 6.3; abrupt, wavy boundary; thickness averages 11 inches, ranges from 9 to 27 inches.
B_{21}-----	20–32--	Dark-yellowish-brown (10*YR* 4/4, moist) very gravelly loamy sand with isolated pockets of yellowish-red (5*YR* 4/6, toward 7.5*YR*, moist) gravelly clay loam; weak, fine, granular structure with no evidence of blockiness; very friable, slightly firmer than B_{21} horizon; loamy sand material has clay bridges between sand particles, clay loam material has smooth shiny clay skins; fine pores in latter material; 64 percent coarse skeleton; pebbles capped with clay loam; no ghosts; pH 6.0 to 6.2; clear, wavy boundary; thickness averages 12 inches, ranges from 0 to 20 inches.
B_{22}-----	32–56--	Dark-reddish-brown (5*YR* 3/4, toward 7.5*YR*, moist, in a few places 5*YR* 3/4) very gravelly clay loam that appears redder than the color name indicates; massive; firm, sticky, and plastic; many 0.1- to 0.2-millimeter diameter yellowish-red (5*YR* 4/6) clay-coated pores; 63 percent coarse skeleton, pebbles capped with clay loam; many, conspicuous soft, porous, leached, silty and clayey ghosts of former calcareous pebbles; many penetrating vertical cylindrical pipes filled with B_1 soil material (fig. 18); pH variable 5.8–7.4; abrupt, irregular, tongued, lower boundary (fig. 17); thickness averages 24 inches, ranges from 1½ to 12 feet.

Howard gravelly loam—Continued

Horizon	*Depth*	*Profile description*
C______	56 in.–20+ft.	Very-dark-grayish-brown (10*YR* 3/3 or 3/2, moist) gravel consisting of coarse sand or loamy coarse sand and pebbles; massive; firm, weakly cemented in most places with secondary carbonate compounds; coarse skeleton about 70–75 percent by weight; a few clay bridges occur just under the B_{22} horizon; very rapidly permeable, pebbles not packed densely; strongly calcareous with 16 percent calcium carbonate equivalent in the less than 2-millimeter size fraction. A few isolated, pale-gray and yellowish-brown silty ghosts and partly softened pebbles occur throughout the deposit.

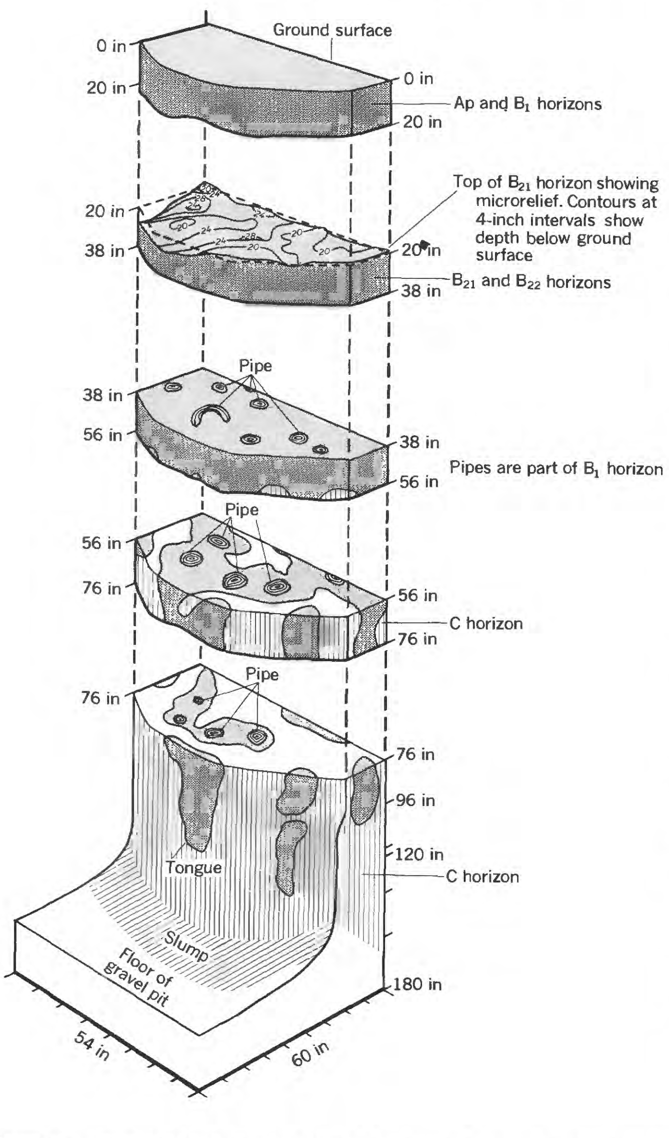


FIGURE 18.—Exploded block diagram showing soil profile of Howard gravelly loam. Tongues of the B_{22} horizon which contain vertical cylindrical pipes filled with B_1 soil material, penetrate the C horizon to a maximum depth of 12 feet. Exposure in Shiner gravel pit at Wysox, Bradford County, Pa. (fig. 17, loc. 2).

HORIZONS OF THE UPPER SOLUM

The uppermost horizon of the soil (A_p) is a plow layer, but at one point in the pit face the following horizons are present between the plow layer and the B_1 horizon. These horizons probably developed below a depression in the ground surface that existed before the land was cleared. Plowing generally destroyed these horizons, except where they existed in a depression and were below plow depth.

Horizon	*Depth below plow layer (inches)*	*Description*
A_{11}_______	0–1	Very-dark-brown (10*YR* 2/2, moist) loam with 5–10 percent pebbles.
A_{12}_______	1–4	Brown (10*YR* 4/3, moist) loam, weak, fine, granular structure; 5–10 percent pebbles.
A_2_______	4+	Yellowish-brown (10*YR* 5/6, moist) gravelly loam, weak, fine granular structure.

PROBABLE EOLIAN MANTLE

As shown in table 13, the plow layer is deficient in gravel when compared to all other horizons of the soil, a fact best explained by assuming dilution with material transported by wind. Indeed, slightly etched ventifacts occur locally just below the plow layer in a 6- to 8-inch lens of sandy material. Leaching alone does not account for the deficiency, since the leached B horizon has as much material larger than 2 millimeters, as does the unaltered C horizon (although it contains few pebbles more than 1 inch in diameter). The addition of 4 or 5 inches of windblown material to the plow layer would dilute the gravel the observed amount.

TABLE 13.—*Reaction, calcium carbonate equivalent, and percentage of coarse skeleton of Howard gravelly loam exposed in Shiner gravel pit at Wysox, Bradford County, Pa.*

Depth (inches)	Horizon	pH	$CaCO_3$ equivalent (percent)	Percentage of coarse skeleton (air-dry weight)			
				Diameter			
				>1 inch	½–1 inch	2 mm–½ inch	>2 mm
0–9________	A_p	6.5	______	1	18	18	37
9–11_______	B_1	6.4	______	8	30	26	64
15–21______	B_1	6.3	______	1	29	29	69
44–48[1]_____	B_1	5.8	______	9	18	37	64
56–64[1]_____	B_1	5.6	______	26	20	17	63
24–28______	B_{21}	6.0	______	3	25	36	64
38–42______	B_{22}	6.6	______	8	22	33	63
44–48______	B_{22}	5.8	______	14	23	30	67
56–62______	B_{22}	7.4	______	40	18	11	69
56–62______	C_1	8.0	16	34	20	14	68
114–120____	C_2	8.2	16	27	25	23	75

[1] Pipe.

CAVITIES AND LEACHED PEBBLES FORMED BY WEATHERING

Three kinds of carbonate-bearing pebbles, ½ to 1 inch in diameter (table 12), occur in the deposit, and each leaves a different residue in the soil when the carbonate is completely leached. Pebbles of calcareous sandstone and siltstone, about 40 percent of the gravel, retain their original shape and about the same color, hardness, and porosity. Pebbles of pale-gray limestone or dolomite, about 4.4 percent of the gravel, when leached leave strong-brown (5*YR* 5/6 and 7.5*YR* 5/6, moist) and yellowish-brown (10*YR* 5/6) soft silty "ghosts" more strongly colored than the surrounding soil horizon, and therefore conspicuous. The ghosts occur only in the B_{22} horizon. Pebbles of black argillaceous limestone, comprising about 14 percent of the gravel, when leached leave a very-dark-brown (10*YR* 3/2 or 2/2, moist), sticky, clayey residue in the bottom of the cavities previously occupied by the pebbles that resembles in appearance the dried-up meat one finds in some English walnuts. These cavities form as much as 10 percent of the B_{22} horizon. The ghosts and cavities are not visible in the B_{21} horizon, presumably because of destruction by tree roots. Their persistence in the B_{22} horizon suggests that there has been very little disturbance, settling, or downward movement of fine material in this horizon. However, destruction of cavities and ghosts in the upper 2 to 2½ feet of the soil implies subsidence, as does the presence of about twice as much chert in the plow layer as in the C horizon. A subsidence of 6 inches, perhaps even 12 inches, is not unreasonable.

The clay residue remaining after carbonate has been leached from the argillaceous limestone or dolomite apparently is the source of most of the clay which accumulates in the B_2 horizons.

EFFECTS OF PRE-EXISTING FORESTS

Remnants of tree roots and stumps are scarce, present only in the upper part of the vertical pipes (fig. 18). At intervals along the pit face, disturbance of the soil indicates that as much as 20 percent of the ground area has been mixed by tree throw, although the trees which fell have long since disappeared (fig. 19). This is shown by part of the finer textured B_{21} horizon that has been displaced upward to a position above the B_1 horizon. Usually this displaced B_{21} horizon is separated from the plow layer by an A_2 horizon that resembles the B_1 horizon except for a slightly paler color. The disturbance destroyed any stratification that once existed and tended to mix clay throughout the profile.

If the soil profile now provides evidence that as much as 20 percent of the ground area has been disturbed by tree throw, it is probable that a much greater proportion has been disturbed since soil development started. Evidence of older tree throws would be destroyed by younger tree throws at the same spot and by the mixing of soil material which takes place when tree roots increase in diameter.

HORIZON BOUNDARIES

Study of the soil horizon boundaries indicates considerable modification by plants. The boundary

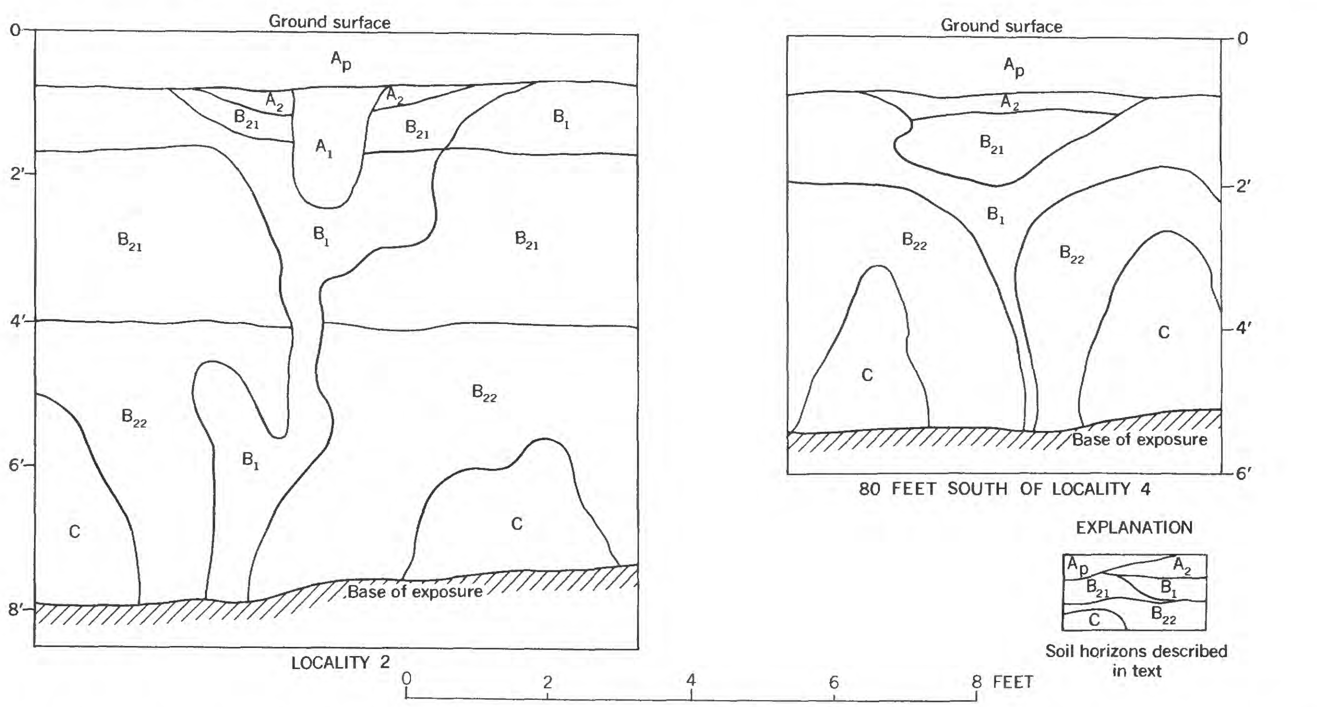


FIGURE 19.—Sections showing soil horizons disturbed by tree throw. Exposure in Shiner gravel pit at Wysox, Bradford County, Pa. Both localities are shown on figure 17.

between the B_1 and B_2 horizons (figs. 17, 18) is a series of mounds and depressions probably fashioned in large measure by tree throw, the base of the B_1 horizon being the bottom of a surface layer that has been disturbed by the roots of trees. The extremely irregular boundary between the B_2 and C horizon is apparently the result of the downward penetration of large roots, now completely disappeared. The nearly vertical pipes thus created localized soil-forming processes and caused the soil horizons to develop convolutions by outward growth from the former roots. Such irregular soil-horizon boundaries are common where the parent material has a farily large proportion of limestone, especially argillaceous limestone (Yehle, 1954). The pipes, occurring as loose sand and pebbles (B_1) within tongues of sticky clay loam (B_2), end upward at the base of old tree stumps now almost completely disappeared, but they persist downward many feet, ending bluntly. Some vertically oriented pebbles near the tops of pipes may have fallen into holes left after roots had decayed, but the sand and pebbles lower down probably were not thus mechanically concentrated; they probably are a residue formed by soil processes which leached and carried away fine material.

The great variation in depth of the B horizon at this pit is illustrated in figure 17. In several places the boundary between the B_2 and C horizons is at a depth of less than 3 feet; in other places the depth is greater than 12 feet, and the maximum observed is 14½ feet. Thickness of solum is not a measure of the age of this soil.

ALLUVIAL SOILS AND SOLS BRUNS ACIDES

The Alluvial soils, which are mapped as the Tioga-Barbour-Chenango-Tunkhannock association, show little or no solum development and are closely related in texture and lithology to the source rock of the alluviums on which they occur. The strongly acid Tioga soils commonly are found in areas where the bedrock is chiefly gray or olive fine-grained sandstone and siltstone, whereas the Barbour soils are in areas where the source rocks are chiefly red. The nearly neutral Chagrin soils are common where the adjacent slopes have contributed calcareous materials to the alluvium. On low terraces and alluvial fans, Sols Bruns Acides have developed and are indistinguishable from soils on glaciofluvial deposits of similar lithology and texture. Chenango and Tunkhannock soils are common on such deposits which are flooded at infrequent intervals.

ORIGIN OF SOILS

Although the soils of the Elmira-Williamsport region owe many of their region-wide features to climate and vegetation, many of the soil differences within the region, even at the great soil group level, are primarily related to kind of parent material and its hydrologic characteristics. Similar soils occur on similar parent material regardless of its age, with the exception of those on flood plains. The soils give no clue as to earlier environments. The soils show only moderate distortions due to root growth and tree throw, although both processes have been active for a long time; thus, the soils must develop or be reconstituted in a short time following such disturbances.

INFLUENCE OF PARENT MATERIAL

The Red-Yellow Podzolic soils occur only on strongly weathered parent material. We believe that these soils, found just outside the Wisconsin drift border, have developed since early Wisconsin time, perhaps some of them in Recent time. Their color and clay-mineral content may have been largely derived from their parent material. The lower B and C horizons of some of these Red-Yellow Podzolic soils may include features inherited from earlier periods of weathering, but other closely associated Red-Yellow Podzolic soils whose parent material consists of mixtures of both fresh and strongly weathered materials unquestionably are younger than the time when such mixing, and therefore such strong weathering, took place.

The argument that the Red-Yellow Podzolic soils in the Elmira-Williamsport region have developed since early Wisconsin time rests on both geologic and pedologic evidence. Scattered remnants of strongly weathered drift and other mantle occur in this area. These deposits are remnants of a once much more continuous strongly weathered mantle which, since weathering, has been in large part either eroded away or buried by or mixed with weakly weathered or unweathered mantle. This has been amply documented by the work of Peltier (1949) and of Denny (1956b). Thus, the possibility of a soil being developed at the ground surface during pre-Wisconsin time and preserved essentially intact to the present time is most unlikely.

The exposure at Penny Hill (p. 30), where the strongly weathered drift lies in a buried gorge, is the most favorable location found thus far for a pre-Wisconsin weathering profile. The weathered horizons in this exposure are very thick, the intensity of weathering gradually decreases downward, and striated stones in the underlying till are still recognizable. Perhaps this till is of pre-Illinoian age; the depth to which it has been weathered is much greater than is common on Illinoian till in the Midwest. However, because the till fills a narrow bedrock gorge, weathering to a great depth may have been facilitated, perhaps by the movement of ground water along the till-bedrock contact.

If the soil profile described here is accepted as being that of a Red-Yellow Podzolic soil, consider the data available on its clay mineralogy and heavy minerals. The greater amount of vermiculite and amphibole at a depth of 16 to 17 feet is unexpected if this soil has not been disturbed and has undergone weathering for a long time. The colluvial mantle on top of the till in the Penny Hill cut indicates that an older weathering profile has been truncated. Thus, it is clear that the Red-Yellow Podzolic soil at Penny Hill, mapped as a member of the Allenwood series is not a relic from pre-Wisconsin time, though some of the features of its B and C horizons may be inherited in part from ancient weathering.

Near the Wisconsin drift border the Red-Yellow Podzolic soils occur side by side with Sols Bruns Acides and Gray-Brown Podzolic soils developed on unweathered or slightly weathered drift and other mantles of Wisconsin and of Recent age. Three facts stand out. First, the soils on parent materials containing no appreciable amount of strongly weathered material are Sols Bruns Acides. Second, the soils on parent materials containing appreciable amounts of strongly weathered material mixed with weakly weathered material are Gray-Brown Podzolic–Red-Yellow Podzolic intergrades. Third, soils entirely on strongly weathered parent material are Red-Yellow Podzolic. Because these three great soil groups may all occur close together, any local difference in climate or in vegetation is too slight to be an explanation of their development in such close proximity. Rather, it appears that parent material has been the prime cause of the differences in soil development in a small area where climate, vegetation, and topography are similar. We conclude that soils classified as Sol Brun Acide, Red-Yellow Podzolic, and Gray-Brown Podzolic–Red-Yellow Podzolic intergrades have formed side by side during the same interval of time and under the same environment. We believe that the Red-Yellow Podzolic soils of the Elmira-Williamsport region have developed in Wisconsin, perhaps some in Recent time, on parent materials that were already strongly weathered.

In other regions, differences between drifts of various Wisconsin substages are reflected in the soils, either in distribution of great soil groups, in amount of clay, in depth of leaching, or in some other feature. However, in the Elmira-Williamsport region, with the exception of the soils on flood plains which have scarcely developed at all, the soils on parent materials of similar lithology and of comparable degrees of drainage are the same regardless of age of drift. The same soils occur on drift of Olean or Valley Heads subages, and we are forced to conclude that any differences that may have existed were obliterated by such processes as mass movement and tree throw. Colluvium mantles the drift in many places (p. 14–16). Since most of the colluvium dates from the building of the Valley Heads moraine (p. 24), most of the soils have formed since late Wisconsin time.

The soils give no clues as to earlier environments. For example, the valley-train terrace of Olean subage near Muncy is one of the oldest surfaces in the region, yet it has a Tunkhannock soil, a Sol Brun Acide, that is essentially the same as the Chenango soil, also a Sol Brun Acide, on the gravel terraces of Valley Heads subage near Owego, N.Y.

Although there are no differences in soils on similar parent materials of different geologic age, local variations in parent material cause marked differences in soils. For example, the contrast between Sols Bruns Acides with nonclayey B horizons and Gray-Brown Podzolic soils with clayey B horizons is striking, particularly where these soils occur on adjacent terrace deposits of about the same age. In some of these places the parent materials of the two soils are virtually identical (see fig. 6), except that the parent material of the clayey soil has more argillaceous limestone.

When the calcareous argillaceous pebbles are leached, a clayey residue remains in the soil. This process can be observed in the lower B horizons of the Gray-Brown Podzolic soils where cavities or ghosts mark the former presence of limestone or dolomite pebbles (p. 49); in many of the cavities there is a residuum of clay, and most of the ghosts are either silty or clayey. These silty and clayey residues become incorporated in the surrounding material when the cavities collapse. Probably the clay in the B horizons of many soils developed on calcareous parent materials of diverse origin was derived in large part from the clay residues of leached limestones.

The amount of coarse skeleton in soil parent materials varies widely, but there is not a commensurate variation in the degree or depth of soil development. For example, in rubbly colluvium or in very gravelly till there is no change in soil development nor any visible difference in properties other than texture when compared with associated soils on parent materials with less coarse material. Also, whether the slope of rubbly colluvium is steep or gentle, the depth of soil is about the same. Nor is there a tendency for Podzols to be more common on rubbly colluvium than on finer textured colluvium or till.

Most steep slopes covered by rubbly colluvium contain many channers or flagstones that locally form small piles on the uphill sides of trees about 60 to 70 years old. This indicates that fragments of rock have moved downslope during the life of the trees. The soils on such slopes, nevertheless, do not differ appreciably in degree of development or in depth of solum from similar soils on gentle slopes where the rate of removal is probably less. These observations indicate either that the soil slips as a mass, which seems unlikely, or that the rate of soil development is rapid enough to keep up with the rate of erosion.

CLIMATE

No evidence of the effect of changes in climate in late Pleistocene or in Recent time was observed in the soils of the region. Likewise, evidence pointing to differences in soil related to microclimatic differences from place to place is very weak.

SOIL FAUNA

Activity of soil fauna, such as earthworms, rodents, millipedes, wireworms, and ants, may cause relatively rapid changes—for example, the destruction of a micropodzol—in the upper part of a soil. Moreover, a Podzol cannot form if the vegetable debris on the forest floor is consumed by animals about as rapidly as it falls and the upper few inches of mineral soil is more or less constantly disturbed.

Great changes in forest fauna may have occurred since settlement, as a result of man's activity. Forests adjacent to cultivated fields, for example, may be invaded by earthworms (Eaton and Chandler, 1942). Earthworm activity is very evident at sites on Mt. Pleasant Farm, near Dryden, N.Y., where a Podzol, observed about 1940 (M. G. Cline, oral communication), had been destroyed by 1954. Thus in a period of about 14 years a marked change in the soil had taken place, probably because of animal activity.

TREE THROW

Tree throw and the resulting disturbance of the soil must be considered in any study of soil development in Northeastern United States (Lutz and Griswold, 1939). Denny and Goodlett (Denny, 1956b) postulate that in Potter County, Pa., most of the soil has been disturbed by this process during the last 300 to 500 years. Yet many exposures of soil show evidence of such distortions in only a few places, indicating either that the rate of tree throw has been greatly overestimated or, more probably, that a rapid rearrangement of soil horizons follows such a disturbance.

Soil horizons developed under forest tend to be discontinuous and variable in thickness, as is shown in the two sections of Mardin and Bath soils on the Mt. Pleasant Farm (fig. 15). The discontinuous segments of B_2 horizons shown in both diagrams are probably the result of tree throw. Near the center of the diagram of the Bath soil, for example, broad tongues of the B_{21} horizon project downward around a segment of the B_{22} horizon which, in turn, surrounds a segment of the B_3 horizon. It is reasonable to suppose that the B_{21} horizon is chiefly material disturbed when trees were uprooted. A small pit about 1 foot deep, shown at the right end of the diagram, is 1 of at least 14 other equally subdued tree-throw pits and mounds present in an area 50 feet square.

The absence of a distinct mound or pit associated with the downward projections of the B_{21} horizon near the center of the Bath soil diagram suggests that the particular tree throw recorded there took place many years ago. That the disturbance of soil by this means is still going on was amply proved in October 1954 when a hurricane passed over the area. Several trees near the trenches were uprooted, and material from the upper part of the very firm B'_{2m} horizon of the Bath soil and from the friable upper horizons was dislodged by the roots.

The evidence of soil disturbance by tree throw at the Mt. Pleasant Farm suggests that the upper 2 to 3 feet of the soil has been disturbed by tree throw several times during the thousands of years since the Valley Heads ice disappeared. But in spite of repeated disturbance, soil-forming processes seem to have been able to efface the damage of tree throw, suggesting that the formation of these soil horizons is a relatively rapid process.

ROOT GROWTH

The hypothesis that certain soil horizons form rapidly is supported by other evidence. When a tree root or a tree stump decays, the cavity that remains is seldom visible for long. Some process, such as root growth, acts to fill or compress the cavity, and no trace is left. In forested areas probably all parts of the solum at one time or another have been penetrated by roots. As roots grow, soil material is pushed aside, rearranged, and redistributed (Stout, 1956). Effects of tree throw that are centuries old are ultimately effaced. Such stirring of the ground is the process that Shaler called the "subsoil plow" (Shaler, 1892). Soils developing on all but the most recent tree-throw mounds also demonstrate that processes now going on tend to renew, repair, or develop the soil. Thus, the soil horizons found today beneath the forest have formed rapidly.

Such rapidity of soil development under forest cover may result in part from previous conditioning. It is quite possible that a disturbed solum can be redeveloped much more rapidly than a solum could develop from unweathered parent material. This hypothesis of rapid soil reconstitution may explain the presence of well-developed soils, such as those of the Red-Yellow Podzolic great soil group, in materials that doubtless were profoundly disturbed in Wisconsin time.

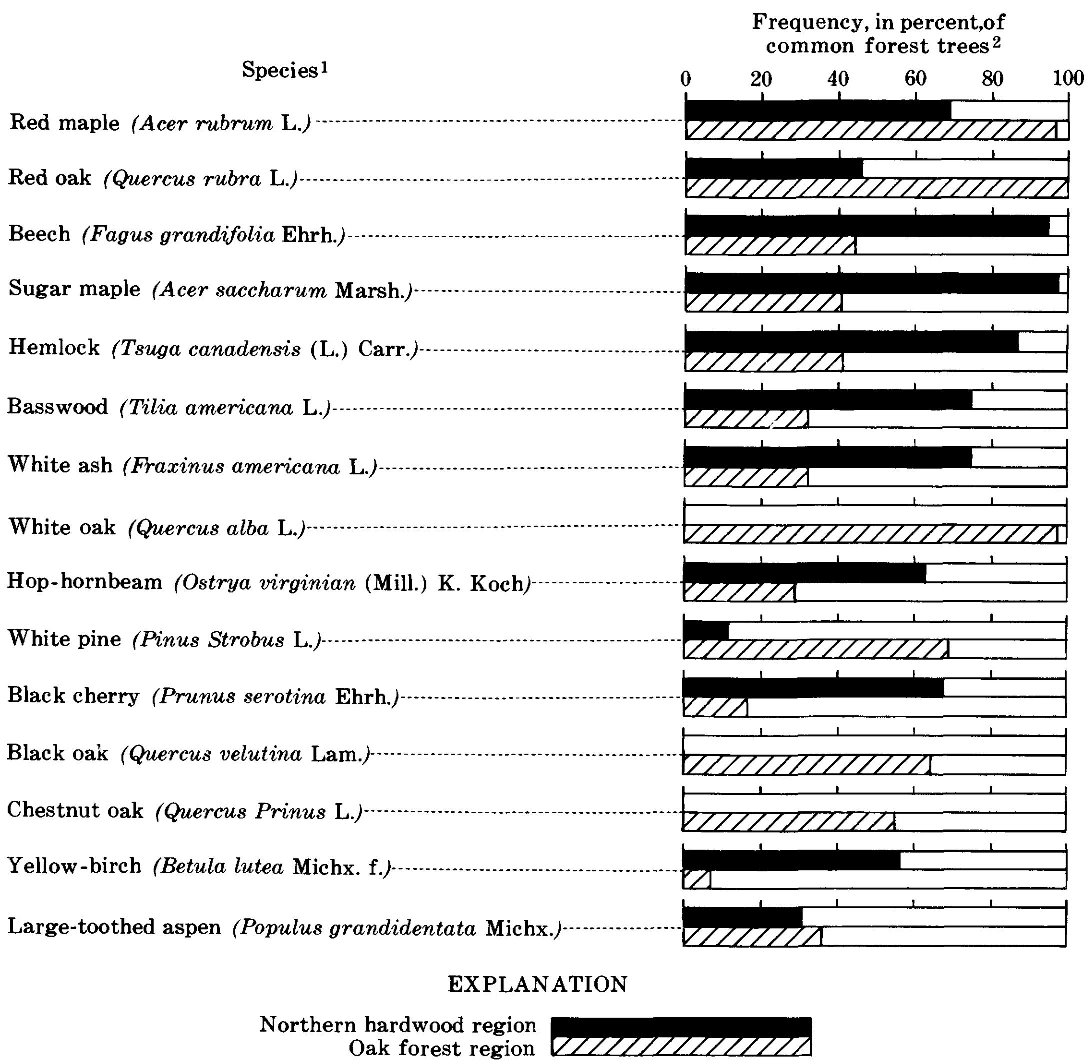
FOREST REGIONS AND GREAT SOIL GROUPS

By John C. Goodlett and Walter H. Lyford

Some of the data gathered during the first field season suggested a close coincidence between certain great soil groups and forest types. To investigate this suggestion, Goodlett, during 1954, made a reconnaissance study of the vegetation and prepared a vegetation map of the region (pl. 6). Goodlett and Lyford also studied concurrently the soil and the vegetation in a limited number of localities. A comparison of the soil map and the vegetation map, however, shows no close relationship between the distribution of the units on either map. The character and distribution of the forest regions and a comparison of their distribution and that of the great soil groups is summarized below.

The vegetation of the Elmira-Williamsport region has been mapped in New York by Bray (1915) and in Pennsylvania by Illick and Frontz (1928). A later map of the entire region by Hough and Forbes (1943) is essentially a combination of the two earlier ones, but is not entirely satisfactory because the two maps did not use quite the same map units. A new vegetation map of the region was prepared for the present study. The map units are essentially those of Illick and Frontz (1928, p. 9), who state in part:

The white oak is found to be the most important indicator-tree of the oak-chestnut forest growth of northern Pennsylvania. Wherever this tree occurs in considerable numbers in Pennsyl-



[1] Listed in order of abundance, from the species found at the greatest number of areas sampled to that present at the smallest number.

[2] Frequency is the number of localities at which a species is found compared to the total number of localities sampled in that region.

Figure 20.—Common forest trees of the Elmira-Williamsport region. These species are present in the forest canopy in at least 25 percent of the 66 localities sampled; the sampling was about equally divided between the two forest regions. The canopy is the upper level or roof of the forest formed by the leafy branches of the taller trees. Nomenclature follows that of Fernald (1950).

vania, other oaks, chestnut, and additional hardwoods, typically southern in range, are also found. Such stands are assigned to the oak-chestnut growth, while those containing few or no specimens of white oak are classified within the beech-birch-maple type.

In plate 6, the oak forest region includes forest where at least some white oak is present, and the northern hardwood region includes forest where white oak is absent, or at least it was not observed. The northern hardwood region is further subdivided on the basis of the presence or absence of red oak. These map units have been used previously by Goodlett (1954) to map the forest regions of Potter County, Pa., immediately west of the region considered here.

The forest regions were mapped largely on the basis of the kind of forest in areas that had never been plowed; the areas are easily recognized because of a distinct microrelief of mounds and pits caused by tree throw. Because many of the trees in these unplowed areas originated as sprouts from roots and stumps of an older generation of trees, the regions mapped probably outline major differences in the forests as they existed before lumbering or agriculture.

Figure 20 gives some idea of the species composition of the forests. Within the northern hardwood region, most forest stands consist predominantly of sugar maple, beech, basswood, hemlock, and white ash, although red oak, red maple, yellow birch, and black cherry are abundant in places. Forests in the oak forest region, on the other hand, consist largely of various kinds of oak and red maple. White pine is the most abundant conifer. In the oak forest region, the forest ground cover generally contains many heath plants such as mountain laurel (*Kalmia latifolia*), blueberries (*Vaccinium vacillans*, *V. angustifolium*, *V. stamineum*), and wintergreen (*Gaultheria procumbens*), which are essentially lacking from the northern hardwood forest. The ground cover in the oak forest region thus tends to be shrubby, whereas the ground cover in the northern hardwood region consists predominantly of ferns and low herbaceous perennial flowering plants.

Comparison of forest regions (pl. 6) with great soil groups (pl. 5) shows little relation between the two. Podzols and Sols Bruns Acides, for example, occur in both forest regions. However, Podzols on plateau tops often support northern hardwood forest. Where these Podzols are underlain by conglomerate of Carboniferous age, the forests usually lack oak trees. Gray-Brown Podzolic soils, mostly confined to the valleys of larger streams in the northern part of the region, generally support only oak forest. In an area of Sols Bruns Acides along the Susquehanna River between Elmira and Owego, N.Y., where oak forest generally grows on the lower valley walls and northern hardwood forest at higher altitudes, some minor contrasts in the soils are perhaps related to changes in vegetation. For example, the occurrence of thin Podzol sola over Sols Bruns Acides corresponds so closely with this change in forest type that the soil change may be a response to vegetation rather than to other factors.

GLOSSARY

Alluvial soils. An azonal group of soils developed from transported and relatively recently deposited material (alluvium), characterized by a weak modification (or none) of the original material by soil-forming processes.

Association, soil. An area of land composed of one or more soil types that occur in a characteristic pattern. The association may consist of soils that are similar or that differ widely in important characteristics. Each soil association, however, has a certain repetitive pattern of the same important soil type or types, and other features that give it a characteristic landscape.

Boundary, soil horizon. The surface or transitional layer that marks the limits of a soil horizon. The boundary is described by its distinctness or width and by its topography.

The terms used to describe distinctness or width are as follows:

Abrupt.—less than 1 inch thick.
Clear.—1–2½ in. thick.
Gradual.—2½–5 in. thick.
Diffuse. More than 5 in. thick.

The terms used to describe topography are as follows:

Smooth.—Nearly a plane.
Wavy.—Pockets with width greater than depth.
Irregular.—Pockets with depth greater than width.
Broken.—Discontinuous.

Calcium carbonate equivalent.—The percentage of calcium carbonate that would be present if all the carbonate in the material were in the form of calcium carbonate.

Catena, soil. A group of soils within one zonal region developed from similar parent material but differing in solum characteristics owing to differences in relief or drainage.

Channers. Thin, flat, angular fragments of rock other than slate, shale, or chert, ranging from 0.079 in. (2 mm) to 6 in. in maximum diameter. Fine channers are 2 mm–3 in. in diameter; coarse channers are 3–6 in. in diameter. A single piece is called a fragment.

Channery soils. Soils that contain channers of rocks other than slate, shale, or chert.

Chroma. The relative purity or strength of the spectral color. This increases with decreasing grayness (sometimes called saturation).

Clay skins. Coatings of oriented crystalline alumino silicate clays. They are commonly found on ped surfaces and in pores. The orientation of the clay is parallel to the ped surface and in thin sections has an abrupt boundary with the unoriented matrix. Under a hand lens the clay skins typically look like tallow which has run down the side of a candle and hardened. They may or may not contain significant amounts of organic matter.

Colluvium. A general term applied to loose and incoherent deposits of rock fragments and finer material accumulated at or near the base of slopes chiefly through the influence of gravity.

CONSISTENCE. The degree of cohesion and adhesion of soil particles or their resistance to separation or deformation of the aggregate. In practice these properties are distinquished by the feel of the soil and the ease with which a lump is crushed by the fingers. Terms commonly used to describe consistence are as follows:

Loose.—Noncoherent.

Friable.—When moist, crushes easily under moderate pressure between thumb and forefinger, and coheres when pressed together.

Firm.—When moist, crushes under moderate pressure between thumb and forefinger, but resistance is distinctly noticeable.

Plastic.—When wet, readily deformed by moderate pressure, but cohesive; wire can be formed.

Sticky.—When wet, adheres to other material; usually very cohesive when dry.

Hard.—When dry, moderate resistance to pressure; barely breakable between thumb and forefinger.

Cemented.—Hard and brittle, and little affected by moistening.

Brittle.—Breaks with a sharp clean fracture, or, if struck a sharp blow, shatters into cleanly broken hard fragments.

DRAINAGE, NATURAL. Natural drainage refers to those conditions which existed during the development of the soil as opposed to altered drainage, which is commonly the result of artificial drainage or irrigation but may be due to natural causes, such as sudden deepending of channels and sudden blocking of drainage outlets. The following relative terms are used to express natural drainage: excessively drained, somewhat excessively drained, well drained, moderately well drained, imperfectly or somewhat poorly drained, poorly drained, and very poorly drained.

FLAGSTONE. Thin, flat, angular fragments of rock other than slate, shale, or chert, ranging from 6 to 15 in. in maximum diameter.

FRAGIPAN. Compact horizons rich in silt, sand, or both, and generally with a low clay content. They occur in many gently sloping or nearly level soils in humid, warm-temperate climates. The fragipan commonly interferes with root penetration. When dry, the compact material appears to be cemented, but the apparent cementation disappears when the soil is moistened. Fragipans occur in soils developed from either residual or transported parent materials.

A fragipan is a loamy subsurface horizon usually underlying a B horizon. Organic-matter content is very low, with a high bulk density relative to the solum above; seemingly cemented when dry, having hard or very hard consistence, but when moist, it has a weak or moderate brittleness (a ped tends to rupture suddenly rather than undergo slow deformation as increasing pressure is applied). It is mottled, slowly or very slowly permeable to water, and usually has occasional or frequent bleached cracks that form polygons. Fragipans are usually found with abrupt or clear upper horizon boundaries 15 to 40 inches below the original surface, vary from a few inches to several feet in thickness, and have gradual or diffuse lower boundaries. They are nearly free of roots except for the bleached cracks. Clay skins are scarce to common both in the polygonal cracks and in the interiors of the peds. In soil descriptions and in diagrams a subscript "m" is added to the major horizon letter to differentiate these fragipan horizons.

GRAY-BROWN PODZOLIC SOILS. A zonal group of soils having a comparatively thin organic covering and organic-mineral layers over a grayish-brown leached layer which rests upon an illuvial brown horizon; developed under deciduous forest in a temperate moist climate.

GREAT SOIL GROUP. A group of soils having common internal soil characteristics; includes one or more families of soils. Among the zonal soils, each great soil group includes the soils having common internal characteristics developed through the influence of environmental forces of broad geographic significance, especially vegetation and climate; among the intrazonal soils, each great soil group includes the soils having common internal characteristics developed through the influence of environmental forces of both broad and local significance; among the azonal soils each great soil group includes similar soils that are without developed characteristics owing to the influence of some local condition of parent material or relief.

HORIZON, SOIL. A layer of soil approximately parallel to the soil surface, with characteristics produced by soil-forming processes. Horizons are identified by letters of the alphabet.

A horizon.—A master horizon consisting of (1) one or more surface mineral horizons of maximum organic accumulation; or (2) surface or subsurface horizons that are lighter in color than the underlying horizon or that have lost clay minerals, iron, and aluminum with resultant concentration of the more resistant minerals; or (3) horizons belonging to both of these categories.

A_1 horizon.—A surface mineral soil horizon having a relatively high content of organic matter mixed with mineral matter; usually dark in color. It may or may not be a horizon of eluviation.

A_2 horizon.—A surface or subsurface horizon, usually lighter in color than the underlying horizon, has lost clay minerals, iron, or aluminum, or all three, with the resultant concentration of the more resistant minerals. It is a horizon of eluviation—of leaching materials out in solution and suspension.

B horizon.—A master horizon of altered material characterized by (1) an accumulation of clay, iron, or aluminum with accessory organic material; or (2) more or less blocky or prismatic structure together with such characteristics as stronger colors that are unlike those of the A or the underlying horizons of nearly unchanged material; or (3) characteristics of both of these categories.

C horizon.—A layer of unconsolidated material, relatively little affected by the influence of organisms and presumed to be similar in chemical, physical, and mineralogical composition to the material from which at least part of the overlying solum has developed.

D horizon.—Any stratum underlying the C horizon (or the B if no C is present) that is unlike the C horizon or the material from which the solum has been formed.

Gleyed horizon.—A strongly mottled or gray horizon that occurs in wet soils. It is designated by the letter "g" used in conjunction with A, B or C (for example, Bg).

HUMIC-GLEY SOILS. An intrazonal group of poorly to very poorly drained hydromorphic soils with dark-colored organic-mineral horizons of moderate thickness underlain by mineral gley horizons.

INTERGRADE SOIL. A soil which possesses characteristics definitive for two great soil groups. The soil is named for both with the first name the name of the great soil group which the soil resembles most closely. For example, Gray-Brown Podzolic–Red-Yellow Podzolic intergrade soils possess definitive characteristics of both great soil groups, but resemble

Gray-Brown Podzolic soils more closely than Red-Yellow Podzolic soils.

LOW HUMIC-GLEY SOILS. An intrazonal group of imperfectly to poorly drained soils with very thin surface horizons, moderately high in organic matter; overlies mottled gray and brown gleylike mineral horizons with a low degree of textural differentiation.

MATERIAL, MODERATELY WEATHERED. *See* Material, unweathered.

MATERIAL, STRONGLY WEATHERED. *See* Material, unweathered.

MATERIAL, UNWEATHERED. The terms unweathered and weakly, moderately, and strongly weathered as used in this report refer to the relative amount of decomposition of mineral grains or rock fragments visually judged to have taken place in a deposit.

Unweathered material.—Shows little or no evidence of decomposition.

Weakley weathered material.—Exhibits a rind or outer shell different in color and generally softer or harder than the interior. In the case of mineral grains this outer material may be only a fraction of a millimeter thick, whereas it may range from paper thin to one-half inch thick on some rock fragments. Generally the outer shell is redder, browner, yellower, or grayer than the interior.

Strongly weathered material.—Generally loose or weakly cemented, or breaks easily compared to fresh rock; it is generally altered in color to a depth of 6 or 8 in. Commonly the altered part is red, brown, or yellow, generally having Munsell values and chromas of 5 to 8.

Moderately weathered material.—Has characteristics that are intermediate between weakly weathered and strongly weathered material.

MATERIAL, WEAKLY WEATHERED. *See* Material, unweathered.

MICROPODZOL. A Podzol with distinct gray A_2 and reddish-brown B_2 horizons, but with the entire solum only about 1 to 2 in. thick. Commonly occur at the surface of the mineral soil.

MOTTLING, SOIL. Contrasting color patches that vary in number and size. Descriptive terms are as follows: Contrast, *faint, distinct,* and *prominent;* abundance, *few, common,* and *many;* size, *fine,* commonly less than 5 mm in maximum diameter; *medium,* ranging from 5 to 15 mm in maximum diameter; and *coarse,* commonly more than 15 mm in maximum diameter.

ORTERDE. *See* Ortstein.

ORTSTEIN. Hard, irregularly cemented dark-yellow to nearly black sandy material formed by soil-forming processes in the lower part of the solum. Similar material, not firmly cemented, is known as orterde.

PARENT MATERIAL. The unconsolidated mass from which the solum develops.

PED. An individual natural soil aggregate.

PODZOLS. A zonal group of soils having an organic mat and a very thin organic-mineral layer above a gray leached layer which rests upon an illuvial dark-brown horizon; developed under a coniferous or mixed foest, or under heath vegetation in a temperate to cold moist climate. Iron oxide, alumina, and, at some places, organic matter have been removed from the A horizon and deposited in the B horizon.

PROFILE, SOIL. A vertical section of the soil through all its horizons, extending into the parent material.

REACTION, SOIL. The degree of acidity or alkalinity of the soil mass, expressed as pH or in words:

	pH
Extremely acid	<4.5
Very strongly acid	4.5–5.0
Strongly acid	5.1–5.5
Medium acid	5.6–6.0
Slightly acid	6.1–6.5
Neutral	6.6–7.3
Mildly alkaline	7.4–7.8
Moderately alkaline	7.9–8.4
Strongly alkaline	8.5–9.0
Very strongly alkaline	≧9.1

RED-YELLOW PODZOLIC SOILS. A group of well-developed well-drained acid soils having thin organic (A_0) and organic-mineral (A_1) horizons over a light-colored bleached (A_2) horizon, over a red, yellowish-red, or yellow and more clayey (B) horizon; parent materials are all more or less siliceous. Coarse reticulate streaks or mottles of red, yellow, brown, and light gray are characteristic of deep horizons of Red-Yellow Podzolic soils where parent materials are thick.

RESIDUUM. Surficial material derived by weathering from the bedrock on which it lies.

SERIES, SOIL. A group of soils that have genetic horizons similar (except for the texture of the surface soil) in differentiating characteristics and arrangement in the soil profile and are developed from a particular type of parent material. A series may include two or more soil types that differ from one another in the texture of the surface soil.

SKELETON, COARSE. That part of the soil material composed of particles greater than 2 mm in diameter. The part of the soil 2 mm or less in diameter is often referred to as fine earth.

SOLS BRUNS ACIDES. A group of acid soils having thin organic (A_0) and organic-mineral (A_1) horizons over yellowish-brown or brown (B) horizons which commonly exhibit blocky structure but have essentially no accumulation of clay or iron and aluminum compounds. The singular is written Sol Brun Acide.

SOLUM. The upper part of the soil profile above the parent material. In this part of the profile, the processes of soil formation take place. The plural form is sola.

STRUCTURE, SOIL. The arrangement of the soil particles into lumps, granules, or other aggregates. Structure is described by grade (weak, moderate, or strong), that is, the distinctness and durability of the aggregates; by the size of the aggregates (very fine, fine, medium, coarse, or very coarse); and their shape (platy, prismatic, columnar, blocky, granular, or crumb). A soil is described as structureless if there are no observable aggregates. Structureless soils may be massive (coherent) or single grain (noncoherent). The terms used to describe shape are as follows:

Blocky, angular.—Aggregates are block shaped; they may have flat or rounded surfaces that join at sharp angles.

Blocky, subangular.—Aggregates have some rounded and plane surfaces; vertices are rounded.

Columnar.—Aggregates are prismatic and are rounded at the upper ends.

Crumb.—Generally soft small porous aggregates; irregular, but tend to be spherical, as in the A_1 horizons of many soils. Crumb structure is closely related to granular structure.

Granular.—Roughly spherical firm small aggregates that may be either hard or soft, but are generally more firm than crumb and without the distinct faces of blocky structure.

Platy.—Soil particles are arranged around a horizontal plane.

Prismatic.—Soil particles are arranged around a vertical line; aggregates have flat vertical surfaces.

TREE THROW. The toppling of trees by any process, such as wind or snow.

TREE-THROW MOUNDS. The mass of material raised by roots when trees fall. When the tree roots decay, the material slumps and commonly forms a circular or oval mound ranging from a few feet to as much as 20 feet in diameter and from a few inches to several feet in height.

TYPE, SOIL. A group of soils that have genetic horizons similar in differentiating characteristics, including texture and arrangement of the soil profile, and developed from a particular type of parent material.

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