GEOLOGICAL SURVEY OF OHIO

WILBER STOUT, State Geologist

Fourth Series, Bulletin 38

GEOLOGY OF HIGHLAND COUNTY

by

JAMES K. ROGERS

COLUMBUS

1936

BLANK PAGE

CONTENTS

Chapter IV—Detailed Descriptions of Localities

Chapter V—Economic Geology

Tables

Figure

Map

BLANK PAGE

INTRODUCTION

The field work on which this report and the accompanying geologic map of Highland County are based was carried on for the Geological Survey of Ohio in the summers of 1929 and 1930. In 1929 the writer spent a month and a half in the field, and in 1930 two months. Previously, parts of the geologic mapping of Bainbridge quadrangle had been done by Professor W. H. Bucher and by Mr. I. M. Streeter and Miss Irene Chrisman under his direction.

The writer is indebted to Dr. Wilber Stout, State Geologist, for making possible this work, and for his active interest during its progress; to Professor Walter H. Bucher for directing the investigation, for visiting the field on numerous occasions, for aid in the interpretation of all the important problems, for valuable suggestions concerning the preparation of the manuscript, and for other assistance without which the conduct of the work would have been impossible; to Professor Nevin M. Fenneman for time spent in the field and aid in coping with the glacial problems, and for criticism of the manuscript; to Professor W. H. Shideler for establishing certain of the Ordovician formation limits; and to many others who have given material assistance in the field studies and the preparation of this report.

CHAPTER I

PHYSICAL FEATURES

LOCATION AND AREA

Highland County is located in southwestern Ohio, between north latitudes 39° 1′ and 39° 23′, and between west longitudes 83° 20′ and 83° 53′. It is bounded on the north by Clinton and Fayette counties, on the east by Ross and Pike, on the south by Adams and Brown, and on the west by Brown County. Its area is 558 square miles.

POPULATION AND INDUSTRY

The population of the county was 25,416 according to the 1930 Federal Census. Hillsboro, the county seat, has a population of 4,040; Greenfield has 3,871 inhabitants. The northern part of the county is crossed by the Baltimore and Ohio Railroad, with a branch line extending from Blanchester to Hillsboro. A branch of the Norfolk and Western Railway extends from Sardinia to Hillsboro. The predominant industry is agriculture, for which the northern and western parts of the county are, on the whole, best fitted.

RELIEF

The highest elevation within the county is Washburn Hill, east of Marshall, 1,334 feet above sea level; and the lowest point is along Baker Fork at the county line south of Sinking Springs, slightly less than 700 feet. The tops of high hills in the eastern part of the county are approximately 1,300 feet. The upland elevations in a north-south belt west of these hills vary from 950 to 1,050 feet, rising somewhat to the westward with the dip of the rock formations. Southwest of Hillsboro the summits reach 1,200 feet and more, and in the northwest part of the county the upland levels are around 1,150, with low relief. West of the meridian of Fairview the elevations are about 1,000 feet, and there are very extensive flat areas.

DRAINAGE

Highland County is drained through Paint Creek, a tributary of Scioto River, and through Ohio Brush Creek, Whiteoak Creek, and East Fork of Little Miami River, all parts of the Ohio drainage system. Rattlesnake Creek flows southeastward across the northeastern part of the county to join Paint Creek, and Rocky Fork has its headwaters a little west of the center of the county and flows eastward, then northeastward to its junction with Paint Creek. Approximately one-half the area of the county is drained by Paint Creek and its tributaries. The southward-flowing headwaters of Ohio Brush Creek drain about one-fifth of the county in the southeastern part, and those of Whiteoak Creek drain a similar area in the southwestern part. The drainage of Little Miami River includes about one-tenth the area of the county in its northwestern part. There is thus a drainage pattern roughly radial from a small area five miles southwest of Hillsboro, which is the highest part of the cuesta made by the Bisher and Lilley formations.

RELATION TO PHYSIOGRAPHIC DIVISIONS

Most of Highland County is included in the Till Plains section of the Central Lowland physiographic province.[1] A narrow strip at the east border of the county is in the edge of the Kanawha section of the Appalachian Plateau province, of which the western boundary is along the dissected escarpment formed here by the Mississippian rocks. Irons Mountain, Fort Hill, and other high hills are remnants of this escarpment. The small unglaciated area at the southeast corner of the county mostly belongs with the Lexington Plain section of the Interior Low Plateaus province, but includes an area of only a few square miles.

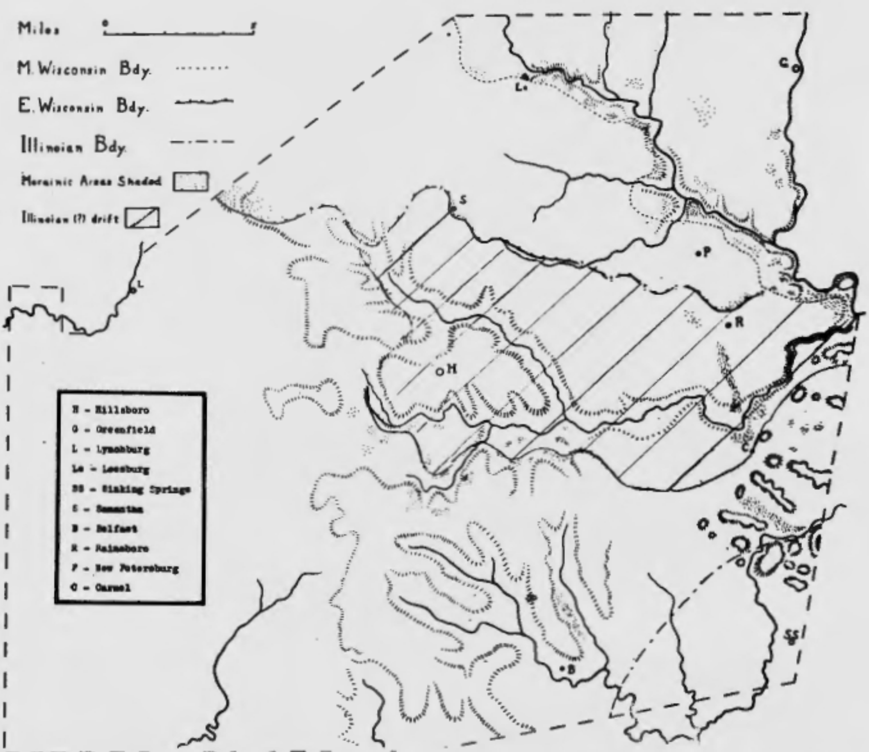


FIGURE. Relation of boundaries of the drift sheets to relief features in Highland County

[1] Fenneman, N. M., Map, Physical divisions of the United States, U. S. Geol. Survey, 1928.

PHYSIOGRAPHIC DESCRIPTION

Basis of Description

On the basis of topography and physiography, the surface of the county was divided by Orton [1] into five parts, which agree in part with the distribution of the various rock series.

In the present report, five physiographic areas are recognized within the county, but with somewhat different grouping from that of Orton. These include two cuestas with a lowland strip between; the area of flat till plains in the lowland strip between; the area of flat till plains in the western part of the county; and a small area of extremely complex structure southwest of Sinking Springs, a part of the Serpent Mound cryptovolcanic structure.[2] (For the stratigraphic column in Highland County, see p. 55).

West-facing Cuestas

The gentle eastward dip of the rock formations in this region, which lies on the east flank of the Cincinnati geanticline, gives the belts of outcrop of the various stratigraphic units a general north-south trend. The more resistant formations produce dissected cuestas or hilly areas above an extensive peneplain, now represented by accordant summit levels to the eastward and somewhat masked by thick drift deposits in the Till Plains to the north and west. Of these irregular, dissected cuestas, the more important ones in this region include one formed by the Bisher and Lilley dolomites and another by the Waverly sandstones. The former extends north and south across the central part of the county and is most prominent west of Hillsboro, where hills of the Bisher and Lilley formations rise about a hundred feet above the nearly flat areas of the Brassfield and upper Ordovician rocks. Calebs Hill, east of Danville, and the low hill northeast of Russell are outlying remnants of this cuesta. Although the remnants of its scarp slope are fairly well defined, if irregular, there is not such a definite dip slope, due partly to the fact that the overlying Peebles dolomite is of about the same degree of resistance to weathering as the Lilley, and partly to the deeper and more complete dissection of the cuesta itself than of the areas immediately east and west of it. There is, however, a distinct decline of summit levels to the eastward, as for instance from the vicinity of Hillsboro or New Market to that of New Petersburg or Harriett.

A study by means of a series of projected profiles shows the Waverly cuesta, or Appalachian Plateau margin, to be of a character similar to that of the Bisher-Lilley cuesta, but much more prominent. Thus it

[1] Orton, Edward, The geology of Highland County: Geol. Survey of Ohio, Report of Progress in 1870, p. 260, 1871.

[2] Bucher, W. H., Cryptovolcanic structure in Ohio of the type of the Steinheim basin (abst.): Geol. Soc. America Bull., Vol. XXXII, pp. 74-75, 1921.

seems probable that the same peneplain is represented by the bedrock surface beneath the Till Plains in southwestern Ohio, by at least a part of the accordant levels between the Bisher-Lilley and Waverly cuestas, and by the accordant summits a few miles east of the latter, within the Appalachian Plateau. This corresponds to the Worthington peneplain described by Ver Steeg,[1] while the accordant levels at the top of the Waverly cuesta or escarpment appear to represent the Harrisburg peneplain. The Waverly cuesta is represented in Highland County only by such outliers as Irons Mountain, Washburn Hill, and Fort Hill. In Ross and Pike counties, its width varies from 6 to 8 miles, and it rises from 300 to 400 feet above the peneplain surface east and west of it. Its irregular scarp slope is always abrupt; but the dip slope has typically an inclination of 40 feet per mile, as measured by the accordant summits.

Region Between the Cuestas

This is a roughly triangular area between the two cuestas, which diverge to the northward within Highland County. Its western boundary is not well defined, but may be taken arbitrarily as a line from New Vienna through Boston to Sinking Springs. The eastern boundary is more definite, following along the western base of Fort Hill, Washburn Hill, and other outliers of the Waverly cuesta. The topography within this area is of low relief except where it is trenched by Rocky Fork and Rattlesnake Creek, which have cut from 100 to 150 feet below the uplands. The bedrock topography of the northern portion is partly obscured by a thick mantle of glacial drift, but the valleys of the major streams are cut in bedrock, and numerous low bedrock hills which rise above the general level have only a thin veneer of glacial drift. Such low monadnock hills are found south and southwest of Leesburg and at Elliott School, south of Greenfield, and there are numerous other examples. To the southward, the drift becomes thinner and disappears altogether northwest of Sinking Springs. There is neither a sharp topographic contrast nor a clearly defined boundary between the glaciated and unglaciated portions; but the area covered by Wisconsin drift is somewhat more poorly drained than the rest and contains more extensive flats.

Flat Till Plains

West of the Bisher-Lilley cuesta and including nearly a third of the county is an area of moderately thick Illinoian drift, for the most part flat and poorly drained. It is only slightly trenched by the tributaries of Whiteoak Creek and the East Fork of Little Miami River, and has no conspicuous elevations above the general level except at its eastern margin, where there are a few outliers of the Bisher-Lilley cuesta and very low,

[1] Ver Steeg, Karl, Erosion surface of eastern Ohio: Pan-Am. Geologist, Vol. 55, p. 186, 1931.

scarcely noticeable hills or benches capped by the Brassfield formation. Bedrock outcrops are scarce, and the topography is almost entirely drift-controlled; yet, from the few rock exposures and from the well records, it is probable that the rock surface is nearly or quite as flat as that of the glacial drift over considerable areas, representing a nearly perfect peneplain on the weak Ordovician shales and limestones.

Minor Physiographic Features

Within the hilly, deeply-dissected belt of the Bisher-Lilley cuesta, the configuration of the slopes is largely determined by the behavior of the several rock formations in erosion, except locally where the glacial deposits are so thick as to control the topography. The tributaries of Ohio Brush Creek, with relatively steep gradients, have cut most deeply below the original upland level and are presumably eroding most rapidly at the present time. Along them the topographic expression of alternately weak and resistant rock units is particularly pronounced. Where the streams flow east or southeast (down the dip or obliquely to it), the rock benches have about the same relations to the stream for considerable distances, as for instance along West Fork of Ohio Brush Creek from near its headwaters most of the way to the Adams County line. The stream flows on weak shale of the Elkhorn and Whitewater formations, with the Brassfield limestone forming a wide, prominent bench from a few feet to fifty feet above it. This wide bench, below which the stream has cut its comparatively narrow valley bottom, gives an impression of rejuvenation, but is apparently only the normal expression of the resistant Brassfield formation between the weak shales. Limestone sinks are fairly common in the wider parts of the Brassfield terrace.

Above the Brassfield bench or terrace, the Crab Orchard shale has a characteristically concave slope. Its base usually extends well out on the Brassfield terrace; the gradient gradually increases in steepness up to the base of the Bisher formation, the profile of the slope resembling part of a parabola. This profile is remarkably constant wherever the Brassfield, Crab Orchard, and Bisher formations outcrop on the same hillside, suggesting an equilibrium between gradient and soil creep as the factor determining the configuration of the slope.

The typical shale of the Crab Orchard formation weathers rapidly to give a soft, "sticky" clay regolith, nearly white at the surface and green underneath. It absorbs water readily, forming a greasy or soapy mass, which often gives rise to landslides when slopes are artificially disturbed, or even in the normal processes of erosion. In eastern Kentucky, the belt of outcrop forms an area of unstable slopes, tending to produce low-angle slides. On drying out, the weathered clay forms a hard crust several inches thick over the moist, plastic clay at depth, cracks from 1 to 3 inches in width and extending to depths of 1 or 2 feet are fairly common. The relatively great volume changes in alternate absorption of moisture and drying, together with the plasticity of the clay, favor extensive soil creep on slopes as low as 1 foot fall in 30 feet, thus explaining the uniformity of slopes over the lower part of the formation and, in part at least, the great width of the Brassfield terrace along Ohio Brush Creek and its tributaries. The steeper slopes over the upper Crab Orchard shale are presumably due to the stronger character of the overlying Bisher formation.

The contact between the Crab Orchard and Bisher formations is nearly always marked by a conspicuous topographic break. This change of slope, together with the frequent occurrence of small springs at the top of the Crab Orchard, makes this contact the most easily recognized horizon within the Silurian system in Highland County, and the most reliable for geologic mapping. At a few localities, however, the lower 5 to 10 feet of the Bisher is so shaly and non-resistant as to resemble the Crab Orchard in topographic expression.

The ridges in the central dissected belt of the county are mostly capped by the Bisher or Lilley formations, except at the eastern margin, where the Peebles is usually present. While somewhat different in lithology, the Bisher and Lilley dolomites are similar in topographic expression, both tending to form flat-topped ridges with moderately steep sides under such conditions as prevail in the maturely eroded region south of Hillsboro. Limestone sinks are of frequent occurrence on some of these ridges, as for instance near the county line southeast of Fairfax. While numerous foreign pebbles and boulders occur on the flat ridge tops, indicating that all but the southeastern corner of the county was covered by glacial ice, the soil is probably in part, at least, residual or only slightly affected by glaciation in the southern part of this hilly belt. In physical characteristics, it differs from that of the areas covered by thicker and more typical Illinoian drift, being redder in color, somewhat less loamy in texture, and more readily subject to erosion on slopes.

The upper part of the Lilley formation resembles the Peebles in its massive character and its physiographic expression: hills and ridges capped by these units are more apt to be rounded than flat-topped and are generally covered by only a thin mantle of glacial drift. The Lilley outcrops more frequently than any of the other units mapped, particularly in the vicinity of Hillsboro. Where the upper Lilley and Peebles dolomites have been cut through by streams, their massive character and the almost complete absence of bedding in the Peebles have resulted in a tendency to form vertical or even overhanging cliffs. Because of this tendency, the two formations were formerly called the "Blue Cliff" and "White Cliff" dolomites, respectively.

In the hilly belt of outliers of the Waverly cuesta, the topographic expression of the rock formations is again pronounced. North of Stultz Hill, the valleys have a considerable amount of filling of morainic and glacio-fluvial material. Above this rise the steep slopes of Olentangy and Ohio shales to their capping of lower Mississippian sandstones. The longer ridges, such as Irons Mountain and Long Lick Hill, have nearly flat tops with abrupt shoulders and steep sides. The top of the Ohio shale is usually marked by a slight shoulder and a change in vegetation, the higher slopes on the Waverly being more thickly covered with underbrush in many cases. Vegetation along this shoulder appears to be particularly affected by a severe drought, such as that of the summer of 1930, when the hills were encircled at this level by narrow girdles of trees with brown, withered foliage.

BLANK PAGE

CHAPTER II

GLACIAL GEOLOGY

PRE-ILLINOIAN PHYSIOGRAPHIC HISTORY

The Summit Peneplain

As has already been pointed out, the summit levels of the greater part of the hills in Highland County show accordance over small areas, but it is only by considering regions larger than a single county that the presence of a peneplain may be established. A study by means of projected profiles suggests that there is only a single erosion surface of low relief in this region, represented by the accordant levels of summits within this part of the Appalachian Plateau and by the rock surface of low relief underneath the adjacent Till Plains, the so-called "Plateau Front" and other deeply dissected cuestas representing areas of more resistant rock never reduced to the peneplain level.

The age of this summit peneplain may be a matter of some doubt. In Vinton County, about 60 miles east of the area in question, the summit peneplain has been designated by Stout[1] as the Harrisburg peneplain, from correlation with the peneplain in western Pennsylvania considered to be the Harrisburg. According to Stout, "...this peneplain apparently correlates with the Harrisburg of Pennsylvania and rises gradually in that direction from an elevation of 1,060 feet in Vinton County to 1,270 feet in Columbiana County, Ohio, to 1,400 feet in Armstrong County, Pennsylvania, to 2,200 feet in Potter County, Pennsylvania, which is the dome of greatest uplift." After extensive studies by means of projected profiles, Ver Steeg[2] considers the accordant summits on the Bainbridge quadrangle at elevations of 900-1,000 feet (corresponding to the peneplain mentioned above) to represent the Worthington, and those at 1,200-1,300 feet (corresponding to the top of the Waverly cuesta) the Harrisburg peneplain, respectively.

Major Valleys and Drainage Changes

The major valleys of Highland County include those of Paint Creek and its tributaries, East Fork of Little Miami River, Whiteoak Creek, and Ohio Brush Creek. All of these have been altered in course to a greater or less extent by glaciation; but in the majority of cases the evidence as to the precise location of the old drainage lines is scant or has

[1] Stout, Wilber, Geology of Vinton County: Geol. Survey of Ohio, 4th Series, Bull. 31, pp. 34-37, 1927.

[2] Ver Steeg, Karl, Erosion surface of eastern Ohio: Pan-Am. Geologist, Vol. 55, p. 186, 1931.

not yet been found. Among the writers who have contributed to the knowledge of preglacial drainage in southern Ohio are James,[1] Wright,[2] Tight,[3] Fowke,[4] Leverett,[5] Fenneman,[6] Stout,[7] and others. The most comprehensive works dealing with this particular region are those of Tight and Leverett.

Of the various drainage systems within the county, Paint Creek and its tributaries offer the most satisfactory evidence of preglacial conditions. According to Fowke,[8] the valley of the present Rattlesnake Creek was followed by a preglacial stream to a point about a mile below the present junction with Paint Creek; from this point it continued almost in a straight line southeast to approximately a mile east of the Ross County line, where it again joined the present Paint Creek. Thus the old channel cut across two loops of the present course of the stream. In the upper one of these, it is doubtful whether the former stream course differed as much from the recent one as the author has shown, but in the lower one, where the stream turns abruptly northeastward in a rock gorge, a mile and a half north of The Point, the old channel is unmistakable.

Quoting from Fowke:

". . . Rattlesnake [Creek] is flowing in a pre-glacial valley which was filled with drift from the junction of Paint Creek to this deep pool three-quarters of a mile east of the Ross County line . . . and . . . after seeking outlets in various directions as shown by abandoned channels and minor terraces, it finally escaped along its present crooked way, regaining its former bed by cutting out the limestone which had made its southern boundary, washing downstream the gravel that it found filling the present pool and making with it a dam which retains the water . . ."

In the prominent loop of Paint Creek north of The Point, the top

---

[1] James, J. F., A brief history of the Ohio River: Pop. Sci. Monthly, Vol. 38, pp. 730-748, 1891.

[2] Wright, G. F.

[3] Tight, W. G., Drainage modifications in southeastern Ohio: U. S. Geol. Survey Prof. Paper 13, p. 111, 1903.

A preglacial tributary to Paint Creek and its relation to the Beech Flats of Pike County, Ohio: Denison Univ., Sci. Lab., Bull. Vol. 9, pp. 25-34, 1 pl., 1895.

[4] Fowke, Gerard, Preglacial and recent drainage channels in Ross County: Denison Univ., Sci. Lab., Bull. Vol. 9, pp. 15-24, 1895.

[5] Leverett, Frank, Glacial formations and drainage features of the Erie and Ohio basins: U. S. Geol. Survey Mon. 41, 1902.

——— Changes in drainage in southern Ohio: Denison Univ., Sci. Lab., Bull. 9, pt. 2, pp. 18-21, 1897.

[6] Fenneman, N. M., Geology of Cincinnati and vicinity: Geol. Survey Ohio, 4th Ser., Bull. 19, 1916.

[7] Stout, Wilber, Geology of Vinton County: Geol. Survey Ohio, 4th Ser., Bull. 31, pp. 16-42, 1927.

[8] Fowke, Gerard, op. cit., p. 17.

of the rock gorge is at a higher level than the floor of the channel cutting across the loop. This and the clear-cut form of the channel, as if it had been eroded rather than filled, suggest that the original blocking of morainic material which caused the diversion around the loop may have been of Illinoian age, and that the channel itself was occupied for a time by Wisconsin marginal drainage.

Lee's Creek, a tributary of Rattlesnake Creek, appears to have been diverted from its old course east of Leesburg and is now flowing in a rock gorge for about a mile and a half. The former course of the stream appears from the topography to have been only a quarter to half a mile north of the gorge. The age of this drainage change is not definitely established; it may have been produced by Early or Middle Wisconsin ice, or possibly by the Illinoian. Small channels in the gravelly Middle Wisconsin drift south of Lee's Creek may represent marginal drainage at the time when the stream was originally diverted, or at a later time when the ice margin had advanced across this creek.

The valley of Paint Creek at Greenfield is much too wide to have been eroded in postglacial or even post-Illinoian time. It is carved in bedrock, but the valley sides, which have a gradual slope, are covered with moderately thick glacial drift. The fact that the valley widens to the north suggests that the preglacial drainage was in that direction, although it should be noted that the gorge north of the junction with Rattlesnake Creek is cut in the Bisher, Lilley, and Peebles dolomites, which have a strong cliff-forming tendency, while at Greenfield the rock above stream level is mostly the Greenfield dolomite, with less of a tendency to form cliffs. The widening of the valley to the north is even more pronounced, however, from Greenfield northward, and its headwaters converge, in going upstream, with those of North Fork of Paint Creek and other southeastward-flowing streams. The upper part of North Fork was demonstrated by Fowke[1] formerly to have drained toward the northwest from a col near Frankfort.

Most of the valley of Rocky Fork is preglacial; but the stream from McCoppin Mill to the junction with Paint Creek has been crowded to the southward by glaciation, presumably by the Illinoian glacier, and now flows in a rock gorge with steep, almost vertical walls. Its former course is problematical, but may have extended from the sharp bend a mile northwest of McCoppin Mill and a little south of Rainsboro to the vicinity of its present junction with Paint Creek, or to the lower end of the valley of Plum Run.

The largest tributary of the preglacial Paint Creek appears to have been a stream entering it from the Beech Flats, an extensive nearly flat area in Pike, Ross, and Highland counties, which now drains to the southwestward to Baker Fork through a narrow gorge west of Fort Hill.

[1] Fowke, Gerard, op. cit., p. 22.

This drainage change was mentioned by Fowke [1] and best described by Tight.[2] The following is quoted from Tight's conclusions regarding the history of Beech Flats:

". . . prior to the advent of the ice, the present location of Beech Flats was represented by a valley with numerous smaller tributary valleys, all tributary to the valley of Paint Creek. The heads of these valleys were D, E, N, etc. At all of these points were cols connecting with adjacent drainage basins. As the ice advanced southward, planing and filling, it made the great drift plain of northern Ross and Highland counties and of Pickaway, Fayette, Franklin, and Madison and other counties to the northward as its comparatively level ground moraine. It reached across the preglacial valley of Paint Creek west of Bainbridge and pushed a great tongue of ice into Beech Flats valley. As this tongue advanced into this valley it divided again and again sending fingers along the tributary valleys clear to their headwaters. Under these ice fingers was deposited the drift of the Beech Flats as a ground moraine. The spur which first separated from the main stream of ice crossed the col at D and probably joined the main mass of the ice sheet beyond Barrett's Mills. The next spur passes up the valley west of Cynthiana. . . . The waters formed in the Beech Flats valley found two outlets. One taking the water from the ice mass in the valley west of Cynthiana developed the gorge by cutting down the col (east of Sparger Hill). The main volume of the water flowed over the col (west of Fort Hill) and developed the Brush Creek gorge . . ."

From the narrowness and apparent recency of the gorge of Baker Fork above Sinking Spring, and from the lack of evidence of its production by an earlier ice sheet, it seems probable that the Beech Flats drainage change was produced by the Illinoian glacier.

The preglacial course of the upper part of East Fork of Little Miami River is shown by Tight [3] as not greatly different from the present, although the lower part of this stream has been completely changed. Whiteoak Creek also appears to have the same general course within Highland County as before glaciation; its valley, like that of Little Miami River, in this county, between the head of the permanent stream and county line, has a gradient of about 8 feet per mile compared to 17 feet per mile for Ohio Brush Creek. While all three streams have been rejuvenated by drainage changes, the rejuvenation of Little Miami River and Whiteoak Creek has not yet extended headward far enough to affect the portions of these streams in Highland County; although Ohio Brush

[1] Fowke, Gerard, op. cit.

[2] Tight, W. G., A preglacial tributary to Paint Creek and its relation to the Beech Flats of Pike County, Ohio: Denison Univ., Sci. Lab. Bull., Vol. 9, pp. 25-34, 1895.

[3] Tight, W. G., op. cit.

Creek and its tributaries have not only been rejuvenated clear to their headwaters, but have eroded much of their drainage basin within this county to an early mature stage.

The former course of Ohio Brush Creek is not clearly indicated by the present topographic evidence. According to Tight's diagram,[1] the preglacial Brush Creek flowed northwestward from a point near West Union, probably joining Cincinnati River somewhere north of Dayton. According to this interpretation, its long, narrow drainage basin was crowded between those of Cincinnati and Teay's rivers, and the stream itself must have followed approximately along the Bisher-Lilley cuesta, the highest land for some distance in either direction. A glance at the topographic maps of Highland County shows that such a course would have been impossible. In his more detailed map,[2] Tight shows only the headwaters of the old Ohio Brush Creek, with a col southwest of West Union, indicating that it must have been reversed north of this point. This col is not readily noticeable on the Peebles topographic map and its locality was not visited by the present writer; but from the topographic evidence of the region and the altitudes of the floors of the larger valleys, it seems more probable that the former drainage of Ohio Brush Creek was toward the east or south. According to Fowke,[3] ". . . the [preglacial] headwaters of Paint [Creek] must be sought to the southwest, possibly as far away as even Brown or Clermont County, for all the streams rising in the area which may formerly have been drained by this lost part of Paint Creek flow southward or westward through gorges or narrow troughs in their whole course, none having the broad valley so characteristic of this. Mr. H. W. Overman, of Waverly, pointed out years ago that the drainage of Ohio Brush Creek was reversed, its natural course being to the north instead of to the south. The same will probably be found true of other streams still more to the west." The former drainage of any large area northeastward to Paint Creek through Beech Flats is apparently precluded by the elevation of the rock surface in the channel north of Fort Hill, which is higher than some of the uplands to the southwest, and by the narrowness of the head of Beech Flats valley. It is doubtful whether any large part of the former drainage from the headwater region of Ohio Brush Creek was eastward through Sunfish Creek or Scioto Brush Creek, because of the narrowness of the valleys of these streams.

The presence of Illinoian drift in the valleys of Ohio Brush Creek and its tributaries in the southern part of Highland County indicates that these valleys were eroded to about their present form before the Illinoian glaciation. Furthermore, the failure of these streams to remove thick drift deposits from their valleys (as along Elm Run) shows that the

[1] Tight, W. G., op. cit.

[2] Tight, W. G., op. cit., Pl. XVII.

[3] Fowke, Gerard, op. cit., p. 18.

amount of bedrock erosion in post-Illinoian time must have been very slight. Considering these various factors, there is ground for believing that Ohio Brush Creek may have had approximately its present course in preglacial time, with the upper part of its valley eroded to early maturity in southern Highland County; in which case, the rejuvenation which produced the narrow gorge in Adams County would probably date back to the evolution of the present Ohio River gorge.

UNGLACIATED AREA

A small area of perhaps a dozen square miles, in the southeast corner of the county, was not covered by the ice, and received no fluvioglacial deposits. In addition, the tops of such hills as Jones Hill, Irons Mountain, and others farther south do not appear to have been glaciated, though the glacial deposits extend well up on the sides of some of them, particularly on Jones Hill, Long Lick Hill, and Head's Hill.

In this unglaciated area, the chief topographic features include the hills which are remnants of the dissected Waverly escarpment, typified by those mentioned above, the hills of the Serpent Mound cryptovolcanic structure, and the narrow gorge of Baker Fork. The outliers of the Waverly escarpment are made up of Ohio shale, with a capping of Waverly shale and sandstone.

The characteristics of the residual soil over the soft Crab Orchard shale have already been mentioned. This formation outcrops along the bed of Baker Fork and within the area of the Serpent Mound structure. The Bisher formation often has a reddish soil, with chert fragments and silicified fossils scattered over the surface at many localities; and some parts of the Lilley weather similarly to a red, sticky soil. One or more zones in the Peebles formation within the unglaciated area are less solid than the rest and readily crumble to a soft regolith which is essentially unweathered, being mainly of calcium and magnesium carbonates. This dolomite is locally called a marl, and is used to some extent as a land plaster, for its lime content, also as a substitute for gravel in road building. The base of the Ohio shale, which usually directly overlies the Peebles in this part of the county, has typically brownish ferruginous crusts, often with considerable quantities of white halloysite. On the tops of the low hills northwest of Sinking Springs, these and scattered blocks of the Hillsboro sandstone mark the upper limit of the Peebles, even where the black shale is not present.

ILLINOIAN DRIFT

Extent and General Characteristics

Nearly 300 square miles, or more than half the area of Highland County, is covered by drift of undoubted Illinoian age; in addition to this, a considerable area of the remainder is doubtfully assigned to the

Illinoian. Within much of the area of its extent, the Illinoian drift is represented on the map only in isolated patches, the intervening areas being mapped as bedrock. Thus in the hilly region south and southeast of Hillsboro, the drift is shown only where its thickness is relatively great, or where it obscures the underlying rock to such an extent as to make mapping of the latter impossible. In the southeastern part of the county, near the drift margin, the bedrock is so near the surface that no drift is mapped, although its presence may be easily recognized in the field. The Illinoian till plains at the west margin of the county have in general a greater thickness of drift, which almost completely conceals the non-resistant Ordovician formations; but it is probable that the bedrock topography has no great amount of relief, and that the thickness of the drift is fairly uniform.

According to Leverett,[1] "The Illinoian drift sheet presents a remarkably flat surface. There are few prominent knolls and no definite morainic ridges except those on the border above described. Much of the surface is so level as to be imperfectly drained. This is especially true in northern Clermont and Brown and adjacent parts of Warren, Clinton, and Highland counties, Ohio. . . .

"The very flat surface is found in the part of this region which is underlain by limestone. . . . In the limestone region there appears to have been a gently undulating upland surface similar to that of the 'blue grass' region of Kentucky, where only the valleys of the main streams and the lower courses of the tributaries are deeply trenched below the uplands. The drift is sufficient usually to fill the shallow valleys, and in some cases it has so completely filled deep preglacial valleys that their courses are traced with difficulty. Among the sandstone hills it has only partly filled the valleys, though its thickness is nearly as great as in the region underlain by limestone."

In its typical development, the Illinoian drift has definite characteristics which readily distinguish it from the Wisconsin. Leverett[2] describes it as consisting "very largely of a compact till. Sand or gravel beds have some development where valleys have been filled, but are very rare on the uplands. Where the till is less than 20 feet in depth its color is a yellow or brown, but if of greater thickness a blue-gray till is usually found beneath the yellow. The yellow till appears to be simply an oxidized part of a sheet which was at first blue. Its texture and the number and kind of rock constituents are so similar to those of the blue till that a separation from that till seems called for only on the ground of difference in color. . . .

"Both the yellow and the blue portions of the till sheet are harder

[1] Leverett, Frank, Glacial formations and drainage features of the Erie and Ohio basins: U. S. Geol. Survey Mon. 41, p. 271, 1902.

[2] Leverett, Frank, op. cit., p. 272.

than the till of Wisconsin age. This is very apparent to persons who have sunk wells in the region of overlap and to anyone passing south from the Wisconsin to the Illinoian area. The indurated character of the Illinoian drift is apparently due to a partial cementation with lime, for the till contains a large amount of fine calcareous material ground from the limestone. The Illinoian till is also characterized by fissures to a much greater extent than the Wisconsin. The fissures extend down from the yellow into the blue portion and are filled with yellow or oxidized clay.

"The Illinoian drift appears to have been deposited in this border tract with very little abrasion of the rock surface. There are occasional exposures of residuary clay between the blue till and the rock, and in many places a very rotten rock surface at the base of the drift. Occasional well sections pass through a black mucky clay, probably a preglacial soil, immediately below the blue till and a few feet above the rock."

While the bluish gray color and noticeable hardness of the Illinoian till, compared to the slate gray or brownish gray color and lesser hardness of the Wisconsin, are frequently of aid in differentiating the drift sheets, their use as criteria for identification of the Illinoian is limited by the scarcity of exposures deep enough to show the unweathered till and by the variations of color and hardness with changes in moisture content. In most cases, the Illinoian must be recognized by the character of its weathering products and by the depth of leaching, as shown in natural or artificial sections. Several measurements are given by Leverett[1] of which the most typical is the following, generalized from exposures near Sardinia:

	Feet
"1. Clay or silt, nearly free from pebbles	2-4
2. Brown till, deeply oxidized and streaked in places with brownish-black seams	3-4
3. Yellow till, usually very stony and slightly cemented; striated limestone pebbles numerous; not so highly oxidized as No. 2	6-8
4. Blue till, very stony and partially cemented; striated limestone pebbles numerous; color very deep blue, almost black in places	10-15"

In numerous localities within the poorly drained areas of Illinoian drift within Highland County, the following generalized section is typical:

	Feet
1. Surface soil; yellowish gray to light gray "mealy" clay, some chert pebbles near base, some black organic matter; grades downward into (2)	1-3
2. Gray and brown variegated clay, or gray clay streaked with brown; highly plastic; some chert pebbles, some manganese and iron oxides near base	3-7
3. Dark red, highly oxidized plastic clay, often sandy, with chert and igneous pebbles; manganese streaks	1-3

[1] Leverett, Frank, op. cit., pp. 273-275.

		Feet
4.	*A.* Red, sandy clay as above, with chalky dolomite pebbles....	½-1
	B. Hard brownish to reddish clay with limestone pebbles; effervesces readily with dilute acid..........................	2-5
5.	Hard, bluish gray unoxidized till, effervesces strongly with dilute acid	....

This corresponds approximately to the gumbotil profile of Kay.[1] In the hilly or well-drained areas of the county, the silt till and mesotil profiles of Leighton and MacClintock [2] are developed. Zone I was found in Highland County only in poorly drained areas of the Illinoian drift. It constitutes the so-called "white clays" found on upland flats of southern Ohio. The origin of these white clays has long been a subject of controversy. They were first described by Orton,[3] who assigned their origin in large part to the action of plants and animals in bringing up the fine mineral matter and leaving it on the surface. According to this view, the surface clays are residual products of the weathering of the drift sheet itself. Some of the fine white clays, however, were deemed by Orton to have been deposited in water, because of their fineness of grain and homogeneity.

The most extensive study of these clays and of the Illinoian glacial deposits with which they are associated has been made by Leverett, whose interpretation of their origin has been widely accepted. The following is quoted from Leverett's description:[4]

"The compact silt extends eastward in a practically continuous sheet from Illinois over southern Indiana, southern Ohio, and the neighboring portions of Kentucky and West Virginia, and is the surface deposit as far north as the border of the Wisconsin drift sheet. It is known to underlie the Wisconsin drift, numerous exposures having been found beneath that drift.

"This silt has long been recognized in the glaciated districts of southwestern Ohio and southeastern Indiana. In the Ohio reports it is referred to as the 'white clay,' and in the Indiana reports as 'slash land.' . . . In the writer's examination in southeastern Ohio and neighboring parts of West Virginia and Kentucky, in 1896, it was found that the silt occurs as far east as Parkersburg, W. Va. . . .

[1] Kay, G. F., Some features of the Kansan drift in southern Iowa (abst.): Geol. Soc. America Bull., Vol. 27, pp. 115-117, 1916.

——— The relative ages of the Iowa and Wisconsin drift sheets; Am. Jour. Sci., 5th Ser., Vol. 21, pp. 158-172, 1931.

——— and Apfel, E. T., The pre-Illinoian Pleistocene geology of Iowa: Iowa Geol. Survey Vol. 34, 1929.

[2] Leighton, M. M., and MacClintock, Paul, Weathered zones of the drift sheets of Illinois: Jour. Geology Vol. 38, pp. 28-53, 1930.

[3] Orton Edward, Geology of Clermont County: Geol. Survey Ohio, Vol. 1, Pt. 1, pp. 440-445, 1873.

[4] Leverett, Frank, Glacial formations and drainage features of the Erie and Ohio basins: U. S. Geol. Survey Mon. 41, pp. 295-6, 1902.

"The extent of this silt northward beneath the Wisconsin drift is undetermined. It has been found at some distance back from the border, both in southeastern Indiana and southwestern Ohio."

Concerning the characteristics of the white clay, Leverett[1] says:

"The color of the silt is a distinguishing characteristic, for it is in striking contrast with both the underlying till and the residuary clay, and is remarkably uniform throughout its entire extent in this region. It is generally of a pale yellow or ashy color from top to bottom, the soil as well as the subsoil being pale and light colored. . . .

"The name silt indicates that this deposit is of fine texture. Ordinarily it contains no grains or rock fragments sufficiently coarse to be detected by the naked eye, but in a few places occasional small pebbles have been noted in it, usually near the bottom of the deposit. The rarity of these pebbles raises the suspicion that they may not be normal to the deposit. In some cases they may have been brought up from the underlying till by burrowing animals long after the silt was laid down; but in other cases they seem to have been brought in during the process of deposition. A few were found in the unglaciated parts of southeastern Ohio, where their presence seems difficult to explain unless they were laid down with the silt. The pebbles are generally of quartz, though a few other very resistant rocks are represented; this is true of pebbles in both the glaciated and unglaciated tracts."

The origin is considered by Leverett to be through a combination of wind and water deposition, more or less similar to the loess of the Mississippi Valley, and Orton's theory of its origin is rejected partly because of its inadequacy to account for the thick loess deposits farther west.

The white clays are linked, at least in part, with the loess in origin also by Fenneman,[2] who points out the relation which would obtain between fineness and thinness of the deposit and distance from the source of supply in the case of wind deposition. Instead of their derivation from a distant source, however, he shows that ". . . it is possible to conceive of the greater part of an eolian deposit as being laid down not for from the place where the material was picked up." In a footnote he adds: "Since this was written, a study of similar deposits in Iowa has caused certain careful observers to entertain the hypothesis that they are residual soil derived from the decay of the drift beneath. This hypothesis and the suggestion here made of local to and fro shifting do not exclude each other. Even if all the factors mentioned should be involved, further investigation is necessary to determine their relative importance."

More recently, the origin of white clays has been reviewed by

---

[1] Leverett, Frank, op. cit., pp. 297-8, 1902.

[2] Fenneman, N. M., Geology of Cincinnati and vicinity: Geol. Servey of Ohio, 4th Ser., Bull. 19, pp. 140-145, 1916.

Westgate,[1] who concludes that they ". . . are due to the weathering on upland flats of the upper two feet or so of the mantle rock, whether that mantle rock is till or residual soil derived from either limestone or sandstone." This contention is based on several lines of evidence. The first of these comes from the findings of soil students that in mature soils, such as those of the poorly-drained uplands where the white clays occur, climatic and other conditions are the determining factors in producing a soil type, while original mineralogical composition is a minor and negligible factor. The second is the reported finding of similar white clays within the area of the Wisconsin drift in two localities. (One of these localities, near Rainsboro, is referred with some doubt to the Illinoian in the present work.) The third is the occurrence of the white clays on the unglaciated uplands in Adams County, which are underlain by several different rock formations. The fourth line of evidence, based on mineralogical examination of samples of the white clays from over Illinoian drift and various rock formations, lies in the finding of only such minerals as might have been derived from the underlying material by weathering *in situ,* together with recognizable differences in mineral composition over different materials. The apparently complete gradation of the white clay downward into the underlying material, particularly in the case of the Illinoian drift, is also noted.

While the evidence cited seems best to support the origin of the white clays from the weathering *in situ* of the underlying rock or drift, there is nothing which necessarily precludes the possibility of a part of these clays being eolian in origin. Further light may very likely be shed on the problem when the loess deposits of the Mississippi Valley have been studied in greater detail.

Below the white clay is a gray and brown mottled or streaked plastic clay (Zone 2 of the section), which is particularly characteristic of the Illinoian drift within this area. It grades upward into Zone 1 and downward into the red clay of Zone 3 without any sharp contact, and is obviously the product of long weathering of the original material of the drift. It appears to be a constant unit of the less gravelly phases of the Illinoian and is frequently present in the gravelly drift as well. The fact that it often reaches a thickness of many feet and is largely devoid of igneous pebbles emphasizes the great age of the Illinoian drift, as compared to the Wisconsin, in which it is not recognized as a characteristic unit. Where it is mainly gray in color, this zone occasionally resembles the unweathered drift in appearance, but is of lighter color and never effervesces with acid. It corresponds to the gumbotil of Kay.[2]

---

[1] Westgate, L. G., White clays or upland-flat soils of southern Ohio: Geol. Soc. America Bull.. Vol. 41, pp. 329-340, 1930.

[2] Kay, G. F., Some features of the Kansan drift of southern Iowa (abst) : Geol. Soc. America Bull., Vol. 27, pp. 115-117, 1916.

Unlike Zone 2, the red clay of Zone 3 may be duplicated in the oxidized portions of the Wisconsin drift; but in the latter it is found at a much shallower depth. Its color varies from brown to dark red; it often has a coarsely sandy appearance; and is hard when dry, but moderately plastic when wet. Pebbles of chert and igneous rock are common, the latter usually somewhat decomposed, but limestone pebbles are absent. Black streaks, seams or small pockets of manganese oxide, are fairly common, but not limited to this zone.

In Zone 4, chalky dolomite pebbles appear. The more thoroughly decomposed of these usually do not effervesce with acid, but this zone grades downward into material which effervesces strongly. Compared to the other zones, this is of slight thickness, but it is important in marking the depth of leaching.

Below Zone 4, oxidation usually extends for a number of feet. The reddish color frequently disappears very gradually, so that the depth of oxidation is indefinite, particularly in porous sandy or gravelly material, where it sometimes reaches 15 to 20 feet or more.

Where slopes are being rapidly eroded, the upper zones are generally absent, and the unweathered till may be exposed. Ordinary gullying on slopes, which is particularly common in the hilly area south of Hillsboro, is mainly confined to Zone 2, the gray and brown mottled clay. In gravelly material, small gullies show reddish or brownish stained gravel, usually without limestone pebbles.

The depth of leaching of the Illinoian drift is generally not readily determined in the flat till plains, because of the scarcity of exposures to a sufficient depth to show unleached material. In the hilly region, it is highly variable, but with a few exceptions, to be considered later, it is usually between 6 and 15 feet.

Marginal and Intra-Marginal Features

The margin of the Illinoian drift within Highland County is not marked by a distinct terminal moraine, but rather by a thinning out and final disappearance of the drift, without topographic break between the glaciated and unglaciated areas. Within the Beech Flats area, however, morainic accumulations are found only a short distance from the outer margin of glaciation. The Beech Flats drainage change has already been mentioned. (See p. 20.)

The glacial filling of the Beech Flats basin consists in part of stratified gravel and clay, both of which are deeply weathered. Some of the clays are perhaps of lacustrine deposition, as for instance, those exposed along the highway between Sinking Springs and Cynthiana, just west of the county line. The gravel deposits which represent the Illinoian outwash form an extensive terrace in the valleys north of Washburn Hill, Long Lick Hill, Irons Mountain, and McNary Hill. The terrace tops slope gradually toward the southeast. The depth of leaching in these terrace materials varies from 8 to 12 feet, with oxidation extending several feet farther. Small knolls rising above the general outwash level are fairly common, particularly toward the northwest, and appear to be morainic or kame-morainic in origin. In the present work they are all referred to the Illinoian, although Leverett[1] describes the hills "on the north side of Beech Flats, in Pike County, and near the eastern line of Highland County" as a part of the Cuba (Early Wisconsin) moraine. They will be considered in more detail under the heading "Doubtful Illinoian Drift."

Aside from the stratified gravel deposits, there are numerous exposures of till in the Beech Flats area, typical of which are the recent cuts along the highway between Cynthiana and Bainbridge and the exposures north of Fort Hill, described by Leverett[2] as follows:

"Near the bend of Brush Creek, a short distance north of Fort Hill, in Highland County, there are deposits of till rising to a height of about 75 feet above the creek and extending to an undetermined distance beneath the creek bed. The till contains not only pebbles, but also boulders of Canadian derivation, some of which are 2 feet or more in diameter. The great thickness of till at this point may seem remarkable, since there is scarcely any drift south and east of this creek. It is probable, however, that it is in the line of a preglacial valley.

"At Mr. Sparger's, about 2 miles northeast of Fort Hill, a well 35 feet deep strikes no rock. On the adjoining farm, at Mr. Eubank's, is a well 22 feet deep which penetrates the following strata:

	Feet
1. Sandy clay	10-12
2. Blue clay	6-8
3. Sand	2

"At Mr. Cameron's, 1 mile south of Cynthiana, a well strikes shale at 20 feet. The drift consists of clay, yellow at top and blue near the bottom. The well is near the north border of Brush Creek Valley. Not more than 100 yards south of this well, on the bank of Brush Creek, is a gravel pit. At Cynthiana, just south of the outer Wisconsin moraine, a well on Joseph Wilson's property was bored to a depth of fully 60 feet without encountering rock. It is described to be mainly in a blue clay, free from grit."

Other well records mentioned by Leverett[3] in the Beech Flats show a heavy deposit of till.

[1] Leverett, Frank, Glacial formations and drainage features of the Erie and Ohio basins: U. S. Geol. Survey Mon. 41, p. 341, 1902.

[2] Leverett, Frank, op. cit., pp. 273-274.

[3] Leverett, Frank, op. cit., p. 268.

In the district between Fort Hill and the south boundary of the county, the margin of the drift is particularly inconspicuous. Scattered foreign boulders occur south and west of Slate Hill, and decomposed drift may be found in the interstream areas north and west of the headwaters of the Middle Fork of Ohio Brush Creek. East of this stream, the soil appears to be entirely residual, mainly from the decomposition of the West Union and Peebles dolomites. To an observer standing on the top of Slate Hill at a time of year when many of the fields have been recently tilled, the white clays of the typical Illinoian drift are plainly visible to the southwest and west, but are not noticed in looking southward. According to Leverett's map [1] of the Scioto glacial lobe, the boundary of the glaciated area extends from the point where Baker Fork enters Highland County westward around the north side of Fort Hill and then southward to the Adams County line just west of High Knob. This boundary cannot be changed materially by more detailed field work.

Upon going a few miles back from the margin of the glaciated area, a thicker and more characteristic drift is found, both on the flat-topped ridges and in the valleys. On the ridge south of North Uniontown, foreign boulders are scarce and the veneer of drift is only a few feet in thickness. The surface is strewn with silicified stromatoporoids and geodes weathered from the Lilley and Peebles dolomites. The next ridge farther west, between Elk Run and Elm Run, has drift to a depth of 12 to 15 feet, all apparently leached and extensively oxidized. This drift contains numerous foreign pebbles and boulders, as well as large numbers of chert fragments from the local formations. Foreign pebbles and boulders, chiefly of crystalline rock, occur on the ridge two miles south of Belfast and on the flat-topped ridges in the vicinity of Fairfax. In general, the drift on these ridgetops at the southern margin of the county is thin and thoroughly weathered and has an appearance of greater age than the thick deposits in the valleys, suggesting the possibility of the drift on the ridges representing a period older than the Illinoian. There is no definite evidence to support this, however, and the fact that the drift on the ridge east of Elm Run is continuous with that of the Elm Run Valley seems to preclude the possibility of the drift on the ridge being older.

In going westward and northward from the vicinity of Fairfax, the drift on the ridges becomes thicker and assumes more of the character of the typical Illinoian of the flat till plains. East of New Market, the white clays are present on the poorly-drained upland flats, and the variegated gray and brown zone is typically developed.

In the valleys of Brush Creek and its tributaries in the vicinity of Belfast, the Illinoian drift forms extensive deposits, some of which have a terrace-like form, partly due to their occurrence on the wide Brassfield terrace. Along the west side of Elm Run, a mile and a half northeast of

[1] Leverett, Frank, op. cit., Pl. XIII.

Belfast, the terrace form is particularly pronounced, and its top is 60 feet above the top of the Brassfield, which marks the approximate level of the valley floor. Dissected remnants of this terrace appear on the west side of the valley for three miles upstream from this point. The top of the terrace declines down stream and toward the center of the valley. In form and in its gravelly character, this terrace has the appearance of outwash. It is deeply weathered, showing variegated gray and brown clay in some cuts to depths of 6 feet or more. Small irregular elevations above its general level at the outer edge may represent kame deposits.

Along Ohio Brush Creek northwest of Belfast, the drift veneer on the Brassfield terrace is much thinner. It declines toward the southeast with the dip of the rock, maintaining about the same elevation above the stream for considerable distances, and also decreases in thickness down stream.

Three miles northwest of Belfast there is an interesting group of hills, apparently kames, in a small valley tributary to Ohio Brush Creek. These do not reach to the level of the flat-topped ridge followed by the Hillsboro and Belfast pike, but stand at the head of the terrace gravel deposit in the valley. Their presence at this point, together with the morainic appearance of the gravelly drift on the ridgetop east of them and the probable outwash character of the terrace in Elm Run Valley, suggests a stand of the ice margin at a position near Berrysville for a considerable period of time, during which the major part of the terrace deposits in Elm Run and Ohio Brush Creek valleys were formed.

On the south slope of the flat-topped ridge between Sugartree Ridge and Fairfax, the drift is abnormally thick, consisting of a large proportion of pebbles in a clay matrix. In many of the ravines southwest of Beechwood School, the thickness of 15 to 20 feet of drift has been cut through, exposing the Crab Orchard clay. The unweathered drift is bluish in color and hard in consistency. The depths of leaching and of oxidation are slight, in some cases as little as 2 or 3 feet, probably because some of the surface material has been removed by erosion. Similar conditions are found on the slope south of the road, two miles east of Sugartree Ridge, where the drift attains a thickness of more than 20 feet. As near as can be made out from the small gullies on the slope, the depth of leaching is as little as 4 feet; again, the upper zones of the normal Illinoian profile have been partly removed by erosion. The unweathered drift includes numerous pebbles from the local dolomite and limestone formations, as well as basalt, gneiss, sandstone, chert, etc.

In the western part of the valley of Buck Run, the wide floor of Brassfield limestone is covered by drift which increases in thickness toward the northwest. The character of the drift is similar to that to the northward, except that it is more deeply weathered. Similar drift, but thinner, also occurs on the Brassfield terrace south and southeast of Belfast.

The rock topography of the southeastern part of the Hillsboro quadrangle is controlled to a large extent by the differential resistance to erosion of the various formations. The Bisher and Lilley cap the flat-topped ridges, while steeper slopes are found just above the contact with the weaker Crab Orchard shale; the very resistant Brassfield forms wide benches where it outcrops above stream level. In most cases, the thicker drift is found on the tops of the ridges or else on the Brassfield terrace, and the steep slopes over the lower Bisher and upper Crab Orchard have little or no drift. The scarcity of drift on this part of the slope is explained partly by the fact that it would originally tend to be deposited in greater thickness on the flatter areas and partly by the fact that erosion is most active at the point where the resistant Bisher dolomite is capped by the weak Crab Orchard clay. There are, however, several localities where the contact of the Crab Orchard and Bisher formations is covered by thick drift, which forms a continuous sheet from the ridgetops to the valley bottoms. A few of these are southeast of Miller's Chapel School, north of Fairfax, southeast of Sugartree Ridge (already mentioned), and southeast of Berrysville.

Gravel Hills

Within the area of the Illinoian drift in the hilly southern and eastern portion of the county, there are several gravel hills or groups of knolls, apparently kame-moraines formed during the retreatal stages of the Illinoian glaciation. The ones three miles northwest of Belfast have already been mentioned. They occur near the head of a small valley tributary to Ohio Brush Creek and consist of small conical hills rising about 80 feet above the floor of this little valley; their tops are about 30 feet below the level of the top of the ridge followed by the road. The thick, gravelly drift of the ridgetop itself opposite these hills is deeply leached and oxidized, as shown in gullies west of the road. On the other hand, the material of the gravel hills is unweathered to within 3 or 4 feet of the surface, where exposed in a small gravel pit in one of them. This slight amount of weathering, as contrasted with other Illinoian sections, appears to be due to removal of some of the surface material by erosion; in fact, it is quite possible that these hills owe their present form largely or even wholly to erosion, and that they represent remnants of a thick gravel deposit dumped in this small valley at a stage of the retreat of the ice front. In spite of the apparent freshness of the gravel at this locality, there can be no question of its Illinoian age.

Somewhat similar gravel hills rise above the thick valley filling east of Head's Hill and north of Irons Mountain. The most typical of these is a small knoll half a mile southeast of Head's Hill. Tarnished reddish brown gravel shows at the surface on the steep sides of the knoll, but there are no cuts to reveal the depth of weathering. Other small hills in this vicinity appear to have about the same composition, but do not show such a noticeably conical form. Unlike the hills northwest of Belfast, these are very near the margin of glaciation.

On the north side of the old Cincinnati and Chillicothe road, two miles east of New Market, there is an exposure of gravel, 30 feet thick, which is leached to a depth of 9 to 12 feet. Similar thick gravel may be traced northeastward from here a mile and a half to a point half a mile west of the Hillsboro and Fairfax pike, south of the South Fork of Rocky Fork. At the latter locality, the gravel forms a number of low, irregular knolls, rising to the westward to the upland level, which is about 1,080 feet. The undulating character of the topography at first suggests a morainic group, but closer study indicates that these knobs have been formed in large part by the erosion of a thick gravel deposit. The higher ones, farther west, have been leached to a depth of at least 6 feet, as indicated by gullies cut into the slopes, and probably to a considerably greater depth than this; but the lower ones have fresh limestone pebbles at the surface. Erosion is now going on very rapidly at this locality. This is indicated by the numerous deep gullies and the absence of a sod cover. There can be little doubt that the weathered material of the gravel deposit has been in large part stripped away, thus accounting for the deceptive freshness of some of the gravel knolls. Indirect evidence in support of this conclusion is found in the large amounts of gravel carried by South Fork of Rocky Fork and left as bars along its lower course.

Another irregular group of gravel hills, now deeply dissected, is found south of the highway, Ohio Route 38, four miles southwest of Hillsboro. This group of hills was originally morainic in character, but has been deeply dissected by erosion, so that it now has long radiating ridges with deep gullies or ravines between. The unweathered material exposed in these gullies consists of a hard bluish clay matrix, with a large proportion of pebbles and boulders, whereas the weathered portion is largely reddish-brown clay with chert and other resistant pebbles.

Flat Till Plains

In the region of flat-surfaced Illinoian drift in the western half of the county, exposures extending down to the unweathered drift are rare, and the true depth of leaching can be determined in only a few places. It is usually more than 6 feet, however, and is frequently shown to be as much as 8 or 9 feet. Since this region is poorly drained, the characteristic profile developed is the gumbotil. It is in this poorly-drained western third of the county that the white clays are most extensively developed. In the strip of low hills at the western margin of the Bisher cuesta, drainage is more complete, yet there are considerable areas of the white clays, particularly in the lowlands. Several fairly typical sections of the drift may be found in this region. An exposure along the road south of the

Norfolk and Western Railway, four miles southwest of Hillsboro, gives the following section:

	Feet	Inches
1. Surface soil	1	0
2. Gray and yellow mottled gumbotil, brown near base	2	6
3. Brown till, oxidized and leached, with black stains	3	6
4. *A*. Red oxidized till with chalky dolomite pebbles	1	0
B. Light brown oxidized till, calcareous	2	0

This is a typical gumbotil profile, although occurring on a fairly well-drained slope. Other exposures in the same vicinity show only horizons 1, 2, and sometimes 3.

At an exposure along the road two miles north of Hoagland, in such a position as to be moderately well drained, no unleached material is found at a depth of 6 feet below the surface. Here the gumbotil profile is not characteristically developed, the weathered material of Zone 2 more nearly resembling the silt till type.

Along the highway two and a half miles north of Sugartree Ridge, a cut shows the depth of leaching to be about 6 feet; other cuts in this vicinity exhibit even smaller depths of leaching. The profiles here appear to correspond to the mesotil type of Leighton and MacClintock.[1] The unweathered drift is hard and of medium bluish-gray color, with numerous pebbles, chiefly from the local dolomite and limestone formations.

Near the bridge, three-quarters of a mile southeast of East Danville, there is an exposure of 21 feet, in which the depth of leaching is apparently only 2 feet, some of the surface material having been removed by erosion. Below the leached zone is brown oxidized drift for 2 feet, overlying an irregular sandy layer of about the same thickness. In this sandy material, which is brown in color, the moisture comes to the surface, making it appear as a prominent dark band across the exposure. Below the sand is hard bluish-gray clay, unstratified, with numerous pebbles, for 16 feet down to the level of the creek.

At a gravel pit one mile south of Danville, the gravel, which appears to make up the flat plain at this point, has a thickness of at least 20 feet.

Thicknesses of till up to 20 feet are exposed along the headwaters of Little West Fork of Ohio Brush Creek, two to three miles south of Sugartree Ridge, and near the county line southeast of Bethel School. Mr. Thomas E. Berry, of Hillsboro, reports the finding of tree trunks at depths of as much as 40 feet in the region west of Danville.

Farther west, a thickening of the Illinoian drift near its margin is described by Leverett [2] as follows:

---

[1] Leighton, M. M. and MacClintock, Paul, Weathered zones of the drift sheets of Illinois: Jour. Geology, Vol. 38, pp. 42-45, 1930.

[2] Leverett, Frank, Glacial formations and drainage features of the Erie and Ohio basins: U. S. Geol. Survey Monograph 41, p. 276, 1902.

"The general thickness of the drift along the Baltimore and Ohio Railroad in Brown and Clermont counties and between that railroad and the outer Wisconsin moraine is 20 feet or less, or an amount scarcely half that found in a trip through a tract 12 to 20 miles to the south. This thickening does not, however, assume the form of a ridge, but as previously noted, simply serves to fill up preglacial inequalities of surface to a somewhat uniform level.

"From the Little Miami Valley westward across Hamilton County, Ohio, there is a nearly continuous sheet of till, the thickness of which on the uplands seldom exceeds 20 feet, but in lowlands and valleys sometimes reaches 100 feet or more."

DOUBTFUL ILLINOIAN DRIFT

General Characteristics

A belt of drift, of which the age is in doubt, extends from the east end of the distinct Cuba moraine south of New Vienna to the gravel hills south of Hillsboro and eastward to the north margin of the Beech Flats area in Pike and Ross counties. It has a width of about seven miles in the vicinity of Hillsboro. In part, this is described by Leverett as of doubtful age, and in part referred definitely to the Early Wisconsin.

In describing the outer or Cuba moraine of the Early Wisconsin, Leverett [1] says:

"On the north side of Beech Flats, in Pike County, and near the eastern line of Highland County, Ohio, this moraine becomes clearly separated from, and distinctly developed outside of, the later ones. It is readily traced westward along the south side of Rocky Fork, from the mouth to the source of that stream, the villages of Cynthiana, Carmel, and Marshall being situated near its southern margin, and Hillsboro just north of it. Its breadth is one to two miles. In the vicinity of Hillsboro, the creek winds among sharp gravelly knolls, which have a contour strikingly different from the remainder of the belt, and which may prove to belong to the earlier drift sheet. Northwest of Hillsboro the moraine for several miles is not well developed, but a mile or two southeast of New Vienna it reappears in considerable strength. From that point it takes a westward course. . . . Continuing westward into Clinton County its margin at the East Fork of Little Miami River is at the crossing of the Martinsville and Hillsboro Pike. . . .

"North of Beech Flats, in Pike County, and in southeastern Highland County, the moraine is of subdued type and stands only 10 to 25 feet higher than the north border of these flats. Toward the west, sharp gravel hills, 80 to 100 feet in height, set in, among which are low tracts no higher than the tracts outside [south] of the moraine, and but little

[1] Leverett, Frank, op. cit., pp. 341-342.

higher than the valley of Rocky Fork, which lies to the north. As already stated, these gravel hills may belong to the earlier drift sheet instead of this moraine. Both north and south of this portion of the moraine there are rocky hills bearing scarcely any drift, which stand much higher than the moraine. The moraine is, therefore, not so conspicuous a feature as it would be on plane tracts, such as are found in northwestern Ohio, or even on those in the adjoining counties, Clinton and Fayette, where there are few rocky hills. In the northwestern part of Highland and in eastern Clinton counties it rises quite abruptly above the flats that border it on the south, in many places a rise of 20 feet being made in as many rods, while the crest of the moraine is 30 to 60 feet above the outer border plain. . . ."

The material of this belt consists mainly of till, but there are numerous gravel hills rising above it. These have, in the main, a crescentic arrangement, forming one loop which extends from west of Hillsboro to Beaver Mill, and another less distinct one reaching from this point to the northern margin of the Beech Flats. Along Clear Creek and Rocky Fork there are extensive terraces which are partly of till and partly of stratified gravel. At some localities the terrace deposits are thick and have a well developed topographic form, while at others there are only thoroughly dissected remnants, without definite terrace outlines. In some places they appear as a thick veneer over rock benches at about the same altitude. They slope to the eastward at about the same rate as the grade of the present streams, or a little less than 10 feet per mile. Their presence has not been noticed east of the head of the gorge of Rocky Fork. With few exceptions, the drift on the bedrock hills in the vicinity of Hillsboro is relatively thin, thicknesses of over 10 feet being uncommon. In the lowlands, the drift is much thicker, and criteria for its age determination are therefore more reliable.

As would be expected, the profiles developed in both till and gravel phases of the drift in this belt more clearly approximate the silt till type of profile of Leighton and MacClintock [1] than the gumbotil type, since the region is fairly well drained. Depths of leaching vary from 4 feet to more than 12 feet, and sections show typically a brownish to reddish color down to depths of 15 feet or more, in the few places where such depths are exposed.

The gravel hills constitute an important exception to this statement, however, in that many of them present a remarkably fresh appearance. Limestone pebbles appear commonly on the slopes of some of them, and depths of leaching are sometimes as little as 2 feet even at the summits, though usually much greater than this. This freshness of appearance, together with the crescentic arrangement of the hills, suggests them at once

[1] Leighton, M. M., and MacClintock, Paul, op cit.

as the logical outer moraine of the Early Wisconsin drift, but other factors make the correctness of such an interpretation very doubtful.

Outer Gravel Hills

In Ross County, two miles southwest of Bainbridge, there is a group of irregular morainic hills, some of which rise to an altitude of 1,000 feet or more above sea level, or nearly 300 feet above Paint Creek. While not examined in detail, these appear to be made up at least largely of very gravelly till, which is leached to depths of as much as 7 to 10 feet. The extensive dissection of these hills and the weathered appearance of the material seem to indicate its Illinoian age, rather than Early Wisconsin.

At the north margin of the Beech Flats area, just west of the Highland County line, there are three conical gravel knolls, the largest of which rises about 70 feet above the surrounding plain. The slopes of these are steep. Gravel appears at the surface, consisting chiefly of stained chert and igneous pebbles; only a few limestone pebbles were found. The depths of oxidation and leaching could only be inferred, but must amount to several feet at the tops of the knolls. These knolls are apparently similar in character to those east of Head's Hill, already mentioned.

In the vicinity of Beaver Mill, south of Rainsboro, there are several low gravel hills which line up to form a ridge with a northwest-southeast trend. The top of this ridge, which rises 75 feet above the surrounding upland, is followed by the road for a considerable distance and has a gravel pit which has been operated for road material. The depth of leaching here is from 5 to 7 feet, with oxidation extending considerably lower. The unweathered material has the appearance of kame gravel, stratified at various angles. It is locally cemented to a hard conglomerate, both here and at an old gravel pit a quarter of a mile farther south. The topography of the ridge is undulating, without any undrained depressions. It continues northward nearly to the highway (U. S. Route 50) west of Rainsboro, but there are no exposures at the north end to indicate whether the material is stratified gravel or till. On the south side of Rocky Fork, near Beaver Mill, there are less conspicuous gravel knolls which show a somewhat greater depth of weathering and have all the appearance of the older drift sheet. The northwest-southeast trend of this group of gravel hills as a whole, together with the character of the material exposed, indicates deposition probably as a kame group or kame-moraine in a re-entrant of the ice margin, presumably with minor lobations west and east of here.

Half a mile northeast of Marshall, a roadside exposure shows reddish-brown weathered till to a depth of 4 feet. There is no cut sufficient to indicate whether this knoll is made up of drift or is of bedrock with a veneer of drift.

The greatest number of gravel hills appear south of Rocky Fork in the Hillsboro quadrangle. Several of these are found in a region of generally thick, deeply-dissected drift southwest of the Hillsboro and Marshall road. They are irregular in shape and rise to altitudes of about a thousand feet. There are not sufficient sections exposed to indicate whether they are of till or of stratified gravel. The hill a mile southwest of Highland County Infirmary, however, appears from the slight exposures afforded to be entirely made up of gravel, none of which has a fresh appearance.

West of the Belfast road, two miles southeast of Hillsboro, there is a ridge of stratified gravel about a mile long, extending nearly north and south. The topographic form, material, and stratification indicate that this is a group of kames. The appearance of the materials is very fresh, limestone pebbles being present at a depth of 2 feet in a gravel cut near the middle of the ridge. Oxidation extends to a depth of somewhat over 3 feet. In a few places, the gravel is cemented together into a conglomerate, which comes out in lumps several feet in diameter. Rocky Fork, which is flowing on bedrock opposite this point, makes a bend around the north end of this ridge. No appreciable amount of gravel is found although the drift is relatively thick on the slopes to the north and west.

A large gravel hill appears just west of the road from Hillsboro to Fairfax, two and a half miles south of Hillsboro. This hill is much higher than the ones farther east, rising to over 1,100 feet. At its top, where a side road crosses it, it has reddish-brown till in which all but the most resistant pebbles are decomposed down to a depth of over 5 feet; it is leached below the bottom of the cut, which is about 8 feet deep. A small opening for gravel on the east side of the hill about a hundred feet south of the road shows leaching to a depth of only 2 to 3 feet, with clean unoxidized gravel at a depth not much greater than this, while still farther south limestone pebbles occur at the surface. This illustrates the unreliability of leaching and oxidation as criteria of age in such gravel hills where the weathered material may have been entirely removed from the surface by erosion. Other much lower gravel hills south of Rocky Fork, a mile northwest of the hill mentioned above, indicate about the same relations, although they do not anywhere give a depth of leaching as great as the maximum. The gravel in these lower hills shows some stratification, although one or two exposures appear to be in gravelly till.

The most interesting group of kame-morainic hills of this belt is one north of Ohio Route 38, three miles southwest of Hillsboro. It consists of several more or less connected hills, the highest of which reaches an altitude of 1,200 feet, or fully as high as the surrounding bedrock hills of the Bisher-Lilley cuesta. The northeastern front is steep and has a crescentic pattern in harmony with the general arrangement of the gravel hills which extend in a loop from west of Hillsboro to the vicinity of Beaver Mill, on Rocky Fork. This crescentic margin is particularly prominent when seen from a summit a quarter of a mile northeast of the highest one, and is suggested by the topographic map. From it and from the modified morainic topography of these and other gravel hills of the same vicinity, it is apparent that a minor glacial lobe must have remained with its margin a few miles south of Hillsboro for a considerable period of time. The original topography of this kame-morainic group has been altered to a large extent by subsequent erosion. There are no undrained depressions or swamps left, and complete radial drainage has been established, with long, prominent radiating spurs, between which are cut ravines a quarter of a mile or more in length. The completeness of the drainage pattern must certainly indicate a long period of erosion, yet the material where exposed is remarkably fresh in character. Limestone pebbles appear at the surface on the slopes of most of the spurs, and the depth of leaching shown at the top of the highest hill is not over 2 or 3 feet. None of the gravel is thoroughly decomposed as in zones 1 and 2 of the gumbotil or silt till profiles, and oxidation was not found to a depth of much over 3 feet. At one point, about two-thirds of the way up the slope on the southwest side of the northernmost hill of this group, there is a ledge of partly decomposed pebbles cemented into a hard conglomerate by bluish-black hydrous iron oxides, possibly with some manganese. Many of the pebbles are brown all the way through and of powdery consistency. This conglomerate layer seems to follow a definite horizon in the gravel, exposed by the erosion of many feet of overlying material. There are no exposures in this group of hills sufficient to indicate the degree and position of stratification. A small cut at the north end shows that the material is mostly fine, pebbles over three inches in diameter being uncommon, and coarse sand making up a considerable proportion of the deposit.

From the thorough dissection of the hills and other evidences of extensive erosion, it is probable that the absence of the higher completely weathered zones of the normal profile in Illinoian drift is due to their removal by erosion, so that the almost unweathered appearance of the gravel has little or no value as a criterion of age.

North of this is a low hill composed of gravel or very gravelly drift, with undulating topography. This shows much less erosion than the hills last mentioned, and the material is much more deeply weathered. West of it low broad swells of gravelly drift extend for a mile or two. While the depth of weathering varies, the appearance is of greater age than in the high kame-morainic hills to the southwest. Drainage is complete, with no swamps.

Two miles southwest of Hillsboro, on the Danville road, there is another group of small hills, apparently kames, about three-quarters of a mile in length and having a general northwest-southeast trend. In contrast to the high gravelly hills farther south, these rise to an altitude of only 1,060 to 1,080 feet, or about 50 feet above the surrounding drift level. In several gravel cuts the depth of leaching is shown to be from 1 to 3 feet, oxidation extending only a slight distance below this. Limestone pebbles occur at the surface at many points on the slopes. Even where leaching and oxidation have extended deepest, only zones 3 and 4 of the typical silt till profile can be discerned, and the general appearance of the gravel is fresh, rather than deeply weathered. This is in contrast to the drift of the surrounding plain or terrace, which in its poorly-drained portions shows the typical gumbotil profile of the Illinoian. The attitude of stratification in one of the kames south of the road is nearly horizontal, with a slight dip to the southwest; but north of the road the dips are steeper. The material ranges in size from coarse sand to gravel and occasional small boulders.

Gravel hills of apparently similar type occur immediately south of Rocky Fork for much of the way from this point downstream for a distance of four miles, several of which have been mentioned above.

On top of a hill a mile and a half northwest of Hillsboro, there is a small deposit of gravel and sand in which a gravel pit has been opened. The depth of leaching is 2 to 3 feet or less, and oxidation to a depth of only 4 or 5 feet, although irregular, with funnel-shaped pipes extending several feet down into the unoxidized material. Limestone pebbles occur at the surface in the field below, and the general aspect of the deposit is one of freshness. The thickness of the gravel may be about 30 feet, and the extent of the deposit is only a few acres. A somewhat similar gravel hill is found just north of the railroad at the northwest edge of Hillsboro.

Drift Sheet

On the bedrock hills in the Hillsboro region, the drift is usually thin, and exposures showing unleached material are rare. In most of the cuts, the drift has a deeply weathered appearance, is reddish or brownish in color, and thoroughly decomposed down to depths of 4 to 6 feet or more, with only the most resistant pebbles left, including chert, quartzite, and so forth. At lower depths red or brownish till comes in which is leached and oxidized, but otherwise only slightly decomposed. Fragments of chert and geodes from the local dolomites are common in the drift, and over the Bisher the lower part of the drift is often dark reddish in color, with silicified fossils.

In the northeast part of Hillsboro, 300 yards south of the cemetery, there is an exposure of till, overlain by nearly horizontal stratified sand, completely leached and oxidized to a depth of 10 feet. An orange color prevails.

Along the Greenfield road, a mile and a quarter northeast of the last, a 5-foot cut shows no unleached drift, and most of that exposed has undergone thorough decomposition.

North of a crossroad a mile and a quarter northwest of the former site of Plainview School, and four and a half miles northwest of Hillsboro, exposures to a depth of 3 to 3½ feet show only thoroughly decomposed tills of the mesotil[1] type of profile. Farther south in the vicinity of the headwaters of Clear Creek, the gravelly till is much less decomposed, and depths of leaching vary from 2 to 4 feet.

An exposure just west of the point where U. S. Route 50 crosses Puncheon Run, west of Rainsboro, has a depth of leaching of nearly 8 feet. The upper 4 or 5 feet of till is completely decomposed, corresponding to zones 1 and 2 of the mesotil or gumbotil profiles. The surface soil consists of mealy loam, creamy to grayish-white in color. This exposure is referred to the Early Wisconsin by Westgate,[2] following Leverett.[3] To the writer, the profile developed here seems to resemble more clearly that of the typical Illinoian.

A quarter of a mile west of the last, a cut of 5-foot depth along the road is completely weathered till. The surface soil is a creamy-gray loam similar to the white clays of the flat till plains, with a thickness of nearly a foot. Below this is a gray plastic gumbotil streaked with brown, extending to the bottom of the section. This is approximately the locality from which one of Westgate's samples was collected.

A road cut a mile and three-quarters east of Rainsboro shows a depth of leaching of somewhat over 6 feet, the upper 3 or 4 feet being brownish in color and thoroughly decomposed.

In a cut along the road to Marshall, a mile west of Carmel, the depth of leaching is over 7 feet. The material is gravelly with some sand and is completely decomposed in the upper part of the exposure.

Valley Terraces

The upper parts of the valleys of Rocky Fork and its chief tributary, Clear Creek, have extensively, though somewhat irregularly, developed terraces, which slope downstream with gradients approximately the same as those of the streams. The terraces are generally from 30 to 50 feet above stream level, but in some cases are considerably higher than this, and frequently have an irregular topography, with small hills rising above the general level. The terrace top usually rises toward the sides of the valley and declines toward the stream. The topographic irregularity is further increased by the advanced degree of dissection.

---

[1] Leighton, M. M., and MacClintock, Paul, op. cit., pp. 42-45.

[2] Westgate, L. G., White clays or upland-flat soils of Southern Ohio: Geol. Soc. America Bull., Vol. 41, pp. 329-340, 1930.

[3] Leverett, Frank, Glacial formations and drainage features of the Erie and Ohio basins: U. S. Geol. Survey Mon. 41, Pl. XIII, 1902

There is usually no sharp line of division between the terrace tops and the slopes above, the bedrock slope merging into the inner edge of the terrace. The material of the terrace varies, as does the degree of weathering. In the main, they appear to be made up of pebbly or gravelly till, but cuts at some points show stratified gravel. The fact that rock benches, apparently representing an old strath-terrace level, approximate the level of the terrace for considerable distances along Rocky Fork still further complicates its interpretation. On the whole, the terraces appear to represent remnants of a valley filling of drift, with more or less water-laid gravel deposits of about the same age.

Exposures along Ohio Route 73, a mile and a half north of Hillsboro, are in poorly stratified gravel, thoroughly decomposed to a depth of 6 feet or more. The depth of leaching is not shown. Cuts of from 4 to 5 feet along Route 62, a mile and a half north of Hillsboro, are entirely in reddish brown, thoroughly weathered drift, without any evidence of stratification. A quarter of a mile east of Route 62 at this point, gullies cut in the terrace show grayish surface soil a few inches thick, gumbotil down to 4 or 5 feet, and unleached till at 6 feet. None of these cuts goes down to the unweathered till, but a section along the North Fork of Clear Creek, near where it is crossed by the road from Hillsboro to Carytown, shows unweathered hard, bluish gray till at a depth of about 6 feet. The appearance of this till is distinctly that of the Illinoian.

A small gravel cut a mile south of Hillsboro, just west of Ohio Route 62, shows the following section:

	Feet	*Inches*
1. Light yellowish clay loam	..	8
2. Gray plastic clay (gumbotil) with some chert pebbles, particularly in a single pebble pavement at the base	2	6
3. Deep reddish-brown clay matrix, igneous pebbles and others numerous	2	0
4. Reddish-brown, oxidized but with dolomite pebbles of chalky consistency	2	6
5. Unweathered coarse sand and gravel	..	..

An old gravel pit a quarter of a mile south of Rocky Fork and a little over a mile east of its junction with Clear Creek shows 20 feet of poorly stratified gravel. The section is in such a position on the side of a spur as to give no reliable indication of the depth of the leaching.

Evidence as to Probable Age

The drift within this belt extending nearly across the county appears to constitute a unit, concerning the age of which the evidences are conflicting. Certain indications point toward an Early Wisconsin age, as stated by Leverett,[1] while others suggest even more strongly that its age

[1] Leverett, Frank, op. cit., Pl. XIII.

is Illinoian. Although a possibility exists of its being referable to the Iowan, this will not be further considered, because of the long distance from any other drift which has been identified as Iowan and because of the present lack of agreement among Pleistocene geologists concerning the advisability of retaining the term "Iowan" as the name of a separate glacial period.[1]

The following considerations favor the interpretation of the doubtful drift as Early Wisconsin in age:

1. The morainic or kame-morainic character and arrangement of the hills from a point west of Hillsboro to the north margin of the Beech Flats, indicating that an ice front stood at this position for a considerable length of time.

2. The remarkably fresh appearance of the gravel in some of these hills and presence, in many places, of the typical Illinoian profiles of weathering.

3. Absence of prominent morainic features at the north edge of this belt between the region south of New Vienna and the valley of Paint Creek.

4. A buried soil layer and drift below it in wells at Marshall, as reported by Orton[2] and quoted by Leverett.[3] These may, however, indicate the presence of an older drift underneath, and in any event cannot be taken as a definite indication that the drift at the surface is Wisconsin in age.

Factors pointing toward an Illinoian age for this belt are:

1. Deep weathering on some of the gravel hills south of Rocky Fork. While there may be differentiated two belts of gravel hills, the lower one immediately south of Rocky Fork being inside a higher one to the south of it, there is apparently no good basis for separating them and calling one Wisconsin in age and the other Illinoian. They show about the same amount of weathering and degree of dissection.

---

[1] Leighton, M. M., New light on the so-called Peorian interglacial epoch and the Iowan-Wisconsin glacial succession (abst.): Geol. Soc. America Bull., Vol. 42, pp. 182-183, 1931.

——— Elimination of the Peorian interglacial epoch from the North American classification (abst.): Geol. Soc. America Bull., Vol. 43, p. 176, 1932.

——— The Peorian loess and the classification of the glacial drift sheets of the Mississippi Valley: Jour. Geology, Vol. 39, pp. 45-53, 1931.

Kay, G. F., Classification and duration of the Pleistocene period: Geol. Soc. America Bull., Vol. 42, pp. 425-466, 1931.

——— The relative ages of the Iowan and Wisconsin drift sheets: Am. Jour. Sci., 5th Ser., Vol. 21, pp. 158-172, 1931.

[2] Orton, Edward, Geology of Highland County, Ohio: Geol. Survey of Ohio, Rept. of Progress in 1870, p. 266, 1871.

[3] Leverett, Frank, Glacial formations and drainage features of the Erie and Ohio basins: U. S. Geol. Survey Mon. 41, p. 345, 1902.

2. Strong probability that the lack of completely weathered zones is at least partly due to the removal of material from the gravel hills by erosion.

3. Presence of fresh-appearing gravel knolls in the Illinoian drift at localities northwest of Belfast and four miles south of Hillsboro.

4. Occurrence of similar drift in the Illinoian of other regions. Similar shallowly-leached hills are found in the Illinoian of northwestern Illinois, where they are largely made up of dolomite pebbles from the Galena dolomite.[1] In south central Illinois, particularly in Christian County, gravel hills within the Illinoian drift sheet, but some miles back from its margin, have only a slight amount of leaching. In many of these, limestone pebbles occur at or near the surface.[2]

5. Complete dissection and drainage in the gravel hills, the drift sheet, and the terrace deposits within this belt; absence of undrained swamps or fresh morainic topography.

6. Deep oxidation and leaching and presence of typical Illinoian profiles of weathering in the drift and terrace deposits throughout this belt.

An additional indication of the more probable Illinoian age is the relation of this belt of drift to the Bisher-Lilley and Waverly cuestas (See Figure). If its age were Wisconsin, two minor but distinct lobations would be required at the south end of the Scioto lobe, and each of these would have its farthest advance in the hilly belt of a dissected cuesta, instead of following adjacent lowlands. This would be out of harmony with the general behavior of the Scioto lobe, which in the main is controlled by the wide, moderately shallow depression of the Scioto Valley.

EARLY WISCONSIN DRIFT

General Characteristics

The Early Wisconsin drift, as here mapped, constitutes a belt from one to six miles wide extending across the county from the region of New Vienna to the west side of Paint Creek Valley near the mouth of Rattlesnake Creek. It is widest at the west, narrowing gradually to the eastward. This belt exhibits marked differences in topography and material from the region to the south of it, and includes some of the most valuable agricultural land of the county. The thickness of the drift varies greatly, from 1 to 2 feet on a few of the rock hills to 50 feet or more in some of the filled valleys.

The till of the Early Wisconsin is slate-gray to brownish-gray in color where unweathered and usually somewhat softer than the bluish-

[1] Leighton, M. M., personal communication, 1930.

[2] Apfel, E. T., and Holmes, C. D., personal communication, 1931.

gray unweathered till of the Illinoian. Except in the moraines and kames, it appears to be more nearly free from gravel and boulders than the Illinoian of the southeastern and central parts of the county. This does not necessarily hold for comparison with the Illinoian of the flat till plains, which is stated by Leverett [1] to be comparatively free from gravel. In the Cuba moraine, the Early Wisconsin is somewhat more gravelly in character, a large proportion of the pebbles ranging from an eighth of an inch to an inch in diameter. Depths of leaching vary from less than 1 foot to 4 feet, and average somewhat greater in the gravelly drift near the margin than a mile or two back from the margin. The surface soil is light to dark gray-brown in color or nearly black under conditions of poor drainage, in striking contrast to the white clays of the undrained areas of Illinoian drift. On the gravelly morainic ridges the surface soil may be reddish brown in color, and is underlain by 2 to 3 feet of reddish brown oxidized and leached gravelly drift, at the base of which chalky limestone and dolomite pebbles occur. Oxidation extends irregularly for several feet farther down. The most distinguishing characteristic of the Wisconsin drift, as compared with the Illinoian, is the complete or nearly complete absence of zones 1 and 2 of the typical gumbotil profile. While Westgate [2] mentions the white clays as appearing also on areas of Wisconsin drift, they were not found typically developed on the Wisconsin by the present writer. The gumbotil, which appears as a zone several feet in thickness of plastic gray clay streaked with brown in the poorly-drained areas of Illinoian drift, is apparently entirely lacking.

The topography on the Early Wisconsin drift is for the most part gently undulating. A few bedrock hills rise above the general level of the drift, which is somewhat over 1,100 feet at New Vienna and declines gradually to the eastward to less than 1,000 feet in the vicinity of New Petersburg. Drainage is much more complete than on the flat Illinoian till plains. There are, however, no steep slopes except where the upland is trenched by Hardin Creek, Big Branch, and Fall Creek.

Outer Border

The description of the outer or Cuba moraine of the Early Wisconsin stage, as given by Leverett,[3] has already been quoted (see p. 35). In its extent from a point two and a half miles south of New Vienna westward into Clinton County, it is easily recognized, both by its topography and its material. Its course as far as Cuba is particularly prominent on the topographic map; the altitude of its summit declines from 1,130 feet south of New Vienna to about 1,050 at Cuba. At the boundary

[1] Leverett, Frank, op. cit., p. 272.

[2] Westgate, L. G., White clays or upland-flat soils of southern Ohio: Geol. Soc. America Bull., Vol. 41, pp. 335, 337, 1930.

[3] Leverett, Frank, op. cit., pp. 341-342.

between Clinton and Highland counties, it rises 60 feet above the plain to the southward in a distance of about three-quarters of a mile. This rise does not, however, indicate the thickness of the drift as bedrock outcrops a comparatively short distance east of here and at New Vienna show that the low Bisher-Lilley cuesta occupies approximately the same position as the moraine and hence presumably underlies it. The best exposure in the Cuba moraine is where the headwaters of Turtle Creek are crossed by the road, a mile and three-quarters southwest of New Vienna. A 15-foot section at this point shows oxidation and leaching to a depth of somewhat over 4 feet. An exposure along the road to New Vienna, three-quarters of a mile east of the last, shows the gravelly nature of the material, with a depth of leaching of a little less than 3 feet.

At other points along the margin of the Early Wisconsin drift sheet, as it is here interpreted, morainic features are rare. In only a few places can the boundary between Wisconsin and doubtful Illinoian be established within a hundred yards, yet the contrast in topography and material is generally noticeable in the course of a mile wherever this boundary is crossed. (See Figure.)

Thus, exposures along the highway between Hillsboro and Samantha have the general appearance and soil profiles (where the latter can be observed) of Illinoian drift, while small cuts along the road northeast of Samantha show typical gravelly Early Wisconsin drift. Similarly, the drift observed along the Greenfield road between the city of Hillsboro and the north margin of the Hillsboro quadrangle has profiles characteristic of moderately well-drained Illinoian, but that exposed just south of where this road crosses Fall Creek is apparently Wisconsin and has limestone pebbles up to within a few inches of the surface. Other exposures along Fall Creek indicate that the boundary lies a short distance south of it between Samantha and the east edge of the Greenfield quadrangle. The edge of the Wisconsin drift appears to be just north of Fall Creek; the low hills south of the creek are of bedrock with only a very thin veneer of drift.

A mile west of New Petersburg a kame, composed largely of coarse gravel and boulders, rises nearly 100 feet above the surrounding area. This till is just within the Early Wisconsin boundary, which here takes a sharp jog of about two miles to the south. It appears to have been deposited in the reentrant between two minor lobations of the ice, one of which advanced just beyond the headwaters of Fall Creek, determining the present course of the upper part of the stream. The other lobe advanced southward to about a quarter of a mile north of Rainsboro. This was probably split into two parts by a bedrock hill, two miles northwest of Rainsboro, one part extending southwest into the valley of Blinco Branch, and perhaps for some distance down that valley. In the immediate vicinity of Rainsboro, the drift where exposed shows the general characteristics of the Illinoian, but exposures a third of a mile to the north have unleached drift at depths of 2 to 3 feet or less, with complete absence of zones 1 and 2 of the typical Illinoian profile. A low ridge crosses the road at this point, trending eastward, then swinging around to northeastward a short distance east of here. This inconspicuous ridge is interpreted as the eastward continuation of the Cuba moraine, which, however, is described by Leverett[1] as being several miles farther south on the north side of Beech Flats.

From this point the Early Wisconsin boundary apparently continues northeastward to the margin of the Middle Wisconsin drift, which overlaps it north of Plum Run.

Drift Sheet

Within this area, the relief was diminished by the deposits of the Early Wisconsin glacier. Preglacial valleys were filled or partly filled, while deposits on the higher hills were comparatively thin. Areas of characteristically low relief occur south of New Vienna, around Carytown, and east of Samantha, but there are no closed depressions, lakes, or extensive swampy areas. With the exception of the Cuba moraine southwest of New Vienna and the kame west of New Petersburg, none of the glacial deposits forms conspicuous prominences above the general level. A low, broad morainic ridge, here about parallel to the Cuba moraine, enters the northwestern part of the county just east of New Vienna and is traceable for about two miles southeastward. Along Hardin Creek, Bridgewater Creek, and Bull Creek in the vicinity of Bridges, are the thickest exposures of drift within the county, so far as now known. Some of these show 50 feet or more of drift, which is, however, in the nature of local valley fillings and not noticeable elevations above the general drift level. In these sections the depth of leaching is generally less than 3 feet, and the drift contains only a moderate amount of gravel with few large boulders. In color, it is more inclined toward the brownish gray of the Middle Wisconsin drift in other exposures.

Just north of the location of Rosebush School, east of Samantha, there is a small gravelly knoll which is apparently morainic or kame-morainic in character, although well within the margin of the Early Wisconsin drift. Old gravel pits in this knoll show limestone pebbles at a depth of less than 2 feet. The kame west of New Petersburg, much more striking in character, has already been mentioned.

A low morainic ridge extending a mile or more into the county from the northwest, west of Highland village, appears to represent a retreatal stage of the Early Wisconsin glaciation, a little later than that which produced the ridge east of New Vienna. Both of these are traceable for some distance northwestward into Clinton County, although they are

[1] Leverett, Frank, Glacial formations and drainage features of the Erie and Ohio basins: U. S. Geol. Survey Mon. 41, p. 341, 1902.

very low and broad, with slopes on the sides so gentle as to be hardly noticeable to a casual observer.

MIDDLE WISCONSIN DRIFT

General Characteristics

The Middle Wisconsin drift, which covers the northeastern part of the county and roughly one-tenth of its area, differs both in topography and material from the Early Wisconsin. Although some of the valley fillings are more than 50 feet thick, according to Leverett,[1] the topography appears to be more largely bedrock-controlled than in the area of Early Wisconsin drift. Bedrock outcrops on the higher ridges are somewhat less numerous in the Middle Wisconsin than in the Early Wisconsin area, except just north of Rattlesnake Creek near its junction with Paint Creek. In the uplands west of Greenfield, the drift is more gravelly than the Early Wisconsin drift outside its morainic phases.

In color, the unweathered Middle Wisconsin drift is medium to dark brownish gray, compared to the slate gray of the Early Wisconsin. This characteristic alone, however, seldom serves to distinguish them, because of the scarcity of exposures of entirely unweathered material and because of the influence of variations in moisture content on the color. The depth of leaching of the Middle Wisconsin is generally from 1 foot to 18 inches, but sometimes so slight that limestone pebbles appear in abundance at the surface. There is usually only the beginning of a soil profile, though the more gravelly materials may show oxidation to a depth of 3 feet or more. Toward the east border of the county, the drift appears to be more gravelly than the Early Wisconsin, but at Leesburg it is not conspicuously pebbly. The differences between the Early and Middle Wisconsin drifts in this area are apparently much less pronounced than those between the Early Wisconsin and the "Doubtful Illinoian"; in fact, no evidence was found within the county which would necessarily require an interval of deglaciation between the periods of deposition of the two Wisconsin drifts here represented.

Morainic Systems

Several morainic systems of the Middle Wisconsin are well developed in this region: two of these cross Highland County and another stage in the retreat of the ice is represented by terraces of outwash gravel along

[1] Leverett, Frank, Glacial formations and drainage features of the Erie and Ohio basins: U. S. Geol. Survey Mon. 41, p. 415, 1902.

"At Greenfield drift exposures in the west bluff of Paint Creek show 50 feet of till. . . .

"In the several members of the morainic system, from Ross and Highland counties northward to the combined moraine in Clark County, the general thickness ot the drift falls between 50 and 100 feet, there being, as a rule, 20 to 30 feet more of drift in the morainic tracts than on the bordering plains. . . ."

Paint Creek south of Greenfield. The course of these is described by Leverett[1] as follows:

"West from the Scioto River for 15 miles or more the morainic system leads over a hilly district and morainic features have an interrupted development, the inner member, which east of the Scioto is everywhere strong, becoming here vaguely defined; but in western Ross County the morainic system again shows distinct members, four of them being readily traced northwestward from this county.

"The outer one follows the southwest side of Rattlesnake Creek across northeastern Highland County. Leaving this creek, it continues northwestward through Clinton and northward through eastern Greene County, constituting the divide between tributaries of the Scioto and Little Miami rivers. . . .

"The second member of the system follows the northeast side of Rattlesnake Creek from its mouth to its source and determines the course of that stream. It becomes merged with later belts in southeastern Clark County. Its width is scarcely a mile, but throughout its entire length it presents sharp knolls and ridges that produce a strong contrast with bordering plane tracts."

While Lee's Creek and Rattlesnake Creek flow in rock valleys and have rocky bluffs on both sides throughout the greater part of their extent, the morainic features on the southwest side of their valleys and of Paint Creek Valley, for three miles below its junction with Rattlesnake Creek, are pronounced and unmistakable. Between Leesburg and Highland, thick drift deposits are shown in cuts along the highway; half a mile east of Highland, a minimum thickness of 25 feet is indicated. Road cuts at Leesburg also show thick drift, the depth of leaching being less than a foot.

The gorge of Lee's Creek east of Leesburg is in bedrock, but gravel knolls along the railroad south of the gorge indicate a deposit of 30 feet or more of more or less water-borne material. Clear-cut channels between these gravel knolls must have been made by displacement of the stream from its channel for a short time at the period of farthest advance of the Middle Wisconsin ice sheet. Presumably, Lee's Creek found its present course, marked by the narrow gorge east of Leesburg, at a slightly later stage.

Between this point and Centerfield there are knolls of morainic or kame gravel on the bedrock slope of the south side of the valley. A mile and a quarter northwest of Centerfield the gravel deposit has the appearance of a terrace, with its top at about 950 feet; whereas farther down the slope are rock outcrops. The gravel is only slightly leached, from a few inches to a foot or more, and has a very fresh appearance where small pits have been opened in it.

[1] Leverett, Frank, op. cit., p. 384.

South of Centerfield the ice of the Middle Wisconsin stage appears to have advanced farther across Rattlesnake Valley than at other points. The hills a mile to a mile and a half south of Centerfield appear to be morainic in character. One of them rises to an altitude of over 980 feet, or about 60 feet above the probable elevation of the rock surface of this part of the upland between Hardin Creek and Rattlesnake Creek. On the upland between Hardin Creek and Big Branch, three-quarters of a mile south of Ash Grove School, a gravel knoll rises about 50 feet above the surroundings. It is of unstratified gravelly drift, leached to a depth of from 1 foot to 18 inches. This hill is probably similar in character to the gravel knoll north of Rosebush School, already mentioned (p. 47) in connection with the Early Wisconsin drift; but it may represent an advance of the Middle Wisconsin ice into the uplands. The topography in the lower part of Big Branch Valley, as well as that along Hardin Creek, is suggestive of morainic material. There is a well developed cross channel between the valleys of Big Branch and Fall Creek, somewhat over a mile southwest of Rattlesnake Creek. The hill southeast of the mouth of Fall Creek is undoubtedly partly morainic in character, although the gravelly material is deposited on a bedrock core.

West of Paint Creek, south of the mouth of Rattlesnake Creek, there is a thick veneering of gravelly morainic material over the bedrock slopes as far southeast as the north side of the valley of Plum Run. On the upland between Plum Run and Paint Creek, small gravel knolls along the road east of Snake Corners School are parts of this morainic system. They are leached to a depth of a few inches to a foot or more. A gravel pit, south of the road three-quarters of a mile west of the mouth of Plum Run, shows leaching to a depth of from 2 to 3½ feet, with noticeable discoloration considerably below this depth.

Small gravel knolls west of Paint Creek above its junction with Rocky Fork may also be of Middle Wisconsin age and are so mapped, although the drift on the upland to the westward is here considered as Illinoian.

The second morainic system described by Leverett is not nearly so well developed within Highland County. It is not marked by conspicuous gravel knolls such as those of the outer moraine nor by particularly great thicknesses of drift accumulation. Northeast of Leesburg, however, cuts along the highways, together with the absence of rock outcrops in the ravines, indicate a probable thickness of 30 feet or more of drift. On the upland southeast of East Monroe, the drift is over 25 feet thick and of gravelly nature, as shown in a cut along the Baltimore and Ohio Railroad. The topography at this point, however, does not have any marked morainic appearance.

Terrace Deposits

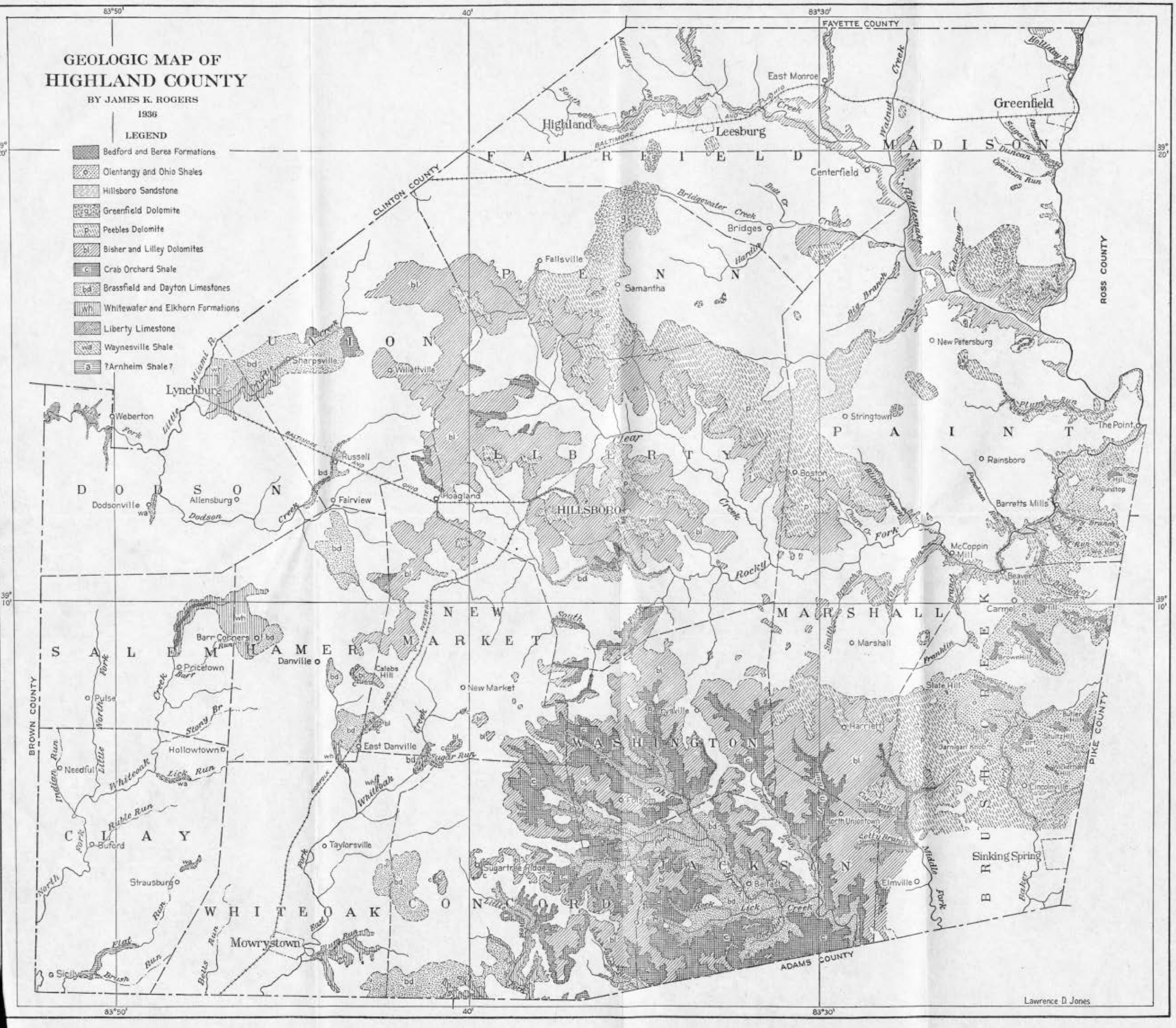
Along Rattlesnake Creek at Centerfield and near the mouth of Fall Creek, there is a distinct terrace from 15 to 20 feet above the valley bottoms. It is slightly higher in the lower part of Hardin Creek Valley. Along Paint Creek below the mouth of Rattlesnake Creek, terraces occur at from 20 to 40 feet above the valley bottom. These are about 20 feet below the floor of the channel which represents the former course of Paint Creek at the eastern border of Highland County.

South of Greenfield, an extensive gravel terrace occurs at about 840 feet, or 50 feet above the level of Paint Creek; it extends up the valley of Sugar Run, rising with the gradient of that stream. Its material is coarse sand and gravel where it is exposed in gravel pits; it is leached from a few inches to a foot or more; and oxidized to a depth of 1 or 2 feet.

The terraces along Rattlesnake Creek and the lower part of Paint Creek within Highland County appear to correlate with the second morainic system, while those south of Greenfield were formed at a later stage of the ice retreat, probably in connection with the third morainic system of Leverett.[1]

[1] Leverett, Frank, op. cit., p. 384.

BLANK PAGE


GEOLOGIC MAP OF
HIGHLAND COUNTY
BY JAMES K. ROGERS
1936
LEGEND
Bedford and Berea Formations
Olentangy and Ohio Shales
Hillsboro Sandstone
Greenfield Dolomite
Peebles Dolomite
Bisher and Lilley Dolomites
Crab Orchard Shale
Brassfield and Dayton Limestones
Whitewater and Elkhorn Formations
Liberty Limestone
Waynesville Shale
?Arnheim Shale?
83°50'
40'
83°30'
39° 20'
39° 10'
FAYETTE COUNTY
CLINTON COUNTY
ROSS COUNTY
PIKE COUNTY
ADAMS COUNTY
BROWN COUNTY
FAIRFIELD
MADISON
PENN
UNION
LIBERTY
PAINT
DODSON
NEW MARKET
MARSHALL
SALEM
HAMER
WASHINGTON
BRUSHCREEK
CLAY
WHITEOAK
CONCORD
JACKSON
Highland
Leesburg
East Monroe
Greenfield
Centerfield
Bridges
Fallsville
Samantha
Sharpsville
Willettville
Lynchburg
Weberton
New Petersburg
Stringtown
The Point
Rainsboro
Boston
Russell
Fairview
Hoagland
HILLSBORO
Allensburg
Dodsonville
Barretts Mills
McCoppin Mill
Beaver Mill
Carmel
Marshall
Barr Corners
Danville
Pricetown
Calebs Hill
New Market
Pulse
Berrysville
Harriett
Slate Hill
East Danville
Hollowtown
Needful
Folsom
North Uniontown
Buford
Taylorsville
Sugartree Ridge
Belfast
Elmville
Sinking Spring
Strausburg
Mowrystown
Sicily
Lawrence D. Jones

CHAPTER III

STRATIGRAPHIC GEOLOGY

INTRODUCTION

The rock series of Highland County is more extensive than that of any other county in the State, with the exception of Adams. The oldest rocks exposed belong to the Arnheim formation of Upper Ordovician age, and the youngest to the Waverly group of Mississippian age. The larger units listed by Orton,[1] with maximum thicknesses are as follows:

	Feet
Waverly	100
Huron	250
Helderberg	100
Niagara series	275
Clinton	50
Cincinnatian	100

These maxima are not all reached at any one point: thus the greatest thickness of the Helderberg is attained north of Samantha and at Greenfield, of the Niagara at and north of Hillsboro and along Rocky Fork, and of the Clinton in the southeastern part of the county. Orton [2] states that the best development of the Niagara series in Ohio is in the region between Ohio Brush Creek and Samantha, while the Helderberg is well shown between Samantha and Lexington (now Highland).

In his *"Revised Nomenclature of the Ohio Geological Formations,"* Prosser [3] lists Orton's classification of 1895 as well as his own. Only a part of the scale is reproduced here:

Orton, 1895	*Prosser, 1905*
Berea shale	Sunbury shale
Berea grit	Berea grit
Bedford shale	Bedford shale
Ohio shale: Cleveland shale	Ohio shale: Cleveland shale
Ohio shale: Erie shale	Ohio shale: Chagrin formation
Ohio shale: Huron shale	Ohio shale: Huron shale
Olentangy shale	Olentangy shale
Upper Helderberg or Corniferous limestone	Delaware limestone
	Columbus limestone

[1] Orton, Edward, Geology of Highland County: Geol. Survey Ohio, Rept. of Progress in 1870, pp. 255-256, 1871.

[2] Orton, Edward, op. cit., p. 257.

[3] Prosser, C. S., Geol. Survey Ohio, 4th Ser., Bull. 7, p. 4, 1905.

Orton, 1895		*Prosser, 1905*	
Lower Helderberg limestone, or Water-lime		Monroe formation	Lucas limestone
			Sylvania sandstone
			Tymochtee member (?)
Niagara group	Hillsboro sandstone	"Niagara group"	Hillsboro sandstone
	Guelph or Cedarville limestone		Cedarville limestone
	Niagara limestone		Springfield limestone
	Niagara shale		West Union limestone
			Osgood beds
Clinton limestone		Clinton limestone	
		Belfast bed	
Medina shale		Saluda bed	
Hudson River group			Richmond formation
			Lorraine formation
			Eden shale

Several different classifications of the Silurian rocks have appeared in the writings of Dr. August F. Foerste, changes being made according to advances in the knowledge of this part of the series. The latest of these appeared in 1931 and is as follows:[1]

Table of Silurian Strata of Kentucky, Indiana, and Ohio

Geologic Series	*Southern Indiana Western Kentucky*	*Western Ohio*	*Southern Ohio Eastern Kentucky*
Cayugan	....	....	Greenfield
Lockport	....	....	Peebles
	....	Cedarville	....
	....	Springfield	....
	....	Euphemia	....
	Louisville	....	Lilley
	Waldron	Waldron	....
	Laurel	Laurel ?	....
Clinton	Osgood	Osgood ?	....
	....	....	Bisher
	....	....	Ribolt
	....	....	Estill
	....	....	Waco
	Basal Osgood	Dayton	Lulbegrud
	....	....	Oldham
	....	....	(Plum Creek)
Medinan	Brassfield	Brassfield	Brassfield
	....	Centerville	....

[1] Foerste, A. F., Silurian fauna of Kentucky: Kentucky Geol. Survey, Ser. VI, Vol. 36, p. 173, 1931.

The stratigraphic column for Highland County, with thicknesses, is as follows:

System	Formation	*Thickness in feet*
Mississippian	Waverly sandstones and shales	200
Devonian-Mississippian	Ohio shale	250-300
Devonian	Olentangy shale	0- 60(?)
Silurian-Devonian	Hillsboro sandstone	0- 20(?)
Silurian	Greenfield dolomite	0-100
	Peebles dolomite	20- 90
	Lilley dolomite	40- 55
	Bisher dolomite	30- 65
	Crab Orchard shale	35- 95
	Dayton limestone	0- 4
	Brassfield limestone	27- 50
Ordovician (Richmond)	Elkhorn shale	12
	Whitewater shale and limestone	80
	Liberty limestone	30
	Waynesville shale and limestone	50
	Arnheim formation	

In mapping, only three separate units of the Richmond group are depicted: The Arnheim (?), being represented by only one outcrop, is grouped with the Waynesville; the Liberty is mapped separately; and the Whitewater and Elkhorn are grouped together because of the limited thickness of the latter formation. The Ordovician formations below the Whitewater are represented by only a limited number of exposures within the county. The writer is indebted to Professor W. H. Shideler for aid in the differentiation of the Waynesville and Liberty.

The Dayton limestone, because of its slight thickness, is grouped with the Brassfield in mapping, although it is more closely related to the overlying Crab Orchard shale. The base of the Brassfield is taken as the beginning of the bluish, crystalline limestone typical of the lower part of the formation and the top of the Dayton as the top of the light greenish-gray, massive, crystalline limestone immediately below the Crab Orchard shale. The Crab Orchard is easily recognized by its color and lithologic contrast with the resistant formations above and below; and its contact with the Bisher dolomite is particularly well defined, being usually marked topographically by a distinct change in slope and often by springs or swampy ground.

The Bisher and Lilley dolomite formations, formerly termed the "West Union" by Foerste,[1] are mapped as a single unit, although at most points where they occur within the county they may be readily distinguished by their lithology and fossils or by the presence of the

[1] Foerste, A. F., Notes on Silurian fossils from Ohio and other central states: Ohio Jour. Sci., Vol. 17, p. 190, 1917.

Cladopora bed (or coral bed) at the base of the Lilley. The Lilley formation varies considerably in lithologic character and fossil content between different parts of the county, and the *Cladopora* bed is not always present as a recognizable horizon. The two formations together constitute a convenient unit for mapping, with an average thickness of somewhat less than 100 feet.

The boundary between the Lilley and Peebles formations is usually marked by a transition zone from 5 to 10 feet, rather than a sharp contact. At most localities fossils are not readily found within this transition zone. The presence of *Pentamerus oblongus* was at first taken as diagnostic for the Peebles, but this fossil was later found to range down nearly to the top of the Bisher and in the region north and northeast of Hillsboro is abundant in the Lilley as that formation is here described. The Lilley is typically blue in color on fresh exposures and weathers to yellow, while the Peebles is light gray and does not change color greatly on weathering. The colors, however, are not a reliable characteristic, particularly in the transition zone between the two formations. The most satisfactory criteria for mapping were found to be (1) the texture, which for the Lilley is usually moderately to coarsely crystalline and for the Peebles is finely and uniformly crystalline; (2) the presence of crinoid fragments in the upper Lilley, contrasted to their almost complete absence from the Peebles. The coral *Pycnostylus guelphensis* is of fairly common occurrence in the Peebles and was not found in any other formation.

The unconformable contact between the Peebles and the Greenfield dolomite is usually definite and easily recognized, although very irregular. While it is accompanied by a distinct change in type of sediment, certain beds well up in the Greenfield bear such a close resemblance in lithology to the Peebles that the identification in isolated outcrops must be checked by fossils.

The contacts between the Greenfield formation and the Ohio black shale series and between the Ohio and Waverly shales are marked by such pronounced lithologic changes as to afford fairly obvious bases for mapping.

DESCRIPTIONS OF FORMATIONAL UNITS

The following general descriptions of the various units of the section in Highland County consist, first, of brief historical reviews based on the literature to which references are given, and, second, of general descriptions of the formations based on observations made during the present investigation. Further details, such as measured sections, important localities, fossil horizons, etc., are given in a separate chapter on "Detailed Descriptions of Localities." Because of their limited exposure here in comparison with other areas, the Ordovician and Mississippian formations were not studied in detail; and their descriptions are taken less from field observation than in the case of the remainder of the systems.

Richmond Group

General Statement

The name Cincinnatian, now in general use for the upper division of the Ordovician, was approved in this sense by Clarke and Schuchert [1] in 1899. Before this time, the term "Cincinnati group" had been used for the upper Ordovician of the Ohio Valley.[2] The subdivisions of the Cincinnatian are, according to Cumings, Utica, Eden, Maysville, and Richmond. The name Richmond was proposed by Winchell and Ulrich.[3] At the type locality in southern Indiana, and in southwestern Ohio, the formation is stated to be 350 feet thick. According to McFarlan,[4] "The Richmond has customarily been recognized as beginning with the Arnheim though the latter had originally been classified with the Maysville and was again referred to it in 1913 by Cumings and Galloway." Above the Arnheim are the Waynesville, Liberty, Whitewater, and Elkhorn formations. The Saluda facies of the upper formations found in Indiana and Kentucky is not present within this area. According to Nickles' [5] description of the Richmond, "The rocks are even-bedded limestones, usually dove-colored or grayish rather than bluish, from two to ten or more inches in thickness, with regular shale alternations, the limestones forming from one-fourth to one-half the whole mass." Nevertheless, Orton's [6] name, "the Cincinnati or Blue Limestone group," is more expressive of its true character.

Arnheim

The name Arnheim was proposed by Foerste [7] for the "Warren beds" of Nickles.[8] The type locality is in Brown County, about six miles from the southwest corner of Highland County. The top of the Mount Auburn bed, upon which the Arnheim rests, is described as containing an abundance of *"Platystrophia lynx"* (=*Pl. ponderosa auburnensis* Foerste).[9]

---

[1] Clarke, J. M., and Schuchert, Charles, The nomenclature of the New York series of geological formations: Science, N. S., Vol. 10, pp. 874-878, 1899.

[2] Cumings, E. R., Nomenclature and description of the geological formations of Indiana: Handbook of Indiana Geology, State Department of Conservation, Pt. IV, p. 416, 1922.

[3] Winchell, N. H., and Ulrich, E. O., The Lower Silurian deposits of the Upper Mississippi Province: Geol. and Nat. History Survey of Minnesota, Paleontology, Vol. 3, Pt. 2, pp. 83-128, 1897.

[4] McFarlan, A. C., The Ordovician fauna of Kentucky: Kentucky Geol. Survey, Ser. VI, Vol. 36, pp. 47-165, 1931.

[5] Nickles, J. M., The geology of Cincinnati: Cincinnati Soc. Nat. History, Vol. 20, p. 88, 1902.

[6] Orton, Edward, Geology of Highland County: Geol. Survey Ohio, Rept. of Progress in 1870, p. 267, 1871.

[7] Foerste, A. F., The classification of the Ordovician rocks of Ohio and Indiana: Science, N. S., Vol. 22, p. 150, 1905.

[8] Nickles, J. M., op. cit., pp. 49–100.

[9] Foerste, A. F., loc. cit.

The top of the Arnheim is a nodular clay layer. The thickness given is 63 feet. Foerste [1] has subdivided the formation into the Sunset or lower division and the Oregonia or upper division. The base of the Oregonia is described as characterized by the appearance of the Richmond fossils: *Leptaena richmondensis-precursor* Foerste, *Rhynchotrema dentata-arnheimensis* Foerste, and *Dinorthis carleyi* (Hall). The Sunset consists of limestones, which may be cross-bedded and wave-marked, valves of *Rafinesquina alternata* (Conrad) being very common. In the main, however, it is comparatively unfossiliferous and is marked by an abrupt transition to the Oregonia,[2] which Cumings [3] describes as "usually a limestone rubble with much shale and quite different in appearance from the Sunset beds."

Waynesville Limestone and Shale

The name Waynesville was proposed by Nickles [4] in 1903 for the division of the Richmond called the *Dalmanella meeki* zone by Cumings. It is described as conformably overlying the Arnheim and consisting of a large amount of clay and clay shale, with some limestone layers up to 5 inches in thickness. At the type locality in northern Warren County, twenty-five miles northwest of Highland County, the thickness is about 50 feet.

The three divisions of the Waynesville listed by Foerste [5] are Fort Ancient (lowest), Clarksville, and Blanchester. The Fort Ancient has none of the brachiopods characteristic of the Richmond formations above the Arnheim except *Dalmanella jugosa* [=*D. meeki* (Miller)]. The faunal assemblage, including *Anomalodonta gigantea* Miller, *Modiolopsis concentrica* Hall and Whitfield, *M. pholadiformis* Hall [=*Whiteavsi pholadiformis* (Hall)], *Opisthoptera fissicosta* (Meek), *Pterinea demissa* (Conrad), and abundant *Rafinesquina alternata loxorhytis* (Meek), suggests a closer relation to the Arnhein. than to the other divisions of the Waynesville.[6] A large number of Richmond bryozoa are introduced in the Fort Ancient, according to Cumings,[7] including: *Bythopora meeki*

---

[1] Foerste, A. F., Preliminary notes on Cincinnati and Lexington fossils of Ohio, Indiana, Kentucky, and Tennessee: Denison Univ., Sci. Lab., Bull. Vol. 16, p. 18, 1910.

[2] Foerste, A. F., loc. cit.

———, The Arnheim formation within the areas traversed by the Cincinnati geanticline: Ohio Nat., Vol. 12, pp. 429-456, 1912.

[3] Cumings, E. R., Nomenclature and description of the geological formations of Indiana: Handbook of Indiana Geology, State Department of Conservation, Pt. 4, p. 428, 1922.

[4] Nickles, J. M., The Richmond group in Ohio and Indiana and its subdivisions: Am. Geologist, Vol. 32, pp. 205-207, 1903.

[5] Foerste, A. F., Preliminary notes on Cincinnatian and Lexington fossils: Denison Univ. Sci. Lab., Bull. Vol. 14, pp. 291-293, 1909.

[6] Foerste, A. F., op. cit.

[7] Cumings, E. R., op. cit., p. 435.

(James), *Hallopora subnodosa* (Ulrich), *Homotrypella hospitalis* (Nicholson), *H. rustica* Ulrich, *Helopora harrisi* James, *Stigmatella crenudata* Ulrich and Bassler, *S. interporosa* Ulrich and Bassler, *S. spinosa* Ulrich and Bassler, *Heterotrypa prolifica* Ulrich, etc. The Fort Ancient is more shaly than the Clarksville and Blanchester. The Clarksville division extends from the *Orthoceras fosteri* horizon to the lower *Hebertella insculpta* layer.[1] A part of the fauna characteristic of the Richmond comes in a few feet above the *Orthoceras fosteri* zone, including *Streptelasma rusticum* (Billings), *Plectambonites sericeus* (Sowerby), *Strophomena planumbona* Hall, *S. Sulcata* (Verneuil), a variety of *Rhynchotrema* resembling *R. perlamellosa* (Whitfield), and *Leptaena richmondensis* Foerste. The Blanchester division, of which the type locality is a mile west of Blanchester, "includes all between the upper and lower *Hebertella insculpta* horizons." [2] In variety of fauna, it is described as the richest part of the Waynesville. The following species are mentioned by Foerste: *Catazyga headi* (Billings), *Dinorthis carleyi-insolens* Foerste, *Strophomena nutans* Meek, *S. neglecta* (James), a precursor of *S. vetusta* (James), *Rhynchotrema dentata* (Hall), abundant *Rafinesquina* and *Plectorthis* (*Austinella*) *scovillei* (Miller).

Liberty Limestone and Shale

The name Liberty was proposed by Nickles[3] for the *Strophomena-Rhynchotrema* bed of Cumings[4] or *S. planumbona* bed of Nickles,[5] the type locality being in southern Indiana. An exposure is mentioned along Cowan's Creek, in Clinton County, Ohio.

According to Cumings,[6] the Liberty formation "consists more largely of limestone than any other member of the Richmond in Indiana. The layers are often several inches or even a foot thick, and shale is much less in evidence than in the other formations. It is from 25 to possibly 50 feet thick, usually from 35 to 40 feet, and very constant in its thickness, as well as in its lithologic characters. It is extraordinarily fossiliferous throughout, especially abounding in brachiopods and small branching bryozoa. No other Cincinnatian formation rivals it in the beauty and abundance of the specimens. The most characteristic fossils are *Strophomena planumbona* Hall, *S. vetusta* (James), *Plectambonites sericeus* (Sowerby) (in the lower part), *Rhynchotrema capax* Conrad, *Dinorthis subquadrata* Hall, *Platystrophia cumingsi*, *Amplexopora pumila* Cumings

---

[1] Foerste, A. F., loc. cit.

[2] Foerste, A. F., loc. cit.

[3] Nickles, J. M., op. cit., pp. 207–208.

[4] Cumings, E. R., Notes on the Ordovician rocks of southern Indiana: Ind. Acad. Sci., Proc. for 1900, pp. 200-215, 1901.

[5] Nickles, J. M., loc. cit.

[6] Cumings, E. R., Nomenclature and description of the geological formations of Indiana: Handbook of Indiana Geology, State Dept. of Conservation, Pt. IV, p. 436, 1922.

and Galloway, *A. granulosa* Cumings and Galloway, *Constellaria polystomella* Nicholson, *Homotrypa austini* Bassler, *H. cylindrica* Bassler, and *Rhombotrypa quadrata* (Rominger)."

In Kentucky, the fossils included by McFarlan [1] as the more characteristic species are *Dinorthis subquadrata* Hall, *Plectambonites rugosus* (Meek), *Rhynchotrema capax* (Conrad), *Strophomena planumbona* (Hall), *Streptelasma rusticum* (Billings), *Rhombotrypa quadrata* (Rominger), *R. subquadrata* (Ulrich), *Protarea richmondensis* Foerste, and *Homotrypa austini* Bassler.

In 1912, Foerste [2] proposed the name Laughery formation to include the Waynesville and Liberty divisions of the Richmond, because of the relationship between their faunas. The type locality is Laughery Creek in Indiana. This name has not come into general use.

Whitewater Formation

The Whitewater formation, or *Homotrypa wortheni* bed, was described by Nickles [3] in 1903, the type locality being near Richmond, Indiana. Other exposures are mentioned along Cowan's Creek and Dutch Creek, in Clinton County, Ohio. Quoting from Nickles' description, "In this division the strata usually present a roughish, concretionary, nodular appearance, both the limestone and the shale . . . The limestone layers, often more or less impure, are seldom over two inches thick and generally less. The thickness of this division is forty-five to fifty feet."

Cumings [4] ascribes a thickness of 80 feet to the formation at Richmond. He states, "Comparatively few species of fossils are restricted to the Whitewater, most of the fauna being the same as that of the Liberty." The characteristic fossils mentioned by him include: brachiopods, *Strophomena sulcata* (Verneuil), *Rhynchotrema dentata* Hall, *Platystrophia acutilirata* (Conrad), *P. acutilirata prolongata* Foerste, *P. acutilirata senex* Cumings, *Hebertella occidentalis* Hall, *Rhynchotrema capax* (Conrad); pelecypods, *Byssonychia obesa* Ulrich, *Ischyrondonta decipiens* Ulrich, *I. truncata* Ulrich, *Ortonella hainesi* (Miller); gastropods, *Bucania crassa* Ulrich, *B. simulatrix* Ulrich, *Lophospira tropiodophora* (Meek), *L. hammelli* (Miller), *Salpingostoma richmondensis* Ulrich; bryozoans, *Batostoma variabile* Ulrich, *Homotrypa constellariformis* Cumings, *H. nitida* Bassler, *H. nicklesi* Bassler, and a new species of *Amplexopora,* all limited to the Whitewater; other common bryozoans are *Bythopora delicatula* (Nicholson), *Homotrypa cylindrica* Bassler, *H. ramulosa* Bassler, *H.*

[1] McFarlan, A. C., The Ordovician fauna of Kentucky: Kentucky Geol. Survey, Ser. VI, Vol. 36, p. 59, 1931.

[2] Foerste, A. F., *Strophomena* and other fossils from Cincinnatian and Mohawkian horizons, chiefly in Ohio, Indiana and Kentucky: Denison Univ. Sci. Lab. Bull. Vol. 17, p. 22, 1912.

[3] Nickles, J. M., The Richmond group in Ohio and Indiana and its subdivisions: Am. Geologist, Vol. 32, pp. 208-209, 1903.

[4] Cumings, E. R., op. cit., p. 438.

wortheni (James), *Homotrypella rustica* Ulrich, and *Monticulipora epidermata* Ulrich and Bassler; coral, *Streptelasma divaricans* (Nicholson).

Elkhorn Shale

The name Elkhorn was proposed by Cumings [1] in 1908 for the highest beds of Richmond age. The type locality is Elkhorn Creek, near Richmond, Indiana, where the formation is about 50 feet thick. In 1922, Cumings [2] states: "The fauna of this formation has been little studied, and may be expected to furnish some very interesting species especially of bryozoa most of which will be new. *Homotrypa wortheni prominens* Bassler seems to be a common form. It has been intimated by Foerste, Bassler, and others that the Elkhorn, or some part of it, may be the equivalent of the Belfast bed of the eastern side of the Cincinnati arch. Until further faunal and stratigraphic evidence is forthcoming, the relationships of these two interesting formations must remain in doubt." Other fossils mentioned from the Elkhorn are *Platystrophia moritura* Cumings, *Hebertella sinuata* Hall, and *Rhynchotrema dentata* (Hall).

SILURIAN

Since the greater part of Highland County is underlain by rocks of Silurian age, the general characteristics of this group, both here and in other regions, are of greatest importance in any treatment of the stratigraphy of the county. While there have been numerous contributors in this field, the greatest share of our knowledge comes from the works of Dr. August Foerste, whose studies of Silurian fossils have been worldwide.

The classification [3] of the Silurian strata of Kentucky, Indiana, and Ohio, reproduced on p. 54, was given in 1931, and will be used with slight modification for the Highland County area, which may be considered as intermediate between the western Ohio and southern Ohio districts. Under the Clinton series for southern Ohio, the name Crab Orchard will be used to include the Clinton units below the Bisher.

Quoting from the accompanying explanation of the distribution of the Silurian fauna,[4] "Some of the Silurian geologic formations can be traced only for relatively short distances. Even in those which can be traced by lithological characteristics for much longer distances, their included faunas often are very local in distribution, except in the case of a few species which have a very wide geographic range, but which occur

[1] Cumings, E. R., Stratigraphy and paleontology of the Cincinnati series of Indiana: Indiana Dept. of Geology and Nat. Res., Annual Rept. 32, p. 678, 1908.

[2] Cumings, E. R., Nomenclature and description of the geological formations of Indiana: Handbook of Indiana Geology, State Dept. of Conservation, Pt. IV, pp. 438-439, 1922.

[3] Foerste, A. F., The Silurian fauna of Kentucky: Kentucky Geol. Survey, Ser. VI, Vol. 36, p. 173, 1931.

[4] Foerste, A. F., op. cit., p. 171.

at so many horizons that in the present state of our knowledge they have but little value in discriminating faunas." Many examples of this are cited, particularly in Kentucky and Indiana.

As has been mentioned, Highland County is located on the east flank of the Cincinnati geanticline, a broad arch extending both northward and southward from the southwestern part of Ohio. This feature was apparently "already well developed in Silurian times," [1] as shown by the thinning of some of the Silurian formations in Indiana toward the axis of the anticline under the unconformity at the base of the Devonian, and by differences between the faunas east and west of the anticline, at least as early as Clinton time.[2] This conclusion is confirmed by the westward thinning of several lower Silurian units in Highland County.

Within the Silurian of Highland County, in contrast to the Ordovician, the lithologic character of the formations becomes an important factor in mapping; and is the dominant factor at those horizons where diagnostic fossils are lacking or are very rare. While mapping on a lithologic basis has well-recognized limitations and is subject to many errors, these errors are minimized by checking identifications wherever possible by means of fossils.

Brassfield Limestone

This lowest part of the Silurian in Kentucky was doubtfully referred to the Clinton by Owen [3] in 1837; in Ohio it was considered to be of Clinton age by Orton; and was so designated in the earlier works of Foerste. In 1906, Foerste [4] proposed the name Brassfield, from a locality in east-central Kentucky. He describes the lower portion as consisting of massive layers, with thinner beds in the middle and upper parts, and interbedded thin clay layers near the top. The lower massive beds are stated to be unfossiliferous, are more bluish in color, and do not weather to as deep a brown, but they are not considered to form a unit distinct from the rest of the formation. They vary in thickness from 16 inches to more than 8 feet.

The overlying parts of the formation are thinly and irregularly bedded, with thin layers of clay which increase in thickness toward the top. Quoting from his description,[5] "Farther northward, from Montgomery County, in Kentucky, to Highland County, in Ohio, the relative quantity of clay in the upper part of the Brassfield section increases. Northwest of Highland County, however, clay occurs only at the very

[1] Foerste, A. F., op. cit., p. 173.

[2] Idem, p. 174.

[3] Owen, D. D., Report of a geological reconnaissance of the State of Indiana. 34 pp., Indianapolis, 1838.

[4] Foerste, A. F., The Silurian, Devonian, and Irvine formations of east-central Kentucky: Kentucky Geol. Survey, Bull. 7, pp. 18, 27-35, 1906.

[5] Foerste, A. F., op. cit., p. 29.

top of the Brassfield section, and at many localities is absent. It is the upper, thinner-bedded part of the Brassfield limestone which is fossiliferous. Most of the fossils occur near the top of the section." The thickness of the formation as a whole varies from about 19 feet at the type locality down to 9 feet at other localities in east-central Kentucky. The possibility is suggested that there may be a thinning of the Brassfield toward the axis of the Cincinnati geanticline, and thicknesses at a number of localities are cited, but the variations are not considered uniform enough in any one direction to be conclusive.

In this description,[1] the identification with the Clinton of New York is questioned, and it is stated that "the fauna of the Brassfield limestone of Ohio, Indiana, and Kentucky appears to differ sufficiently from the fauna of the Clinton limestone of New York to warrant the assumption of the presence of some sort of barrier between the two areas." No attempt is made, however, to correlate the Brassfield with any other horizon than the Clinton in the New York section.

In 1914, Schuchert[2] correlated the Medina, Cataract, and Brassfield with each other. According to his statement, "the normal marine junction of the Cataract and Brassfield seas is prevented by the Medina delta. For these reasons, Medina, Cataract, and Brassfield are to be retained as names for independent marine faunas and formations."

The term Belfast bed was proposed by Foerste[3] in 1896, for a unit described as follows: "Between the Clinton of Ohio and the upper fossiliferous beds of the Cincinnati formation occur in many parts of the state a series of unfossiliferous beds which it is difficult to assign definitely either to the Upper or the Lower Silurian. Quite frequently the upper part of these unfossiliferous beds consist of a firm rock breaking up and becoming shaly parted after being exposed for a time to the influences of weathering. Where fresh it has a bluish color, but where long exposed it is yellowish or brownish. It has a massive structure in places, being made up of layers 4 to 12 inches thick, with thin partings. Containing in addition to lime a considerable amount of argillaceous material, it is in strong contrast with the very pure Clinton limestones, which overlie it . . ." In the vicinity of Belfast it is 4 feet thick.[4] The Belfast sections were previously described by Foerste[5] in another paper.

More recently, Foerste has given up the name Belfast. In 1931 he

---

[1] Foerste, A. F., op. cit., p. 35.

[2] Schuchert, Charles, Medina and Cataract formations of the Siluric of New York and Ontario: Geol. Soc. America Bull., Vol. 25, p. 294, 1914.

[3] Foerste, A. F., An account of the Middle Silurian rocks of Ohio and Indiana: Cincinnati Soc. Nat. History Jour., Vol. 18, pp. 163-164, 1896.

[4] Foerste, A. F., op. cit., p. 168.

[5] Foerste, A. F., On Clinton conglomerates and wave marks in Ohio and Kentucky: Jour. Geology, Vol. 3, pp. 179-185, 1895.

states:[1] "The term Belfast, proposed for an arenaceous limestone in Highland and Adams counties in Ohio, was dropped when it was learned that it could be traced laterally into limestone strata containing a typical Brassfield fauna. The Belfast is merely a local phase of the base of the Brassfield."

In the same publication he says:[2] "The Brassfield fauna belongs to the upper part of the Medinan, and its areal distribution extends from Alabama, Georgia, and western Tennessee northward to southern Ontario and western New York. The Centerville fauna belongs to a distinctly older part of the Medinan, and is correlated provisionally with the Edgewood fauna of southwestern Illinois and Missouri. Both the Brassfield and Edgewood faunas are of southern origin..." On page 175 he continues: "The Brassfield limestone is the most widely distributed of those Silurian formations whose faunas invaded from the South. It occurs in Oklahoma, Arkansas, Alabama, Tennessee, Illinois, Indiana, Ohio, southern Ontario, and western New York. The Brassfield is the only Silurian fauna of southern invasion which in Ohio crosses from the western to the eastern side of the Cincinnati anticline, and which therefore is known in east-central Kentucky as well as in the west-central part of that State." Farther on he states: "The Brassfield fauna is a relatively large one. It consists of 34 species of brachiopods, 27 bryozoans, 22 cephalopods, 17 gastropods, 14 trilobites, 13 corals, 9 pelecypods, 6 echinoderms (3 crinoids, 2 starfish, and 1 cystid), 2 hydrozoans, 2 graptolites, and 1 ostracod."

Foerste[3] has recently separated layers at the base of the Brassfield in southwestern Ohio which bear a Silurian fauna with some Ordovician aspects, designating this unit as the Centerville formation and correlating it with the Edgewood farther west.

THICKNESS AND CHARACTER IN HIGHLAND COUNTY

The Brassfield limestone ranges in thickness from 27 feet northeast of Lynchburg to 40 feet near the county line southeast of Belfast and 50 feet in the vicinity of the Serpent Mound structure. It consists in the main of bluish-gray to pinkish or nearly white crystalline limestone, with some brown layers in the upper part of the formation. The individual beds vary from 1 inch to 8 inches in thickness, 2 to 4 inches being most common. The bedding planes are distinct and for the most part evenly spaced and continuous for considerable distances, but with minor irregularities which give uneven surfaces to some of the slabs. Shaly partings are more abundant in the upper part

---

[1] Foerste, A. F., The Silurian fauna of Kentucky: Kentucky Geol. Survey, Ser. VI, Vol. 36, pp. 170-179, 1931.

[2] Foerste, A. F., op. cit., p. 170.

[3] Foerste, A. F., op. cit., p. 184.

of the formation, and the percentage of shale increases in going from east to west across the county. In the lower part, many of the more finely crystalline layers show indistinct lamination, with narrow dark gray bands from one-sixteenth to one-fourth inch apart, the wider bands between being bluish gray in color. Numerous recrystallized fossil fragments, particularly of brachiopods and bryozoans, are found throughout the Brassfield. These are only occasionally well enough preserved to be readily identified, although collection of identifiable specimens is not difficult when plenty of time is available. Chert is generally present in the lower part of the formation as distinct layers, concretions, or irregular masses, usually following definite horizons. Glauconite grains are not abundant enough in any single bed in Highland County to be readily noticeable to the unaided eye, but are found in the lower part of the Brassfield by the use of the microscope or by dissolving away the carbonates in dilute hydrochloric acid. In Adams County, there is a conspicuous and fairly constant glauconite layer in the lower part of this unit.

Hematite occurs throughout the upper 6 to 8 feet in the southeast and central parts of the county, but is not present farther west. While a part of the oolitic hematite is probably primary, its occasional occurrence in thin shells around oolitic carbonate grains, and its greater abundance at the weathered outcrop than a few feet back from it, suggest some secondary enrichment at the surface. The apparent concentration at the outcrop is particularly evident at the exposure along Rocky Fork southeast of Hillsboro.

The presence of conglomerate in the Brassfield within Highland County has been noted by Orton,[1] Foerste[2] and Prosser.[3] According to Orton, the conglomerate occurs near the base of the Clinton (Brassfield), and the pebbles "appear to have been derived from the Blue limestone or Cincinnatian rocks." Foerste, whose more extensive study is based on observations of a large number of localities, demonstrates that the conglomerate occurs near the top of the formation and that the pebbles are derived from the Clinton itself. He concludes[4] from the presence of the large pebbles and ripple marks that they indicate waters shallow enough to permit erosion, in fact, probably a slight elevation above sea level. He considers it probable that shallow waters extended at various times over the Blue Grass region in Kentucky and Ohio, but not that the land was of any great elevation. It is doubtful, however, whether this

[1] Orton, Edward, The geology of Highland County: Geol. Survey Ohio, Rept. of Progress in 1870, p. 270, 1871.

[2] Foerste, A. F., On Clinton conglomerates and wave marks in Ohio and Kentucky: Jour. Geology, Vol. 3, pp. 50-60, 169-197, 1895.

[3] Prosser, C. S., Ripple-marks in Ohio limestone: Jour. Geology, Vol. 24, pp. 456-475, 1916.

[4] Foerste, A. F., op. cit., p. 185.

intraformational conglomerate has as much significance as it was originally thought to have.

In size, the individual pebbles range up to 1 foot or more in longest dimension, sizes of 4 to 8 inches being much more common. They are flattened in shape, with rounded edges, and generally occur in the rock with their long axes nearly horizontal. Cross-bedded layers are frequently associated with the pebble layers in the upper part of the Brassfield.

Large ripples, termed "para-ripples" by Bucher,[1] are common in the Brassfield formation. Although of somewhat more frequent occurrence in the upper hematitic layers, they occur also in the lower part, which is generally more thinly and evenly bedded. In wave length, they range from 1 to 2 feet, and in amplitude up to 6 inches.

The Brassfield outcrops in three general areas within Highland County. The first of these is an irregular belt, from three to five miles wide, extending across the county from three miles north of Lynchburg to four miles southeast of Mowrystown. This belt represents the almost complete beveling of the formation by peneplanation, and in it the rock is obscured at most points by a coating of glacial drift. The second general region of outcrops is in the wide and prominent rock terraces along Ohio Brush Creek and its tributaries in the eastern part of Concord Township, Jackson Township, and the southern part of Washington. Here the thickness of the formation is greater and the overburden usually less. The third area is along Rocky Fork south of Hillsboro, extending from near the mouth of South Fork for about four miles upstream. Only the upper hematitic part of the formation appears above the stream level at this locality. East of these three areas, the eastward regional dip carries the Brassfield beneath younger formations.

FAUNA

The following is quoted from Cumings:[2]

"Fauna.—The more common and characteristic species as determined by Foerste, are as follows: *Illaenus daytonensis* H. & W., *I. ambigous* Foerste, *I. madisonianus-elongatus* Foerste, *I. madisonianus depressus* Foerste, *Proetus determinatus* Foerste, *Cyphaspis clintoni* Foerste, *Odontopleura ortoni* Foerste, *Encrinurus thresheri* Foerste, *Calymene niagarensis* (Whitfield), *C. vogdesi* Foerste, *Deiphon foerstei* (Barrande), *Phacops pulchellus* Foerste, *Dalmanites wortheni* Foerste, *Plectambonites*

[1] Bucher, W. H., Large current ripples as indicators of paleogeography: Nat. Acad. Sci. Proc., Vol. 3, pp. 285-291, 1917.

———, On ripples and related sedimentary surface forms and their paleogeographic interpretation: Am. Jour. Sci., 4th Ser., Vol. 47, pp. 149-210, 241-269, 1919.

[2] Cumings, E. R., Nomenclature and description of the geological formations of Indiana: Handbook of Indiana Geology, State Dept. of Conservation, Pt. IV, p. 447, 1922.

prolongatus (Foerste), *P. transversalis* (Wahlenberg), *Leptaena rhomboidalis* (Wilckens), *Strophomena daytonensis* Foerste, *S. striata* Hall, *S. hanoverensis* Foerste, *Orthis flabellites* Foerste (and varieties), *Hebertella fausta* (Foerste), *H. daytonensis* Foerste, *Platystrophia reversata* (Foerste), *P. daytonensis* Foerste, *P. brachynota* (Hall), *Dalmanella elegantula* (Dalman), *D. elegantula parva* (Foerste), *Rhipidomella hybrida* (Sowerby), *Triplecia ortoni* (Meek), *Atrypa marginalis* (Dalman), *Camarotoechia convexa* (Foerste), *Stricklandinia triplesiana* Foerste, *Homotrypa confluens* (Foerste), *Aspidopora parvula* (Foerste), *Lioclemella ohioensis* (Foerste), *Hallopora magnopora* (Foerste), *Chasmatopora angulata* (Hall), *Hemitrypa ulrichi* (Foerste), *Ptilodictya whitfieldi* (Foerste), *Ptilodictya expansa* Hall, *Clathropora frondosa clintonensis* (H. & W.) *Phaenopora expansa* H. & W., *P. fimbriata* (James), *P. magna* (H. & W.), *P. multifida* Hall, *Pachydictya bifurcata* (Hall), *P. bifurcata instabilis* (Foerste), *P. crassa* (Hall), *P. emaciata* (Foerste), *Trigonodictya eatonensis* Ulrich, *Rhinopora verrucosa* Hall, *Dictyonema pertenue* Foerste, *D. scalariforme* Foerste, *Corynotrypa elongata* (Vine)."

The following additional species are mentioned by Foerste[1] for eastern Kentucky, together with others not listed:

Cyathophyllum calyculum Foerste (=*Enterolasma caliculum* Hall), *Rhynchotrema scobina* (=*Camarotoechia neglecta* Hall), *Heliolites subtubulata* (McCoy), *Clathropora frondosa* Hall, *Whitfieldella* sp.

Dayton Limestone

GENERAL DESCRIPTION

The term "Dayton stone" was used in the early Ohio reports by Orton[2] and others. Thicknesses of 5 to 10 feet and more are mentioned in the Montgomery County report (p. 149), but these undoubtedly include more than the present limits of the formation. Foerste[3] states: "In Ohio, there evidently is an unconformity between the top of the Brassfield limestone section and the base of the Dayton limestone. This is indicated by the large pebbles found in the ferruginous and wave-marked rock immediately overlying the Brassfield section south of the Elk Run bridge, two miles east of Belfast...Here many of the pebbles are four to eight inches long, and some are even twelve inches in length."

[1] Foerste, A. F., The Silurian, Devonian, and Irvine formations of east-central Kentucky: Kentucky Geol. Survey, Bull. 7, pp. 27-35, 1906.

[2] Orton, Edward, The geology of Montgomery County: Geol. Survey Ohio, Rept. of Progress in 1869, p. 149, 1871. Also mentioned by J. S. Newberry in Part I of the same volume, p. 15.

——— Geology of Highland County: Geol. Survey Ohio, Rept. of Progress in 1870, pp. 271-272, 1871.

[3] Foerste, A. F., Silurian, Devonian, and Irvine formations of east-central Kentucky: Kentucky Geol. Survey, Bull. 7, p. 43, 1906.

A stratigraphic unit was named the Beavertown marl and described as follows by Foerste [1] in 1885: "Between it (the 'Clinton' group) and the Niagara group is a fine clayey or marly bed, about 9 inches thick, which in some places becomes quite hard, and in others is replaced by a soft blue clay. In connection with the Dayton limestone it usually attains the hardness of stone and is characterized by a number of minute species, which, considering the small attention hitherto paid to this course of stone, is unusually great. For the present it will be called the Beavertown marl, on account of its prominent development near that village, and will be considered as a part of the Clinton group." The Beavertown marl fauna is mentioned by Foerste [2] at Sharpsville, in Highland County. Quoting from his description, "...the top of the ferruginous Clinton presents a lithological characteristic difficult to describe, except that it is a sort of consolidated marl of peculiar color. This marl surface contains a number of fossils characteristic of the so-called Beavertown marl, overlying the Clinton south of Dayton and also south of the Soldiers' Home. These are *Raphistoma affine* Foerste, *Cyclora alta* Foerste, *Loxonema subulatum* (?), one of the small *Tellinomyas, Orthis biforata* (=*Platystrophia lynx* Eichwald), *Orthis elegantula* Dalman (=*Dalmanella elegantula* Dalman), *Orthoceras inceptum* Foerste, and *Calymene vogdesi* Foerste...The present locality is the most southeastern exposure, containing the Beavertown marl fauna, so far as known."

This horizon has since been included by Foerste [3] in the Dayton limestone.

THICKNESS AND CHARACTER IN HIGHLAND COUNTY

The Dayton limestone is typically from 3 to 4 feet thick in Highland County and generally consists of one thick, massive bed and two or three thinner ones. Its upper part is somewhat shaly in the exposures farthest northwest. In texture it is mostly dense, often with scattered crystals of calcite plainly visible in a fine ground mass. The color is light greenish gray in the fresh rock, in some cases weathering to drab or brown. No fossils were found in this unit. The residues from solution of the basal layer in dilute hydrochloric acid contained abundant glauconite grains, but practically none were found higher up. The Dayton appears to be absent in some localities, having presumably been eroded away before the deposition of the Crab Orchard formation.

[1] Foerste, A. F., The Clinton group of Ohio: Denison Univ. Sci. Lab., Bull. Vol. I, pp. 65-66, 1885.

[2] Foerste, A. F., On Clinton conglomerates and wave marks in Ohio and Kentucky: Jour. Geology, Vol. 3, p. 176, 1895.

[3] Foerste, A. F., Silurian fossils from the Kokomo, West Union, and Alger horizons of Indiana, Ohio, and Kentucky: Cincinnati Soc. Nat. History Jour., Vol. 21, p. 2, 1909.

The type locality is at Dayton, Ohio, but this unit is said by Foerste [1] to range southward to Lewis County, Kentucky, and westward almost to Richmond, Indiana. He correlates it provisionally with the thin limestone at the base of the Osgood in Indiana, which, however, is practically unfossiliferous. In the same description he states, "The Dayton limestone evidently is of Lower Clinton age, and provisionally is correlated with the Walcott [Wolcott?] limestone, at the top of the Lower Clinton."

FAUNA

In southern Ohio, the following species are listed by Foerste:[2]

Calostylis cf. *spongiosa* Foerste, *Clathrodictyon vesiculosum* Nicholson and Murie, *Ptychophyllum riboltense* Foerste, and *Zaphrentis* cf. *intertexta* Foerste (which forms also occur at Ribolt, Kentucky); *Alveolites* sp., *Camarotoechia neglecta* Hall, *Coenites* sp., *Cyathophyllum* sp., *Discosorus* cf. *conoideus* Hall, *Drymopora* sp., *Euomphalopterus* sp., *Favosites* cf. *niagarensis* Hall, *Gypidula* sp., *Halysites catenularia* Linnaeus, *Heliolites* sp., *Homoeospira* sp., *Illaenus* cf. *daytonensis* Hall and Whitfield, *Lyellia* sp., *Orthis flabellites* Foerste, *Pentamerus* cf. *oblongus*, *Platystrophia reversata* (Foerste), *Rhinopora verrucosa* Hall, *Rhipidomella hybrida* (Sowerby), *Spirifer niagarensis* (Conrad), *Strombodes mammilaris wilmingtonensis* (Foerste), *Syringolites* sp., and *Whitfieldella* cf. *nitida* (Hall).

Crab Orchard Shale

DESCRIPTION

In his reports on the geology of Lincoln and Garrard counties, in Kentucky, in 1882, Linney [3] used the name Crab Orchard shale for a group of clay shales overlying the Medina. The thickness he gives is from a mere trace to 40 feet, though Foerste [4] shows that Linney's estimates are erroneous, and that there is a minimum thickness of 75 feet in the Crab Orchard region. When fresh, these shales are described by Linney as black, green, olive, blue, and red; the color of the weathered shale is gray, white, or green. In the shale are hard, thin dolomite layers, with curved (cross-bedded) laminae. Selenite and pyrite are also mentioned.

---

[1] Foerste, A. F., The Silurian fauna of Kentucky: Kentucky Geol. Survey, Ser. VI, Vol. 36, p. 185, 1931.

[2] Foerste, A. F., loc. cit.

[3] Linney, W. M., Report on the geology of Lincoln County: Kentucky Geol. Survey, 36 pp., 1882.

——— Report on the geology of Garrard County: Kentucky Geol. Survey, 30 pp., 1882.

[4] Foerste, A. F., Silurian, Devonian, and Irvine formations of east-central Kentucky: Kentucky Geol. Survey, Bull. 7, p. 68, 1906.

In eastern Kentucky, Foerste divided the Crab Orchard into the following units:

Crab Orchard division of Silurian	Alger formation	Estill clay
		Waco limestone
		Lulbegrud clay
	Indian Fields formation	Oldham limestone
		Plum Creek clay

He mentions a possibility that the Estill clay is represented in Adams and Highland counties by the unfossiliferous clays between the Dayton and the fossiliferous Ribolt clays.

In Highland County, the Crab Orchard is usually a soft, light green clay shale with occasional thin beds of impure orange-drab dolomite. Fossils are not common and where found are poorly preserved. The dolomite layers usually contain abundant fucoid markings. These thin layers show a tendency toward lenticular or even concretionary character and are finely laminated, the laminæ frequently indicating cross-bedding. They are very finely crystalline and tough, occur at intervals ranging from 2 or 3 feet to 20 feet or more, and vary in thickness from ½ inch to 6 inches. On weathering, the soft shale of the Alger becomes a sticky, highly plastic clay, much lighter in color than the unweathered rock. This soft clay hardens and cracks at the surface in dry weather. Its effect on soil creep and sliding, as well as the topographic expression of the formation, is discussed on page 13.

The upper part of the greenish clay shale series is fossiliferous, and has been given the name Ribolt by Foerste.[1] The fossils within this upper part of the formation occur in the thin, hard layers. No attempt was made in the mapping of Highland County to separate this from the remainder of the shale series.

THICKNESS AND CHARACTER IN HIGHLAND COUNTY

In thickness, the Crab Orchard formation shows a considerable variation within the county: At the southern county line, southeast of Belfast, it is 95 feet thick, while its thickness northeast of Sharpsville is only a little over 30 feet, but its base is not exposed. The difficulty of establishing the base of the formation with exactness may render the thicknesses as mapped at some points slightly inaccurate, but from a number of measured sections it is clear that the thinning takes place somewhat irregularly toward the north and west, and that the rate of westward thinning is more rapid in the western half of the Hillsboro quadrangle than in the eastern half.

[1] Foerste, A. F., Silurian fauna of Kentucky: Kentucky Geol. Survey, Ser. VI, Vol. 36, p. 188, 1931.

FAUNA OF RIBOLT CLAY

The following species are listed from the Ribolt by Foerste:[1]

Anoplotheca cf. *obsoleta* Foerste, *Brachyprion (Stropheodonta) mundula* Foerste, *Bucaniella* cf. *trilobata* (Conrad), *Camarotoechia congruens* Foerste, *C. neglecta* (Hall), *Chonetes vetustus* Foerste, *Dalmanites clintonensis, Liocalymene clintoni* Foerste, several species of ostracods, particularly of the genus *Mastigobolbina; Pterinea emacerata* (Conrad), *Schuchertella* cf. *subplana* (Conrad), *Atrypa reticularis* (Linnæus), *Brachyprion* cf. *planus* Foerste, *Calymene niagarensis* Hall, *Gyronema* sp., *Leptaena rhomboidalis* (Wilckens), *Pholidops squamiformis* (Hall), *Schuchertella* cf. *prosseri* Foerste, and *Spirifer radiatus* Sowerby.

Bisher Dolomite

GENERAL DESCRIPTION

The Lower or West Union Cliff of Orton [2] is not described from the locality of West Union, but from the hillside northeast of the former site of Bisher's dam, southeast of Hillsboro, where its thickness is given as 45 feet. Locke [3] had described the "Cliff limestone" at West Union as 86 feet thick and divided it into three parts, the upper a "rough, porous, soft limestone, filled with cavities which have been occupied by fossil animals, and which have decayed out;" the middle, "aluminous, and somewhat arenaceous, of a slaty structure, dark gray color, and comparatively hard;" the lower, more sandy than the others.

Orton [4] gives the following analysis from a sample at West Union: Carbonate of lime, 42.8 per cent; carbonate of magnesia, 34.79 per cent; silica and sand, 18.8 per cent; alumina and iron, 2.2 per cent. An analysis of a typical specimen of the "yellowish, impure magnesian limestone" from the vicinity of Hillsboro is listed in the same report:[5] Siliceous matter, 2.60 per cent; alumina and iron, 3.20 per cent; lime-carbonate, 62.60 per cent; magnesia-carbonate, 31.32 per cent. On the same page he states that the West Union Cliff limestone forms the first line of cliffs in ascending the hill east of Bisher's dam, and that "The stone is rather massive than even-bedded in its appearance, though in quarrying it can generally be raised in rough courses of 6, 8 or 10 inches. . . . It weathers easily. . . . It abounds in fossils, but generally they are poorly preserved, as internal casts. . . ." The thickness is stated to increase toward the south.

---

[1] Foerste, A. F., loc. cit.

[2] Orton, Edward, The Cliff limestone of Highland and Adams counties: Geol. Survey Ohio, Rept. of Progress in 1870, pp. 295-309, 1871.

[3] Locke, John, Geological Report: Geol. Survey Ohio, Second Ann. Rept., p. 242, 1838.

[4] Orton, Edward, op. cit., p. 303.

[5] Orton, Edward, op. cit., p. 274.

The name Bisher, from the typical exposure at Bisher's dam, was used by Foerste[1] in 1917 and 1919, corresponding to the Lower or West Union Cliff of Orton. Later, Foerste gave a somewhat different definition to the West Union formation. Exposures with the Bisher fauna are described from Port William, in Clinton County, as far south as Lewis County, Kentucky. Correlation with the Osgood of southern Indiana is suggested; but later Foerste[2] has considered the Bisher as representing a slightly lower horizon than the Osgood. In this later classification he places the Bisher in the Clinton series and the overlying Lilley in the Lockport series. In 1905, Prosser placed the West Union above the Osgood in his *Revised Nomenclature of the Geological Formations of Ohio.*

THICKNESS AND CHARACTER IN HIGHLAND COUNTY

The thickness of the Bisher formation ranges from less than 30 feet at the west margin of its outcrop to over 60 feet in the hills east of Elm Run, 50 feet being the normal thickness at the localities where it is best exposed.

There is considerable variation in lithologic character, often within short distances. The gray, massive, crystalline dolomite is usually impure, and weathers quickly to a yellow or brown color which is characteristic of most of its outcrops. The *Whitfieldella* bed presents this type of lithology, as well as much of the upper part of the formation at some localities. The more silty massive beds split up into thin plates upon weathering, although apparently solid in the unweathered rock. Silty to sandy shale and shaly dolomite horizons may be present in any part of the formation and make up the bulk of the lower part of it in the south-central part of the Hillsboro quadrangle. Thin fossiliferous chert layers are present in the upper Bisher, particularly in the Hillsboro region and in the vicinity of the Serpent Mound structure. Quartz-lined geodes are common at many localities. In the northeastern part of the area of outcrop of this unit, there are occasional local small reef-like irregularities in the bedding, up to several yards in diameter. Other local variations in the character of the Bisher are described more fully in the next chapter.

FAUNA

The fauna of the Bisher, as here listed, was described by Foerste[3] in 1919. Most of these species come from a richly fossiliferous horizon 8

[1] Foerste, A. F., Notes on Silurian fossils from Ohio and other central states: Ohio Jour. Sci., Vol. 17, p. 190, 1917.

——— Silurian fossils from Ohio, with notes on related species from other horizons: Ohio Jour. Sci., Vol. 19, pp. 367-373, 1919.

[2] Foerste, A. F., Silurian fauna of Kentucky: Kentucky Geol. Survey, Ser. VI, Vol. 36, p. 173, 1931.

[3] Foerste, A. F., Silurian fossils from Ohio, with notes on related species from other horizons: Ohio Jour. Sci., Vol. 19, pp. 369-370, 1919.

to 10 feet above the base of the formation, generally known as the "*Whitfieldella cylindrica* zone or bed," which Foerste[1] describes as continuous throughout Highland and Adams counties and occurring as far south as Martins, Lewis County, Kentucky.

FAUNA OF BISHER DOLOMITE

Cornulites clintoni Hall
Chasmatopora angulata (Hall)
Clathropora frondosa Hall
Pholidops subelliptica Savage
Orthis flabellites Foerste
Dalmanella elegantula (Dalman)
Rhipidomella hybrida (Sowerby)
Rhipidomella magnicardinalis Foerste
Platystrophia daytonensis (Foerste)
Platystrophia pauciplicata Foerste
Leptaena rhomboidalis (Wilckens)
Plectambonites transversalis (Wahlenberg)
Schuchertella confertus Foerste
Schuchertella prosseri Foerste
Stropheodonta plana Foerste
Camarotoechia acinus subrhomboidea Foerste
Camarotoechia neglecta Hall
Camarotoechia pisa (Hall and Whitfield)
Camarotoechia roadsi Foerste
Camarotoechia cf. *stricklandi*
Rhynchotreta cuneata americana (Hall)
Atrypa reticularis elongata Foerste
Atrypa rugosa Hall
Trematospira camura pauciplicata Foerste
Spirifer eudora (Hall)
Spirifer harinensis (Foerste)
Spirifer nanus (Foerste)
Spirifer niagarensis (Conrad)
Spirifer radiatus (Sowerby)
Spirifer radiatus obsoletus Foerste
Cyrtia myrtia Billings
Whitfieldella cylindrica Hall
Whitfieldella, form from which *cylindrica* is a derivative
Diaphorostoma cliftonense Foerste
Diaphorostoma niagarense (Hall)
Platyceras angulatum (Hall)
Illaenus depressus Foerste
Bumastus ioxus (Hall)
Cyphaspis sp.
Encrinurus sp.
Calymene niagarensis Hall
Trimerus delphinocephalus Green
Cheirurus niagarensis (Hall)
Dalmanites limulurus brevicaudatus Foerste

Lilley Dolomite

GENERAL DESCRIPTION

Although the term "West Union Cliff," as used by Orton[2] in 1871, included approximately the same as the present Bisher formation, he incorrectly[3] identified the overlying "Blue Cliff" with the Springfield farther north. Foerste[4] later used the term West Union for the series of dolomites and shales between the top of the Crab Orchard formation and the base of the Peebles (then called Cedarville). Quoting from this description,[5] "At Hillsboro, Ohio, the West Union formation is separable into two members containing very different faunas. The upper, or

[1] Foerste, A. F., op. cit., p. 368.

[2] Orton, Edward, The geology of Highland County: Geol. Survey Ohio, Rept. of Progress in 1870, p. 274, 1871.

[3] See Foerste, A. F., Silurian fossils from Ohio, with notes on related species from other horizons: Ohio Jour. Sci., Vol. 19, p. 367, 1919.

[4] Foerste, A. F., Notes on Silurian fossils from Ohio and other central States: Ohio Jour. Sci., Vol. 17, pp. 190-194, 1917.

[5] Foerste, A. F., loc. cit., pp. 190, 194.

Lilley member, exposed at various localities on Lilley Hill, consists of about twenty feet of massive limestone usually overlaid by two or three feet of clay. It has been identified with certainty so far only in the vicinity of Hillsboro. . . . It is sufficiently distinct to merit a separate designation locally, and hence the name *Lilley* bed or member is here proposed to include both the clay shale and the underlying limestone, since they contain the same fauna. Both the Zink [1] and the Trimble quarries are located on the west side of Lilley Hill, along the eastern edge of Hillsboro. For the underlying part of the West Union formation the term *Bisher* member is proposed, the typical fauna occurring northeast of Bisher dam, a mile southeast of Hillsboro and outcropping along the hillside northward as far as the lower part of the valley immediately southeast of the town. . . ."

Writing in 1919, Foerste [2] extended his description of the Lilley member as follows:

"The overlying rock, or Upper Cliff, was called by Orton the Blue Cliff. The best exposures of the Blue Cliff are stated to be at Hillsboro, along the abandoned line of the Cincinnati and Hillsboro Railroad, at Academy Hill, and at the Trimble quarry at the eastern end of the railroad cut at the eastern margin of the city of Hillsboro. The prevailing color is blue, weathering into various shades of drab and buff. The thickness of the Blue Cliff proper is from 20 to 30 feet; it is underlaid by 5 to 15 feet of blue shale or soapstone, producing a maximum thickness of 30 plus 15, or 45 feet. The basal part of the Blue Cliff proper generally consists of quite massive limestone courses, often more or less crinoidal. The Blue Cliff was incorrectly identified by Professor Orton with the Springfield dolomite of the more northern counties of Ohio. . . .

"Among the fossils cited by Professor Orton from the Upper or Blue Cliff are *Halysites, Favosites* and Zaphrentid corals identified by him as *Streptelasma.* The spherical concretions stated to be common in Marshall Township, in Highland County, unquestionably are a form of stromatoporoid. . . .

". . . the Lilley member corresponds to the Upper or Blue Cliff."

THICKNESS AND CHARACTER IN HIGHLAND COUNTY

The lithology of the Lilley formation, as it is here considered, remains recognizable, though not constant, throughout the parts of the county where it is present. The fauna, however, varies to a considerable extent within a few miles of the type locality. Since the Bisher and Peebles formations are generally unmistakable in reasonably good outcrops,

[1] Zig, according to Dr. Shideler who visited this quarry with the writer.

[2] Foerste, A. F., Silurian fossils from Ohio, with notes on related species from other horizons: Ohio Jour. Sci., Vol. 19, pp. 367-368, 1919.

and the physical character of the Lilley itself is fairly distinctive, this formation could usually be identified as a definite unit in the series within Highland County, even without much dependence upon its fossils. Its base is usually marked by one or two massive beds, sometimes irregular in bedding and fracture, which contain numerous corals and crinoid fragments. Below this is the Bisher, generally a yellowish brown dolomite with shaly layers near the top. At the top of the Lilley, or near it, in the quarry sections at the east margin of Hillsboro is the *Holophragma* zone, containing *Holophragma calceoloides* in abundance. At the quarry on the Beecher estate (Trimble quarry of early reports) there are two shale layers in the upper Lilley; in the typical exposure at the old Corporation quarry, there is one shale layer, about three feet thick, containing the *Holophragma* zone. In other sections, the clay shale layer is generally absent.

While the large brachiopod form *Pentamerus oblongus* is not present in the Lilley at Hillsboro and has been generally considered as characteristic of the Peebles, in the region four to six miles north and east of Hillsboro it occurs down to within 2 or 3 feet of the cherty layers in the upper Bisher. This cannot be due to absence of the Lilley as a stratigraphic unit, for it retains its characteristic lithology and thickness, with the usual zone of transition into the Peebles.

In fresh exposures below the weathered surface rock, the Lilley is light blue in color and frequently occurs in moderately even beds 2 to 4 inches or more in thickness. It is often crinoidal and ranges from coarsely to finely crystalline in texture. In weathered exposures the color of the rock is yellowish or brownish to a depth of 4 or 5 feet; it is occasionally porous in texture; and in some cases is stained nearly black with an asphaltic impregnation. Where packed with *Cladopora* or crinoid fragments, it generally shows rounded forms in weathered exposures, with little evidence of bedding or joints, or with very irregular bedding. This is particularly true in the southern part of the county. The upper part of the formation in many localities grades through a transition zone of 3 or 4 feet into the uniform light gray, finely crystalline dolomite typical of the Peebles. This upper part of the Lilley has few bedding planes and is a light yellowish gray in color; it often has crinoid fragments, while the Peebles generally does not.

The Lilley is correlated by Foerste[1] with the Louisville limestone west of the Cincinnati anticline and with the Lockport of the New York section. *Cyathophyllum radicula* Rominger, *Omphyma verrucosa* Rafinesque and Clifford, and *Strombodes striatus* are considered characteristic of the Lockport in its westward extension.

---

[1] Foerste, A. F., op. cit., p. 374.

——— Silurian fauna of Kentucky: Kentucky Geol. Survey, Ser. VI, Vol. 36, pp. 190-191, 1931.

FAUNA

Foerste's[1] list of fossils from the Lilley at Hillsboro is as follows:

Acervularia parveyi Foerste
Anastrophia internascens Hall
Brachyprion newsomensis Foerste
Atrypa reticularis hillsboroensis Foerste
Calymene cf. *vogdesi* Foerste
Camarotoechia indianensis (Hall)
C. neglecta (Hall)
Coenites verticillatus (Winchell and Marcy)
Cyathophyllum roadsi Foerste
Dalmanites brevigladiolus Foerste
Diaphorostoma hillsboroensis Foerste
Encrinurus cf. *ornatus* Hall and Whitfield
Halysites labyrinthicus (Goldfuss)
Holophragma calceoloides Lindstrom
Lepteana rhomboidalis (Wilckens)
Plasmopora follis Edwards and Haime
Poleumita parveyi Foerste
Poleumita prosseri Foerste
Proetus collinodosus Foerste
Rhipidomella hybrida (Sowerby)
Rhynchotreta cuneata americana (Hall)
Strombodes striatus (D'Orbigny)
Trochonema fatuum Hall
Zaphrentis digoniata Foerste
Also a stromatoporoid.

The following species are listed from Crooked Creek, in northern Adams County:

Cyathophyllum radicula Rominger
Cystiphyllum niagarense (Hall)
Favosites spinigerus Hall
Heliolites subtubulatus (McCoy)
Omphyma cf. *verrucosa* Rafinesque and Clifford
Striatopora cf. *flexuosa* Hall

Peebles Dolomite

GENERAL DESCRIPTION

For the dolomite next above the "Blue Cliff" in the Niagaran series, Orton[2] used the terms Guelph or Cedarville, or, as a local designation, Pentamerus limestone. Its dolomitic character and lack of distinct bedding, and the occasional presence of black bituminous matter in it, were mentioned in Orton's description, as were also the three common fossil genera, *Pentamerus, Trimerella* and *Megalomus*. The upper part of the "Pentamerus limestone" or the Megalomus beds he considered to

[1] Foerste, A. F., op. cit., p. 190.
[2] Orton, Edward, The geology of Highland County: Geol. Survey Ohio, Rept. of Progress in 1870, pp. 277-278, 1871.

be the equivalent of the Cedarville limestone of Ohio and the Guelph of Ontario.

Foerste[1] used the term Cedarville for this division of the Highland County section as late as 1919; but in 1923, he[2] preferred the name Guelph, stating: "The term Guelph is used here merely to avoid using the term Cedarville dolomite for strata not containing a fauna similar to that of the Cedarville area. It does, however, contain *Megalomus canadensis*, species of *Trimerella*, and other fossils known in the Guelph of Ontario. *Liospira perlata* and tall species of *Coelocaulus* occur.

"The base of this so-called Guelph in the quarries in the eastern part of the town of Hillsboro is formed by a *Pentamerus* horizon which corresponds approximately to the Springfield dolomite of Greene, Clarke, Miami, Montgomery, and Preble counties, farther north in Ohio. The overlying part of this so-called Guelph should correspond in age to the Cedarville dolomite of the counties just mentioned, but it does not contain the same fauna."

In 1929, Foerste[3] proposed the name Peebles for this unit, correlated with the Guelph of Canada but considered to override the Cedarville to the northward. Southward it may be traced as far as the Ohio River.[4]

Foerste writes: "The Peebles formation is exposed typically at Peebles, Ohio. It includes at this locality that part of the Niagaran which intervenes between the top of the Bisher west of town and the base of the Greenfield 2 or 3 miles eastward. At Hillsboro, the Lilley formation intervenes between the Bisher and the Peebles."

THICKNESS AND CHARACTER IN HIGHLAND COUNTY

Lithologically, the Peebles has a finely crystalline texture and light gray color, both of which are remarkably uniform where the rock is unweathered. In its typical development it has no conspicuous bedding and jointing is generally not pronounced. It is a very pure dolomite, as shown by the following analysis, quoted by Orton,[5] from the quarry of Col. Trimble, near Hillsboro:

---

[1] Foerste, A. F., Silurian fossils from Ohio, with notes on related species from other horizons: Ohio Jour. Sci., Vol. 19, p. 368, 1919.

[2] ———Notes on Medinan, Niagaran, and Chester fossils: Denison Univ., Sci. Lab., Bull. Vol. 20, p. 41, 1923.

[3] Foerste, A. F., The correlation of the Silurian section of Adams and Highland counties with that of the Springfield area (abst.): Ohio Jour. Sci., Vol. 29, pp. 168-169, 1929.

[4] Foerste, A. F., Silurian fauna of Kentucky: Kentucky Geol. Survey, Ser. VI, Vol. 36, p. 191, 1931.

[5] Orton, Edward, The geology of Highland County: Geol. Survey Ohio, Rept. of Progress in 1870, p. 278, 1871.

Carbonate of lime	54.25
Carbonate of magnesia	43.23
Silica	0.40
Alumina and iron (trace of iron)	1.80
	99.68

(For modern analyses of this formation, see Chapter V.)

The thickness given by Orton is from 20 to 90 feet, the latter thickness being reached only at the eastern margin of the county, near Rocky Fork. The minimum thickness given, for Lilley Hill, is much too small for that locality. The greatest thickness of this unit appears to be present along a belt extending from west of Samantha to near the mouth of Rocky Fork, in which belt its thickness is 90 feet or over; but northeastward from this, and particularly north of Rattlesnake Creek, it thins rapidly and irregularly.

In the small unglaciated area at the southeast corner of the county, the Peebles is frequently disintegrated and the product appears as a soft, crumbly material, locally called "marl." It has been used to some extent as agricultural lime and for road building.

FAUNA

Quoting further from Foerste's description:[1] "At Hillsboro, *Pentamerus oblongus* is abundant at the base of the Peebles formation. The general character of the fauna of this formation, as exhibited in Highland and Adams counties, is shown by the following list: *Amphicyrtoceras* cf. *pettiti, Amphicyrtoceras tantalum, Coelocaulus macrospira* (Hall), *Dinobolus conradi* (Hall), *Eccyliomphalus circinatus* (Whiteaves), *Eotomaria areyi, Eotomaria halei* Clarke and Ruedemann, *Goniophora crassa* Whiteaves, *Hormatoma whiteavesi* Clarke and Ruedemann, *Megalomus canadensis* Hall, *Monomorella* sp., *Pentamerus oblongus* Sowerby, *Poleumita crenulata* Whiteaves, *Poleumita scamnata* Clarke and Ruedemann, *Pycnostylus guelphensis* Whiteaves, *Straporollus parveyi* Cleland, a globose stromatoporoid, *Trimerella acuminata* Billings, and *Trimerella grandis* Billings. This is a Guelph fauna, comparable to that exposed in the southern part of Ontario and western New York. It differs distinctly from the Cedarville as exposed in Clinton, Greene, Clarke, Montgomery, Miami, Preble, and Darke counties, in western Ohio . . ."

[1] Foerste, A. F., Silurian fauna of Kentucky: Kentucky Geol. Survey, Ser. VI, Vol. 36, p. 191, 1931.

Greenfield Dolomite

GENERAL DESCRIPTION

The Niagaran series is followed by the Greenfield dolomite member of the Bass Island formation, of lower Monroe age.[1] The following summary is taken from Carman's [2] excellent account of the Monroe division.

The type locality is in the vicinity of Greenfield, in Highland County; its occurrence farther south along the eastern margin of the county and in Adams County becomes irregular, as it is cut out by the unconformities at the base of the Hillsboro sandstone and the black shale series. While its outcrop forms a belt to the northwestward across the State, it is generally thickly drift-covered.

Quoting from Carman's description,[3] "The Greenfield is a drab, fine-grained dolomite with carbonaceous partings and commonly in beds of 2 to 6 inches, although at places with thicker beds or massive ledges. This massive phase is rough textured and vesicular, with corals and stromatoporoids, and is a kind of reef rock which at places can be seen to pass laterally into the even-grained, bedded type. The thickness of the Greenfield is apparently between 75 and 100 feet, but a complete section is not known at any place. . . .

"The Greenfield, as in fact most of the Monroe, is characterized by undulating bedding with local dips of 1 to 3° in various directions, forming low domes and shallow basins 40 to 100 feet across, which are apparently original structures. There may be also small folds of secondary origin. The undulations are so irregular in arrangement, and the direction and amount of dip changes at such short intervals, that no dependence can be placed upon elevations of contacts or rock layers in correlating strata from exposure to exposure."

While some localities are mentioned in northern Ohio at which there is a slight unconformity underneath the Greenfield, most of the exposures in that part of the State "show apparent conformity with very characteristic transition changes and with very wide-spread uniformity of the beds just below and just above the contact." [4]

No specific mention is made of unconformity at the base of the Greenfield in southern Ohio, yet the character of the contact between it and the underlying Peebles has all the appearance of an unconformable one. Not only the local irregularities of the contact and the pronounced

[1] Lane, Prosser, Sherzer and Grabau, Nomenclature and subdivision of the upper Siluric strata of Michigan, Ohio, and western New York (abst.): Geol. Soc. America, Bull., Vol. 19, pp. 553-556, 1909.

[2] Carman, J. E., The Monroe division of rocks in Ohio: Jour. Geology, Vol. 35, pp. 486-488, 1927.

[3] Carman, J. E., op. cit., p. 486.

[4] Idem.

variations in dip within the lower Greenfield[1] suggest this, but also the variations in thickness of the Peebles (since the lower contact of the latter is a fairly regular one). For instance, the thickness of the Peebles at the Seven Caves, along Rocky Fork, is over 90 feet; five miles northwest of this point, north of Rattlesnake Creek, its thickness is from less than 40 to 60 feet. At this latter locality, the base of the Greenfield varies as much as 15 feet in elevation between outcrops 200 or 300 feet apart. The Greenfield itself, as here mapped, varies in thickness from 0 to about 100 feet within the county; but since there is no single complete section, and since both upper and lower contacts are irregular, the maximum thickness cannot be established with exactness. The Peebles, as has been stated, has its greatest thickness within the county in general along a line from the Caves, near the mouth of Rocky Fork, to the hill west of Samantha. North of this the Greenfield comes in, thickening rapidly for a few miles to the northward, the Peebles becoming thinner in this direction. Although other units of the Monroe division of rocks may be present in Highland County, these rocks were all included with the Greenfield in mapping.

THICKNESS AND CHARACTER IN HIGHLAND COUNTY

Of the lithological characteristics, the most striking is the presence of carbonaceous partings, as mentioned by Carman, together with gray-and-drab lamination in places somewhat similar in appearance to that of the Manlius limestone in central New York. These, with the abundance of the ostracod *Leperditia,* generally serve to identify the Greenfield at once, where it is well exposed. The carbonaceous material has been described in a paper by Napper,[2] who divides the Greenfield member in the quarry at Greenfield into two parts, the lower one gray, the upper buff. The upper or buff part is generally more open-textured and vesicular than the lower portion and occurs in heavier beds; but there is complete gradation between the two. In the lower or gray strata, the carbonaceous material is said to occur as volatile matter near the base, as "carbon lines" or bands, sometimes twenty-five to the inch, and as thin sheets, which "burn with an oily, sooty flame, leaving a thin rock stratum." Napper considers the origin of this material to have been from the decay of a plant, *Sphaerococcites* (?) *glomeratus* Grabau, which fossil occurs in some of the carbonaceous partings. The "carbon sheets" are described as most numerous in the lower part of the buff strata. Solidified "rock tar" is also mentioned from cavities in the buff division. It should be

---

[1] For a description of local irregularities in the bedding of the Greenfield dolomite and of peculiar concretions found in the Greenfield quarries see Napper, C. W., Concretionary forms in the Greenfield limestone: Ohio Jour. Sci., Vol. 18, pp. 7-13, 1918.

[2] Napper, C. W. Occurrence of carbonaceous material in the Greenfield member of the Monroe formation: Ohio Jour. Sci., Vol. 16, pp. 155-158, 1916.

noted, however, that asphaltic impregnations are common in the underlying Niagaran series in different parts of the county and do not necessarily have any connection with the carbonaceous laminae which are found only in the Greenfield.

While no detailed microscopic study was made of the carbonaceous laminae of the Greenfield in connection with the present investigation, it is suggested that their nature may be somewhat comparable to that of the varves in the Green River series described by Bradley.[1] It is not meant to imply, however, that the carbonaceous laminae of the Greenfield actually are varves.

FAUNA

The following species are listed from the Greenfield by Foerste;[2] those marked with an asterisk are also mentioned by Carman.[3]

**Camarotoechia hydraulica*
**Hindella (?) (Greenfieldia) rostralis*
Hindella (?) (Greenfieldia) whitfieldi
**Leperditia angulifera*
**Leperditia ohioensis*
**Rhynchospira praeformosa*
**Schuchertella hydraulica*
Whitfieldella rotundata
Whitfieldella subsulcata
Pentamerus pesovis (unknown locality in Adams County)

SILURIAN-DEVONIAN

Hillsboro Sandstone

GENERAL DESCRIPTION

Named by Orton[4] in 1871 from the locality of Hillsboro, the Hillsboro sandstone was originally referred to the Niagaran series because of its apparent close association with the rocks of that group in the imperfect sections at Lilley Hill and elsewhere within the county. Prosser,[5] in 1916, published a more extensive account of the formation, with sections which would seem to indicate a position below the Monroe (Greenfield) dolomite, or interstratified with the upper Cedarville (Peebles) and basal Greenfield.

The ambiguity concerning the position of the Hillsboro in the

---

[1] Bradley, W. H., The varves and climate of the Green River epoch: U. S. Geol. Survey, Professional Paper 158, pp. 87-110, 1930.

[2] Foerste, A. F., Silurian fauna of Kentucky: Kentucky Geol. Survey, Ser. VI, Vol. 36, pp. 192-193, 1931.

[3] Carman, J. E., op. cit., p. 488.

[4] Orton, Edward, The geology of Highland County: Geol. Survey Ohio Report of Progress in 1870, pp. 283-285, 306-309, 1871.

[5] Prosser, C. S., The Stratigraphic position of the Hillsboro sandstone: Am. Jour. Sci., 4th Ser., Vol. 41, pp. 435-448, 1916.

stratigraphic column was cleared up by Carman and Schillhahn[1] in 1930. From a study of a large number of sections, some of which were better exposed than any seen by Orton or Prosser, they demonstrated that the Hillsboro occurs in two types of deposits: "(a) bedded sandstone resting on either the Niagaran or the Greenfield dolomites: (b) masses of sandstone which are cavity fillings enclosed in either the Niagaran or the Greenfield dolomites." Other conclusions set forth in this paper are as follows:

"The Hillsboro sandstone exists in a hiatus which extends from the Greenfield dolomite of Upper Silurian to the Ohio shale of Upper Devonian. The presence of black shale, almost identical with the Ohio shale, around the margins of some of the sand masses indicates that the deposition of the sand took place just before the deposition of the Ohio shale in Upper Devonian time.

"In both physical and microscopic characteristics the Hillsboro sandstone is almost identical with the Sylvania sandstone of basal Devonian age in northwestern Ohio. It probably represents some of the finer sand of the Sylvania shifted southward during the Silurian-Devonian erosion interval which, in Highland County, lasted until Upper Devonian time."

THICKNESS AND CHARACTER IN HIGHLAND COUNTY

Lithologically, the Hillsboro is a white or yellowish sandstone, frequently stained to a reddish-brown color by iron oxides, and showing little or no stratification. It is unfossiliferous; certain small cavities, elongated and generally less than an inch in length, suggest at first examination the possibility of moulds of small fossils, but never show any definite evidence of organic origin. Many of the sand grains are well-rounded, and some are frosted, suggesting wind action; others have hexagonal pyramid and prism faces from secondary growth. The grains are fine: according to Carman and Schillhahn,[2] the greater proportion of them are under a quarter of a millimeter, and from 40 to 80 per cent are between a sixteenth and an eighth of a millimeter in size. The sandstone is very friable and never closely cemented.

While the Hillsboro outcrops on many hills within Highland County, it is never present in great volume. Its presence in pockets within the dolomite, as well as in sheets, formerly led to over-estimation of its thickness, particularly where sections were poorly exposed.

---

[1] Carman, J. E., and Schillhahn, E. O., The Hillsboro sandstone of Ohio: Jour. Geology, Vol. 38, pp. 246-261, 1930.

[2] Carman, J. E., and Schillhahn, E. O., op. cit., p. 257.

DEVONIAN

Olentangy Shale

GENERAL DESCRIPTION

The Olentangy shale, named by Winchell[1] in 1874, has long been known as a standard unit of the geologic section in northern and central Ohio. Its occurrence in the southern counties of the State was described by Lamborn[2] in 1927. Quoting from this description, "..... A number of exposures showing the contact of the Olentangy shale with the older formations have been observed along the line of outcrop from Greenfield south to the Ohio River. Although the overlapping relations of the shale indicate a disconformity at the base of the formation, these relations are not always evident from exposures of the contact . . ." Several localities at which the Olentangy is present in Highland County are shown on the accompanying map,[3] and sections are given from localities in Adams County. A section described from the Black Hollow School, northeast of Peebles, Adams County, includes 60 feet of shale within this formation, the upper 10 feet consisting of blue and black shale alternating.

Concerning the distribution and character of the formation, Lamborn[4] states: "Along the Olentangy River from Columbus northward through Franklin and Delaware counties, and even across the divide as far as Sandusky, Erie County, exposures at this horizon show that the Olentangy shale is normally present in thicknesses ranging from 23 to 40 feet. In contrast to this regularity, the Olentangy formation from Deer Creek, Pickaway County, south to the Ohio River is local in its development, being completely absent at many localities.

"On lithological grounds, the plane of separation between the Olentangy shale and the overlying formation is not distinct in southern Ohio. The layers of black shale, which occur interstratified with the blue shale and which characterize the Olentangy shale in central Ohio, increase in number toward the south. In some localities the Olentangy shale passes by decrease in the amount of blue shale and increase in black shale into the overlying formation in such a manner that it is quite arbitrary where the contact is drawn."

THICKNESS AND CHARACTER IN HIGHLAND COUNTY

Lamborn gives thicknesses from 0-57 feet for Adams and Highland counties. Since no fossils were found and similar barren green shales

---

[1] Winchell, N. H., On the Hamilton in Ohio: Am. Jour. Sci., 3rd Ser., Vol. 7, pp. 395-398, 1874.

[2] Lamborn, R. E., The Olentangy shale in southern Ohio: Jour. Geology, Vol. 35, pp. 712-722, 1927.

[3] Lamborn, R. E., op. cit., p. 713.

[4] Lamborn, R. E., op. cit., pp. 716-17.

occur higher up in the Ohio shale, no certain statement seems possible concerning the actual presence of the shale. The writer has included possible equivalents with the Ohio shale in mapping.

DEVONIAN-MISSISSIPPIAN

Ohio Shale

GENERAL DESCRIPTION

The name Ohio black slate was first used by Andrews [1] in 1871. In northern Ohio, this division is represented by the Huron, Chagrin, and Cleveland formations.

Evidence as to the age of the Ohio shale based on a study of conodonts is cited by Ulrich and Bassler.[2] The following is quoted from their paper: ". . . In other words, none of the Genessee and Portage conodonts from New York localities could be accurately identified in the equally larger conodont faunas from the Ohio black shale in Ohio, the major upper part of the New Albany black shale in Kentucky, or in the Chattanooga shales in east and central Tennessee and Alabama. On the other hand many of the New York Devonian species of conodonts were satisfactorily recognized in unquestioned Devonian black shales that underlie 400 to 500 feet of Chattanooga shales in southwestern Virginia. Some of the same and other New York species are represented also in the locally developed basal parts of the New Albany shale of Kentucky in which they are associated with such other typical Devonian fossils as *Schizobolus truncata* (Hall). In so far then as the evidence of the conodonts is concerned the post-Devonian age of the Chattanooga and Ohio shales, as long advocated by the senior author, seems conclusively established."

This conclusion is not generally accepted as yet. The possibility still exists that the lower concretion-bearing part of the Ohio shale is of Upper Devonian age. Only detailed stratigraphic and paleontologic studies (based largely on conodonts) can definitely solve this stratigraphic problem.

THICKNESS AND CHARACTER IN HIGHLAND COUNTY

The Ohio shale makes up the greater part of the high hills at the eastern margin of the county between Sinking Springs and Rocky Fork and is present at the tops of some other hills, such as Quaker Hill, west of Samantha, and a few of the higher hills just west of Paint Creek, both north and south of Rattlesnake Creek. Its thickness varies with

---

[1] Andrews, E. B., Report of progress in the Second Geological District: Geol. Survey Ohio, Report of Progress in 1869, Pt. II, p. 64, 1871.

[2] Ulrich, E. O., and Bassler, R. S., A classification of the tooth-like fossils, conodonts, with descriptions of American Devonian and Mississippian species: U. S. Nat. Mus. Proc., Vol. 68, Art. 12, p. 3, 1926.

the irregularity of the lower contact, but is never far from 300 feet within Highland County. It rests with a pronounced erosional unconformity[1] on either the Peebles or the Greenfield dolomite, except where the Hillsboro sandstone is present as a sheet deposit above the latter.

In lithological character, the Ohio is a moderately soft, fissile dark brown or gray shale with darker, more bituminous layers. It weathers to a lighter brown or gray color. Where freshly exposed, it generally exhibits prominent jointing.

Large calcareous concretions are generally present in the lower 40 to 50 feet of the formation. They represent two types, one not far from spherical, the other of a flat ellipsoidal shape. The former generally show a core of more or less coarsely recrystallized calcite. The latter have been found by Dr. J. H. Hoskins,[2] of the Department of Botany, University of Cincinnati, to contain petrified driftwood *(Callixylon sp.)* in every case investigated by him. In Adams County, just south of the Highland County boundary, good specimens of *Callixylon*[3] have been found in the lower part of the Ohio shale. This is interesting in view of the fact that large trunks of these trees occur in rather large numbers in the New Albany shale in southern Indiana.[4]

The presence of these large concretions in the lower part of the Ohio shale might be interpreted as indicating age relationships with similar black shales elsewhere, as for instance the Huron shale of the Great Lakes region,[5] or the Genessee shale of western New York.[6] Such a conclusion would seem hazardous, however, since similar large concretions characterize also the lower portions of the Marcellus and Skaneateles shales in New York, suggesting that concretions tend to form in the basal parts of black shales in general.

Pyrite is present in sufficient quantity to give noticeable amounts of copperas, or iron sulphate, upon weathering; and sulphur springs are also common in the black shale areas.

The weathering of this shale produces a clay soil of poor quality. Many of the areas of outcrop are on steep slopes, where the regolith consists mainly of small plates and flakes of weathered shale, and creeps rapidly downhill, allowing very little true soil to form and remain in

[1] No exposures were seen as good as those inserted by E. M. Kindle, Unconformity at the base of the Chattanooga shale in Kentucky, Am. Jour. Sci., 4th Series, Vol. 33, pp. 120-136, 1912.

[2] Personal communication, through Dr. W. H. Bucher.

[3] *Callixylon* is common in the lower half of the upper Devonian formations of central and western New York—Arnold, C. A., Petrified wood in the New Albany shale: Science, New Ser., Vol. 70, pp. 581-582, 1929.

[4] Arnold, C. A., loc. cit.

[5] Daly, Reginald, The calcareous concretions of Kettle Point, Lambton County, Ontario: Jour. Geology, Vol. 8, pp. 135-136, 1900.

[6] Hall, James, Natural history of New York, Division IV, Pt. IV, Geology, pp. 220, 230, 1842.

place. Near the top of the formation, the steeper slopes frequently have only occasional oaks, without a complete sod covering between them, and with little or no other vegetable growth. This is the condition near the top of Slate Hill.

On the flatter areas, particularly the unglaciated region northwest of Sinking Springs, the base of the black shale has considerable quantities of halloysite developed as a weathering product. This mineral is frequently present in thicknesses varying up to nearly a foot, even where the shale has been entirely removed by erosion. Together with the brown ferruginous crusts which often mark the base of the formation, the halloysite indicates the former presence of the black shale on many of the low hills north and west of Sinking Springs.

Because of its small area of outcrop and number of good exposures in Highland County, no attempt was made to subdivide the formation or to undertake a detailed stratigraphic study.

FAUNA

As in the case of the other formations, the limited amount of time available for mapping the county made detailed, systematic fossil collecting impossible. *Lingula,* conodonts and fish remains, as well as other fossils, are not rare within this formation, however. The relatively large, amber-colored spore cases of *Sporangites* are present in enormous numbers in many layers.[1] No modern studies on the fossil content of the Ohio shale in Ohio have been published.[2]

Reference to the various fossils then known from the Ohio shale was made by Prosser[3] in 1912. The following is quoted from page 523 of this report: "Certain layers in the lower part of the Ohio shale in central Ohio, but in that portion of the shale in which the concretions containing *Dinichthys* and *Dadoxylon* occur, contain immense numbers of the spores named *Protosalvinia huronensis* by Dawson. According to Dr. Dawson, Professor Orton sent specimens of these spores to him from the Erian shales of that State (Ohio), which on comparison seemed undistinguishable from *Sporangites (Protosalvinia) Huronensis*.[4] These spores have been reported and described by Dr. John M. Clarke from the Marcellus and Genessee shales of Ontario County, New York,[5] and Prof.

---

[1] White, David, and Stadnichenke, T., Some mother plants of petroleum in the Devonian black shales: Kentucky Geol. Survey, Ser. VI, Vol. 21, pp. 99-117, 1925.

[2] For a rather large, typically Upper Devonian fauna in the basal beds of the New Albany shale on the west side of the Cincinnati Arch, see Savage, T. E., The Devonian Fauna of Kentucky: Kentucky Geol. Survey, Ser. VI, Vol. 36, p. 235, 1931.

[3] Prosser, C. S., Devonian and Mississippian formations of northeastern Ohio: Geol. Survey Ohio, 4th Ser. Bull. 15, pp. 519-529, 1912.

[4] The Geological history of plants, 1888, p. 51, quoted in Prosser, C. S., op. cit., p. 523.

[5] Am. Jour. Sci., 3d Ser. Vol. 29, 1885, pp. 285, 286, referred to by Prosser, C. S., op. cit.

Henry S. Williams reported '*Sporangites* [*Protosalvinia*], the same forms as those of the Ohio black shales' from the Genessee shale near Attica, Wyoming County, New York.[1] Other specimens of *Sporangites* were recorded by Professor Williams in this Bulletin from the recurrent black shales in the Portage formation of the Genessee section. Large numbers of spores, apparently of *Protosalvinia,* occur in certain layers of the black shale of the Huron in northern Ohio."

MISSISSIPPIAN

Waverly Group

The following general statement concerning the Bedford and Berea formations of the Waverly group is quoted from Hyde.[2] "In southern Ohio the Bedford consists of interbedded sandstones and shales, the former sometimes greatly in excess, the Berea of similar sandstones with limited quantities of shale. The sandstones in both are fine grained and of exactly the same type while between the two there is a transition zone. . . .

"In the area under immediate consideration, central and southern Ohio, the Bedford is from 90 to 100 feet thick, the Berea from 5 to 40 feet thick. In Scioto County on the Ohio large amounts of sandstone are found in the Bedford, but this diminishes to the northward so that there is much more shale in Pike and Ross counties. . . . In Pike and Ross counties the sandstones are frequently limy. When present, the sandstones are in beds from a few inches to two or three feet thick, but the 'shale' beds intervening . . . are largely made up of very thin, hard, platy sandstones of which there may be 12 or 18 in a foot."

The occurrence of these units in Highland County is limited to the tops of a few hills, such as Irons Mountain, Washburn Hill, and Long Lick Hill. There are only a few good exposures; hence detailed descriptions of the Waverly formations and generalizations with regard to them cannot be made from Highland County alone.

---

[1] U. S. Geol. Survey Bull., No. 41, 1887, p. 32, quoted by Prosser, C. S., op. cit.

[2] Hyde, J. E., The ripples of the Bedford and Berea formations of central and southern Ohio, with notes on the paleogeography of that epoch: Jour. Geology, Vol. 19, pp. 257-258, 1911.

BLANK PAGE

CHAPTER IV

DETAILED DESCRIPTIONS OF LOCALITIES

INTRODUCTION

The descriptions of the individual localities within this chapter are intended to illustrate the general characteristics of the units described in Chapter III, and to present information concerning the local development of these units. Obviously, only the more important outcrops can be mentioned for each formation. Since the Ordovician and Mississippian are not so well displayed as the rest of the series, and since their importance here is not proportionately so great as in other areas, they are only briefly treated.

ARNHEIM

Only one outcrop was found within Highland County which belongs to a formation below the Waynesville. This occurs half a mile east of Sicily, in the southwest corner of the county where a 15-foot section is exposed, referred to as the Arnheim(?).

WAYNESVILLE

Near the cemetery one-half mile east of Mowrystown, there is an exposure of between 10 and 15 feet of the upper (Blanchester) division of the Waynesville formation. The rock consists of alternating shale and limestone layers, rich in fossils, particularly brachiopods. According to Professor W. H. Shideler, who visited this locality with the writer, the upper layers of the Waynesville are shown, but the contact with the overlying Liberty does not appear. Bluish limestone with some shale is also exposed at a slightly lower level in the bed of Plum Run at the bridge near by.

Along Flat Run just north of Strausburg, 4 or 5 feet of the Waynesville is exposed. Limestone layers predominate here and average perhaps one inch in thickness. The fossils are mostly weathered out and are readily collected; in fact, this is one of the most prolific localities for collecting in Highland County, both as to number of individuals and of species.

A similar exposure at about the same horizon occurs along Lick Run, two and a quarter miles northeast of Buford.

LIBERTY

A section along Whiteoak Creek north of Pricetown includes the upper 10 feet of the Liberty formation and the lower Whitewater; the contact between the two is exposed in several small gullies at 1,003 feet elevation.

An outcrop along Little North Fork of Whiteoak Creek, one and one-half miles north of Pulse, represents the lower part of the Liberty. Several feet of thin shale and limestone beds are exposed.

Exposures of the Liberty occur in ravines on both sides of Little Miami River from two to four miles southwest of Lynchburg. The best section is along a ravine west of a cemetery, two and one-half miles southwest from Lynchburg, and includes 30 feet of richly fossiliferous limestone and shale, the limestone predominating throughout most of the section. Neither the upper nor the lower contact is shown.

WHITEWATER

The Whitewater formation is exposed in a number of stream sections within the county, particularly in the southern part of the Hillsboro quadrangle.

Ohio Brush Creek flows on the Whitewater or Elkhorn from a mile west of Folsom to about a mile east of Belfast, and reappears in the stream bed half a mile north of the county line, three miles southeast of Belfast. Only the top of the Whitewater is shown, however, since the gradient of the stream is about the same as the dip component of the rocks in the direction of the flow.

Along Little West Fork of Ohio Brush Creek there are numerous exposures of the upper part of the Whitewater, none of them affording a good continuous section. Near the county line four miles south of Sugartree Ridge, the upper part of the formation is fairly well represented. Numerous slabs of the thin-bedded, fossiliferous limestone, which alternates with soft gray shale, are to be found in the stream bed.

Along the road two miles due east of Mowrystown, there is an outcrop of the upper beds of the Whitewater, others occurring in ravines farther south.

A twenty-foot section of the upper Whitewater occurs along a tributary of East Fork, Whiteoak Creek, one mile southeast of East Danville. This is one of the best localities in the county for collecting from the Whitewater, the rock being argillaceous and the fossils well weathered out. Bryozoans are particularly abundant and may be literally scooped up by the handfuls.

The lower part of the Whitewater outcrops on the slopes along Whiteoak Creek north of Pricetown. Other outcrops occur just south of Dodsonville.

A section of the Whitewater occurs along Turtle Creek between Lynchburg and Sharpsville, the larger part of the formation being exposed.

ELKHORN

The Elkhorn formation is present in numerous outcrops along Ohio Brush Creek and its tributaries northwest of Belfast, the best exposures being along the south branch of Lost Fork, one and one-half miles northwest of Fairfax. There is nine feet of purplish, even-bedded shale and thin limestone layers in the bank of the stream, the shale predominating. The purple color is more pronounced in certain beds of the shale, while other beds have a slightly greenish tint. There is a marked local dip to the south, and the Brassfield appears in the stream bed a quarter of a mile to the southeast.

A number of exposures of the Elkhorn occur on the slopes along Little West Fork of Ohio Brush Creek three miles southeast of Sugartree Ridge. In several of these the fossils are fairly numerous and are well weathered out. A nine-foot section below the Belfast bed two miles southeast of Sugartree Ridge consists of alternating purple and greenish to gray shale, with a few impure limestone layers.

Other outcrops of the Elkhorn, with less pronounced purple color and shaly character, are those along Whiteoak Creek, one and three-quarters miles east of East Danville, and along Turtle Creek, two miles northeast of Lynchburg.

BRASSFIELD

The Brassfield formation is well exposed in all the larger valleys south of Hillsboro, and occasional outcrops are found in a belt extending from two miles southeast of Mowrystown to Sharpsville. The exposures in the hilly region south of Hillsboro are due to the much deeper dissections by streams here than to the westward. Many of these streams flow down the dip or obliquely to it, so that the formation appears either in the beds of the streams or as a wide terrace above stream level for considerable distances. On the other hand, the belt of outcrops across the country farther west is the result of beveling of the eastward dipping formations by a surface of low relief. Good sections of the Brassfield are fairly abundant along Ohio Brush Creek and its tributaries, while in the region of low relief west of the Bisher escarpment they are rare, partly because the formation thins and becomes more shaly (and therefore less resistant to erosion) to the west, and partly because the preglacial surface was one of low relief and was covered throughout most of the area by a thick blanket of drift.

Probably the best-known Brassfield outcrop in Highland County is along Rocky Fork, two miles southeast of Hillsboro, on the Belfast road. This is the Bisher dam locality described by Foerste.[1] It was earlier mentioned by Orton. There is now no remaining evidence of the dam or mill, although their former site is pointed out by residents of the

[1] Foerste, A. F., Silurian fossils from Ohio, with notes on related species from other horizons: Ohio Jour. Sci., Vol. 19, p. 367, 1919.

vicinity. Only the upper part (less than 8 feet) of the formation is exposed, together with the Dayton limestone. The Crab Orchard and Bisher outcrop on the hillside above. At the creek level and for 2 or 3 feet above are beds of reddish, hematitic, crystalline limestone, varying from 3 to 8 inches in thickness. These have well-developed "giant ripples." Above are thinner beds, with only a very small proportion of shale, up to the base of the Dayton. Certain layers appear at the outcrop to be composed almost wholly of oolitic hematite, yielding hand specimens of promising appearance, but actually of low iron content. The same layers, traced back into the less weathered rock, are bluish, crystalline limestone, with relatively few and scattered grains of hematite. Thus the hematite which appears to be quantitatively important at the outcrop is only a surface enrichment, apparently largely due to the removal of the calcium carbonate.

A Brassfield outcrop along Elm Run, two and a quarter miles northeast of Belfast, is described by Prosser.[1] Here the beds are ½ to 3 inches thick, and the crystalline limestone contains fossils and some limestone pebbles. The large ripples trend north 80° east; the wave length varies from 26 to 36 inches; and the maximum amplitude is 2½ inches. The ripple-marked layer is underlain by a bed 1 foot thick, which contains "numerous pebbles of Brassfield limestone. The majority of the pebbles are rather flat and fairly well rounded on the margins. The sizes are up to 8 or 9 inches. The pebbles as a rule lie flat (horizontal) or at least nearly so in the rock, but there are some interbedded at more or less of an angle."[2] The same exposure was earlier described, together with numerous others, in a paper by Foerste,[3] in which he shows that the pebbles themselves were of Clinton age. A mile farther south along the same stream, cross-bedded layers and some pebbles occur in the upper Brassfield.

Other localities at which pebbles within the Brassfield were found by Foerste include outcrops along a small tributary of Brush Creek just northwest of Belfast, as well as several about three-quarters of a mile southwest of Belfast. Typical of these is one along a small brook, north of a sharp bend in the dirt road, three-quarters of a mile southwest of Belfast. Quoting from Foerste's description,[4] "There is evidently an upper horizon of the Clinton, scarcely more than 15 inches thick, which is full of pebbles. Many of these are 8 to 10 inches in diameter. The pebbles are always very flat and rarely contain fossils. . . ." Those found by the writer were small, and resembled rolled mud pellets. No sand was

[1] Prosser, C. S., Ripple marks in Ohio limestones: Jour. Geology, Vol. 24, p. 468, 1916.

[2] Prosser, C. S., op. cit.

[3] Foerste, A. F., On Clinton conglomerates and wave marks in Ohio and Kentucky: Jour. Geology, Vol. 3, pp. 50-60, 169-197, 1895.

[4] Foerste, A. F., op. cit., p. 182.

found in this part of the formation, and the pebbles are not considered to be of great importance.

Along Ohio Brush Creek three miles southeast of Belfast, practically the whole of the Brassfield formation is exposed with a thickness of 38 feet. The rock is typically light blue crystalline limestone in even beds varying from 3 inches to 1 foot or more in thickness. There are thin shaly partings and small amounts of chert present. About 5 feet above the base of the formation appears a ripple-marked surface, exposed in the stream bed over an area of several hundred square feet. The ripples are symmetrical, with an average distance between crests of 15 inches and depth of troughs of 4½ inches; their trend is approximately north 15° west. Similar large ripples occur at a somewhat higher horizon in the Brassfield a quarter of a mile west of this, with a trend approximately east-west. Here appear in the stream bed two puzzling sets of raised ridges approximately parallel and perpendicular, respectively, to the trend of the ripples, and rising from 4 to 6 inches above the crests. The material of these ridges is dark blue, compact, crinoidal limestone, which shows no evidence of shattering or brecciation. Since the bedding planes are not disturbed or the beds fractured, these ridges cannot be due to superficial buckling in the stream bed, although such buckling is not uncommon in beds of streams flowing over the Brassfield. Thus it would appear that they must be either a primary sedimentary feature or the result of consolidation or cementation along joints.

Numerous Brassfield outcrops occur south and west of Belfast, where this unit forms a distinct terrace. South of Bee Run, three-quarters of a mile west of Mount Zion school, recent deepening of a road gutter has exposed the upper Brassfield and basal Crab Orchard. The elevation of the base of the Crab Orchard is here 848 feet. Other exposures are along Rock Lick and its tributaries. Two of these may be noted: one at a bridge a quarter of a mile north of Wildwood School, where a hematite layer of the upper Brassfield appears in the creek bank with several inches of red shale; the other along the road between Belfast and Fairfax, where a prominent ledge is formed on the north side of Rock Lick.

One mile northwest of Belfast, a partial section of the Brassfield is exposed along the road cut east of the bridge, while the Elkhorn and "Belfast" show in the banks of the creek. From 5 to 7 feet above the base of the Brassfield occur cherty layers with some glauconite; and crystals of calcite and sphalerite were found a few inches above this horizon. The rock varies from finely crystalline, laminated limestone with glauconite grains to coarsely crystalline blue limestone, more or less laminated. The upper part of the formation here has several intercalated greenish shale layers.

A mile and a quarter east of Folsom along a tributary of Ohio Brush Creek, the following section occurs:

	Feet	Inches
Brassfield—		
Coarse, pink, hematitic limestone	..	10
Coarse, gray, crystalline, crinoidal limestone	1	0
Bluish gray, medium crystalline limestone	..	9
Greenish clay shale	1	4
Covered	2	0
Fine bluish gray limestone	2	0
Covered	1	0
Light blue, finely crystalline limestone	..	10
Light blue limestone, coarsely crystalline, very fossiliferous	1	6
Covered	..	6
Bluish gray, finely crystalline limestone	..	7
Covered	2	0
Yellowish gray crinoidal limestone	..	11
Light gray, finely crystalline limestone	4	0
Bluish gray, more or less laminated limestone	5	6
Bluish gray limestone, occasional chert lenses	3	6
Gray, coarsely crystalline limestone with corals, irregular bedding, much jointing	2	6
Gray, laminated crystalline limestone	..	6
Bluish gray crystalline, crinoidal limestone	1	1
Blue, heavy-bedded, crystalline limestone	1	1
Blue limestone, thin-bedded	..	6
"Belfast"—		
Soft, bluish gray, calcareous shale with some harder beds up to 1 inch in thickness	3	0
	36	11

Slabs of hematite, doubtfully in place, occur at the highest exposure, where are large ripples at a horizon about 3 feet below the top of the section. Although almost the entire Brassfield formation is shown here, including the "Belfast bed," the Dayton limestone is not exposed and may be absent.

Three-quarters of a mile northwest of the last, the upper part of the outcrop appears in the stream bed and along the road. The highest outcrop is an 18-inch ledge of hematitic limestone, underlain by a green clay layer. These are probably very near the top of the Brassfield.

Numerous exposures along both branches of Lost Fork show the Elkhorn and Brassfield, the latter forming a wide and distinct terrace. Partial sections of the Brassfield occur in several of the ravines three-quarters of a mile south of Folsom and along a brook side of the road two miles south of Folsom. The exposure in this brook extends from the base to within about 10 feet of the top of the exposure, showing nearly 30 feet of bluish gray crystalline limestone in even beds averaging about 3 inches in thickness.

Near the Adams County line along Buck Run, there are several exposures of the Brassfield, the best of which is in the stream bed at the county line. Here the basal layers, including the softer "Belfast bed," form a ledge across the stream.

Two exposures along the south branch of Lost Fork, a little over a mile southeast of Millers Chapel School, are worthy of note in that the limestone layers in the bed of the stream are buckled up into arches, from a few inches to nearly a foot in height. These arches are similar to those sometimes found in quarry floors and are presumably caused by expansion of the exposed layers by increase in temperature.

Along Little West Fork of Ohio Brush Creek, with its tributaries, the whole of the Brassfield and the Dayton outcrop, a typical section being the one at the road intersection, two and a quarter miles southeast of Sugartree Ridge. Here the top of the Elkhorn, Brassfield, and Dayton are well shown. Local variations in dip make the thickness variations subject to slight inaccuracies. The thickness of the Brassfield is about 32 feet. The section follows:

	Feet	Inches
Dayton—		
Light greenish gray limestone, massive beds	3	0
Brassfield—		
Coarsely crystalline, crinoidal limestone layers, separated by greenish shale	2	0
Bluish crystalline limestone, distinctly laminated, in beds 3 to 6 inches thick	2	6
Covered	2	0
Blue crystalline limestone of varying texture, large ripples near top	3	6
Soft greenish clay	..	5
Blue crystalline, crinoidal limestone, with more shaly partings than below	4	6
Blue limestone, beds even, 4 to 8 inches thick	3	4
Blue crystalline limestone, beds even, 2 to 4 inches thick, with shaly partings, some chert	9	8
"Belfast"—		
Greenish layers of gray shale with layers up to 3 inches thick	3	0
Impure limestone, light greenish color, crystalline texture, with glauconite grains; pebbles of purple Elkhorn shale at base	1	2
	35	1

9732

Along the south edge of the county from the westernmost tributaries of Ohio Brush Creek to two miles southeast of Mowrystown, the Brassfield is present at no great depth below the surface, but due to the slight relief there are few outcrops. A quarry two and one-half miles southeast of Mowrystown shows only 5 feet of rock above the water level. As no Cincinnatian rock is present on the quarry dump, it is probably entirely in the lower and middle Brassfield. The part exposed is all light blue limestone, except a few shaly partings; it is mostly crystalline and fossiliferous. The beds range from 2 to 8 inches in thickness, and are somewhat less regular than in exposures farther east. Quarrying has been abandoned largely because of difficulties encountered in draining a quarry on a surface so nearly flat, and because of the overburden, which is 8 feet thick on the west side of the quarry.

Another exposure occurs half a mile north of the county line, three and one-half miles east of Mowrystown. At this locality, the Elkhorn and so-called "Belfast bed" appear to be thinner than farther east and are not so readily discernible, because of poor exposure. At the base of the section are several feet of shale and limestone, apparently the Whitewater, with characteristic fossils. This is followed by a covered interval of a foot or two, above which are blue, thin-bedded limestone layers of the basal Brassfield, including the so-called "Belfast bed," totaling about 4 feet, and followed by a covered interval of 4 or 5 feet. Still higher is 12 feet of blue, finely crystalline, partly crinoidal layers, 4 to 10 inches thick and very fossiliferous in the lower part. A total of about 20 feet of the Brassfield is shown in which there are no hematitic or shale layers apparent.

Two small quarries have been opened in the Brassfield along Ohio Route 38, three and four miles, respectively, northeast of Mowrystown. These afford only limited exposures, similar in character to that in the quarry southeast of Mowrystown, but containing a slightly larger proportion of shale. Both have a considerable overburden of glacial drift, although the Brassfield is somewhat nearer the surface in this vicinity than immediately to the north or south.

Along Sugar Run two miles east of Danville, the lower 12 feet of the Brassfield is well exposed. The "Belfast bed" is only about 2 feet thick and is followed by blue crystalline beds of the Brassfield, which average 3 or 4 inches in thickness. Recently a quarry has been opened in the Brassfield formation at Danville, exposing about 15 feet of it.

The Brassfield forms a slight bench 15 feet or more above the flat plain, two miles south of Fairview. Three quarries have been opened in the formation at this point, but are now abandoned and filled with water. The character of the rock in the limited exposures afforded is similar to that in the quarries east of Mowrystown except that it is here somewhat more shaly.

Along Dodson Creek there are several outcrops of the Brassfield, particularly at and north of Russell.

In the quarry owned by Mr. Frank Sharp, at Sharpsville, is exposed one of the best sections within Highland County for studying the character of the Brassfield formation. The local dip is here at the rate of about 50 feet per mile toward the north, but does not remain constant for any considerable distance in any direction. Details of the Sharpsville section follow:

	Feet	Inches
Dayton—		
Weathered, reddish brown limestone, finely crystalline..	2	3
Shaly parting	..	1
Light gray, compact, crystalline limestone, with glauconite grains	1	8
Purplish red, fossiliferous shale	..	3
Brassfield—		
Bluish gray shale, with limestone layers up to 1½ inches in thickness	2	6
Bluish crystalline limestone	..	11
Limestone beds 2 to 3 inches, with about equal proportion of shale	2	0
Bluish crystalline limestone	..	8
Shaly parting	..	3
Gray, crystalline limestone, beds 2 to 5 inches, with greenish shaly partings	4	10
Gray, crystalline limestone, beds 2 to 3 inches, finely laminated, with thin shaly partings	2	2
Dark gray limestone, finely laminated, with shaly partings	1	10
Gray, crystalline limestone, irregular bedding planes, shaly partings	1	0
Gray crystalline limestone, beds 2 to 3 inches, with shaly partings; occasional thin chert layers	1	8
Gray, granular, coarsely crystalline limestone bed	1	0
Fine crystalline, gray limestone	..	4
Irregular light gray chert bed	..	1-3
Medium gray, crystalline, limestone, finely laminated, beds 5 to 8 inches	4	6
Quarry floor.	—	—
	28	0

9733

(Mr. Sharp states that drillings indicate a thickness of 2 feet of limestone below the quarry floor, making a total of about 27 feet for the Brassfield.)

DAYTON

The important outcrops of the Dayton are mostly associated with the Brassfield exposures, though it is not found in all of the localities where the Brassfield occurs.

An exposure along the brook a short distance south of Elmville is mentioned by Foerste.[1] Here it occurs in beds about a foot thick, with its usual lithologic character.

The Dayton is well exposed along Rocky Fork, two miles southeast of Hillsboro. It is 43 inches in thickness, occurs in massive beds, and is crystalline and compact. It is sharply set off in appearance from the thin-bedded upper Brassfield and the soft Crab Orchard shale.

At the Sharpsville quarry, the typical light gray, massive, compact,

[1] Foerste, A. F., On Clinton conglomerates and wave marks in Ohio and Kentucky: Jour. Geology, Vol. 3, p. 185, 1895.

crystalline limestone of the Dayton is 20 inches thick. Above it there is over 2 feet of weathered, reddish brown, crystalline limestone, separated from the lower massive bed by a shaly parting. Glauconite grains are present in the lower part of the formation at this locality. Although Foerste[1] mentions a Beavertown marl fauna at the base of the Dayton in this locality, no fossils were found by the present writer within the typical part of the formation, either here or elsewhere within Highland County.

CRAB ORCHARD

The Crab Orchard shale outcrops over large areas in Highland County, mostly on the slopes in the dissected region south of Hillsboro. Scattered outcrops occur west of the Bisher cuesta on the sides of hills capped by Bisher dolomite, as well as along Clear Creek and its tributaries. Of the very numerous outcrops only a few will be mentioned specifically.

On the hillside east of Ohio Brush Creek, three-quarters of a mile north of the county line southeast of Belfast, both top and bottom of the Crab Orchard are shown. The thickness is here 95 feet. Not much of the character of the formation as a whole is indicated.

Numerous outcrops, particularly of the lower part of this unit, are found along the various roads south and southwest of Belfast, but generally only weathered clay is shown.

A number of small ravines, two miles southeast of Sugartree Ridge, are cut through glacial drift and into Crab Orchard shale. The shale is light to medium green in color, with a few dolomite layers. The gullies and ravines are apparently of comparatively recent development and are deeply cut, so that drainage is very complete. For this reason it appears that the soft shale supports an overburden of drift on steep slopes without any conspicuous amount of slumping (when mapped in 1929), in contrast to the frequent small slides on many less steep slopes made up of clay from this formation. (See p. 13.) The lower contact of the Crab Orchard is seldom exposed, but from the interval between the Dayton limestone and the base of the Bisher in the section already described under the Brassfield, two miles southeast of Sugartree Ridge, the thickness of the Crab Orchard at this locality is 71 feet. About the same thickness is found in the hill a mile southeast of Sugartree Ridge.

Along South Fork and its tributaries, three to four miles south of Hillsboro, there are several outcrops of the upper part of the formation. At one of these, just east of the road between Pleasant Hill School and Harrisburg School, old landslides produce an irregular topography south of the stream. In some of them there are as many as four separate down-slipped blocks, one above the other, with small closed depressions and trees tilted 30° from the vertical. The slides took place on a slope which averaged 10°. Blocks of the basal Bisher were carried down several feet,

[1] Foerste, A. F., op. cit., p. 176.

and at the lower end the slide in at least one case filled the stream, causing it to cut a new channel.

At the former site of Bisher's mill, two miles southeast of Hillsboro along the Belfast road, the lower and upper parts of the Crab Orchard are exposed in small gullies on the hillside east of Rocky Fork. The thickness is about 50 feet. The lower part of the formation has a number of conspicuous thin dolomitic layers, averaging somewhat over an inch in thickness. They are orange-brown in color, irregular in thickness, compact, and finely laminated.

On the west and south slopes of Calebs Hill and the west slope of the hill north of East Danville, small gullies are cut into the upper part of Crab Orchard, showing soft, light greenish clay. The lower contact is not exposed, and no outcrops of the Dayton were found, but the approximate base of the Crab Orchard is indicated by the change in slope to the almost flat surface over the Brassfield. The thickness of the shale at these localities is probably between 35 and 40 feet.

Along Clear Creek at an abandoned road, half a mile north of U. S. Route 50, a small outcrop of the Crab Orchard has a few poorly preserved fossils. This is at an elevation of about 900 feet, while outcrops along the headwaters of Clear Creek, about three miles northwest of Hillsboro, are as high as 1,040 feet.

At Bridges, the lower contact of the Bisher and a few feet of the greenish shale below are shown along Hardin Creek. This is the northeasternmost outcrop of the Crab Orchard formation found within the county.

The upper part of the Crab Orchard is well exposed along the headwaters of Clear Creek, between the Wilmington road and the New Vienna road, three miles and a half northwest of Hillsboro. Near the upper contact is greenish gray shale for 2 feet, below which the shale is of light green color typical of the formation. At 6 and 9 feet, respectively, below the top of the Crab Orchard, there are layers of very hard, laminated yellowish brown dolomite, not regular in thickness, but ranging from 1 to 3 inches or more. In them fucoid markings are abundant. Other similar layers occur at intervals lower down in the section.

A low hill a mile and a quarter northwest of Willettville is capped by Bisher dolomite, but has exposures of the Crab Orchard formation in gullies on its sides, as well as the typical greenish gray to nearly white clay soil. While the base of the shale is not exposed, its thickness cannot be much over 30 feet at this point.

BISHER

The type locality is on the hillside northeast of the site formerly occupied by Bisher's dam, two miles southeast of the Hillsboro courthouse, along the Belfast road. Orton's and Foerste's descriptions of this locality have already been mentioned under the general description of the

Bisher formation. The rock is deeply weathered, so that its lithologic character cannot be as well judged at this point as in other sections, but its appearance at the surface is entirely typical. The *Whitfieldella* bed, while readily found a short distance above the change of slope which marks the contact of the Crab Orchard and the Bisher formations, is not as conspicuous as at some other localities.

Of the other outcrops of the Bisher, which are abundant throughout the dissected Bisher-Lilley cuesta in the central part of the county, only a few will be mentioned specifically.

On the slopes surrounding the headwaters of Elm Run, there are numerous good exposures, with fairly complete sections in some of the ravines and along the road east of Berrysville. Along a brook three-quarters of a mile northeast of Berrysville, a 40-foot section, beginning perhaps 10 or 15 feet above the base of the Bisher, shows the gray, shaly character of the lower part of it; but the upper 25 feet of the exposure is thicker-bedded yellow dolomite. The base of the Lilley does not appear in this section, but is shown in another small ravine about 200 yards farther east. In exposures along the valley side half a mile south of these, the lower 15 feet of the Bisher is largely shaly dolomite and soft gray, gritty shale, with some harder dolomite layers. This shale weathers to give a light gray regolith, which shows in some of the gullies and resembles the whitish clay from the underlying Crab Orchard shale. The characteristic change of slope which usually indicates the Crab Orchard-Bisher contact is here some 10 to 15 feet above the actual contact, due to the non-resistance to weathering of this basal portion of the Bisher.

The following incomplete section along the road, a mile and three-quarters east of Berrysville, is unusual in that it shows a thickness of over 60 feet for the Bisher, which is generally about 50 feet thick in this area.

	Feet	Inches
Base of Lilley—Heavy, irregular dolomite bed, with crinoids; thickness varies, averaging about 18 inches.		
Top of Bisher—Brownish dolomite, a few inches.		
Mostly covered	22	0
Gray clay in road gutter	..	6
Covered	4	6
Brownish dolomite, beds up to 4 inches	1	0
Covered	9	0
Brownish dolomite	1	4
Covered	2	0
Brownish dolomite, heavy-bedded	1	8
Brownish dolomite, thin-bedded	..	10
Covered	..	8
Soft gray shale	2	0
Yellowish gray shaly dolomite	1	4
Soft gray shale	1	0
Covered	2	0

	Feet	*Inches*
Yellowish brown dolomite, obliquely fractured..........	3	0
Soft gray shale....................................	4	0
Yellowish brown shaly dolomite......................	6	0
Covered	3	0
Approximate top of Crab Orchard shale.	—	—
Approximate total thickness of Bisher..............	65	10

This measurement is probably 2 or 3 feet too great for the total thickness of the Bisher. The large proportion of shale in the lower part of the formation in this section is notable.

At the head of Setty Branch, a mile south of North Uniontown, the Crab Orchard-Bisher contact is exposed, as well as the lower part of the Bisher formation. This is gray, crinoidal, and more coarsely crystalline than usual in the lower 5 feet, resembling somewhat the lithology of the Lilley. Above this is a compact, brownish gray dolomite with a considerable amount of chert. Higher on the slope, the weathered fragments on the surface have an appearance entirely unlike that of the usual Bisher: they are compact and crystalline in texture, bluish gray in color, and have smoothly rounded edges in contrast to the usual angular float of the Bisher. These fragments appear on the slope more or less of the way for 40 feet above the base of the Bisher; but none were found above that level. This unusual phase of the lower Bisher resembles the Brassfield somewhat in lithology. Its fauna was not worked out, due to the limited time available for the field work, but it may, upon further study, prove to constitute a distinct and recognizable unit in the series.

Small geodes are very numerous on all the slopes over the Bisher in this section of the country and in the valleys below, particularly the upper part of the valley of Setty Branch. Some of them have beautifully developed quartz crystals, occasionally amethystine in color.

A section of the upper Crab Orchard and basal Bisher is found along one of the smaller headwaters of South Fork near the highway, four miles south and a little west of Hillsboro. The elevation of the contact between the two formations at this point is 1,048 feet, by barometer. The section follows:

	Feet	*Inches*
Bisher—		
Yellowish brown dolomite, beds ½ to 2 feet thick, with minor partings at from 1 to 6 inches................	6	6
Laminated yellowish brown dolomite..................	1	3
Yellowish brown shaly dolomite......................	1	1
Crab Orchard—		
Soft greenish gray shale............................	6	0
Yellowish brown dolomite, laminated.................	..	1–2
Soft grayish green shale............................	5	0

9735

Where the same road crosses one of the headwaters of Ohio Brush Creek half a mile south of Harrisburg School, the following nearly complete section of the Bisher is exposed:

	Feet	Inches
Approximate base of Lilley—Heavy bed of crinoidal dolomite.		
Yellowish brown crystalline dolomite, some crinoids, beds 6 to 18 inches thick	5	0
Yellowish brown laminated dolomite beds, 1 to 3 inches thick	7	0
Yellow brown laminated dolomite; some crinoids; appears thin-bedded where exposed in stream beds	8	6
Gray shaly dolomite, with shaly partings	2	6
Obliquely fractured gray dolomite	2	0
Gray silty shale	2	2
Covered	5	0
Yellowish brown dolomite, appears thin-bedded along stream bed; some heavier layers, up to 18 inches	9	0
Top of Crab Orchard, soft grayish green shale.		

Total thickness of Bisher, 41 feet, 2 inches; measurement of individual beds checked by hand leveling.

An exposure three-quarters of a mile east of Swine Valley School, north of Sugartree Ridge, gives an interval of only a little over 30 feet between the base of the Bisher (elevation 1,053) and the base of the Lilley (1,085). Elevations by barometer are probably accurate to within a few feet. At this point, the *Whitfieldella* bed is well exposed 10 feet above the base of the Bisher. In gullies on the slope, the shaly layers of the lower part of the Bisher weather to a light-colored clay, similar in general appearance to that from the Crab Orchard shale.

On the south side of Calebs Hill, seven miles southwest of Hillsboro, the *Whitfieldella* bed outcrops near the base of the slope. Above it, the upper part of the Bisher is exposed, with the basal layers of the Lilley near the top of the hill. The interval from the *Whitfieldella* bed to the base of the Lilley is about 25 feet. Scattered blocks of the Bisher at the west end of the hill show abundant fucoids, but none of the fucoid layers were found in place. The Crab Orchard-Bisher contact appears south of the road at the west end of the hill.

The next hill north of Calebs Hill also has outcrops of the *Whitfieldella* bed on its north slope. South of a side road a mile and a half northeast of Danville, the hillside affords good collecting, with numerous fossils weathered out from the Bisher and particularly from a coral bed at the base of the Lilley. The base of the Lilley is about 25 feet above the *Whitfieldella* bed.

The *Whitfieldella* bed is well exposed along the road on the north side of the isolated hill east of Russell.

In the Beecher quarry, in the northeast part of Hillsboro, a few feet of the upper Bisher is exposed above the quarry floor. The dolomite is brownish in color and finely laminated. There are occasional thin chert lenses which are richly fossiliferous.

In a cut, originally made for a railroad which never was built, about a quarter of a mile east of the Beecher quarry, the Bisher is exposed with abundant chert layers. The dolomite is moderately thin-bedded, but contains no noticeable amount of shale. It will be noted that few, if any, of these thin, fossiliferous white chert layers were found in the Bisher exposures southwest of Hillsboro, many of which showed considerable amounts of "gritty" gray shale. Northeast and east of Hillsboro and in the southeastern part of the county, the thin chert bands afford excellent collecting at numerous localities. South and east of Belfast and at other localities such chert fragments are present in considerable quantities in the glacial drift, but not all of them come from the Bisher formation.

As has already been mentioned, the terrace-like form of the low bluffs of Rocky Fork and Clear Creek in the Hillsboro quadrangle is due in part to the resistance of the Bisher formation, but the rock bench is generally covered by a thick mantle of drift, so that exposures are few. Outcrops occur along the bluff north of Rocky Fork just south of Highland County Infirmary and in several places between the mouth of Clear Creek and McCoppin Mill.

A fairly complete section is found along a small brook east of Bates School, three miles and a quarter northeast of Hillsboro. Here, as south of North Uniontown, the lower part of the formation exposed has a lithologic character distinct from the remainder: it is bluish in color and crystalline in texture, resembling the Brassfield in general appearance. The section is as follows:

	Feet	*Inches*
Base of Lilley		
Covered	2	0
Brown dolomite; weathers to give appearance of concretionary "nodules," which are similar to the rest of the rock in color and texture	1	0
Covered	2	0
Yellowish brown dolomite; beds up to a foot in thickness with minor partings	4	0
Yellowish brown dolomite; numerous chert layers	1	6
Hard dolomite, some chert, quartz geodes	2	0
Shaly dolomite	1	0
Covered	6	0
Dolomite, with large proportion of chert layers	1	6
Covered	2	0
Dolomite, beds 2 to 4 inches, with some chert	2	0
Covered	1	0
Obliquely fractured layer	..	10
Covered	..	4
Dolomite, beds 2 to 4 inches, numerous chert layers	1	6
Covered; large amounts of fossiliferous chert in float or else washed down from above	11	0
Thin-bedded brown dolomite	3	0

9737

	Feet	Inches
Shaly brown and gray dolomite	1	6
Covered	4	6
Bluish, crystalline	2	0
	—	—
Total thickness exposed below Lilley	50	8

The proportion of chert in the Bisher is larger here than at any other locality visited. (For analyses of the rocks at this and other localities, see Chapter V.)

A section of the upper Crab Orchard and lower Bisher is found along the upper course of a small brook, half a mile east of the Wilmington road and four miles northwest of Hillsboro. The thickness of the Bisher cannot be accurately determined here, since there are only occasional outcrops of the upper Bisher and Lilley; but it is apparently over 30 feet. Following is the section:

	Feet	Inches
Bisher—		
Brown thin-bedded dolomite	1	0
Reddish brown crystalline dolomite (weathered): *Whitfieldella* bed	1	6
Gray shaly dolomite	1	0
Reddish brown crystalline dolomite (weathered)	3	0
Gray shale with yellowish brown dolomite layers	5	0
Crab Orchard—		
Soft grayish green shale	4	0
Hard, fine-textured, laminated orange-brown dolomite, with fucoids	..	2
Soft grayish green shale	2	10
Hard, fine, laminated orange-brown dolomite, irregular in thickness	..	1–3
Soft light shale.	—	—
	18	9

The Bisher is well exposed in the gorge of Rattlesnake Creek and in small tributary gorges, particularly below the mouth of Hardin Creek. Along Fall Creek, the upper 20 feet of the formation consists of heavy-bedded to very thin-bedded or shaly dolomite, some of the heavy beds being bluish in color when unweathered, crystalline, and crinoidal. As is common in the Bisher, the apparently thick beds of unweathered exposures often break up into thin beds or plates when long exposed to weathering. A poorly exposed section along a brook a mile northeast of New Petersburg consists largely of thin-bedded dolomite masses and small pyrite grains in the shale near the contact with the basal coral-bearing bed of the Lilley.

Beneath the bridge over Rattlesnake Creek at East Monroe, the *Whitfieldella* bed is exposed a few feet above low water level; it is underlain by 5 feet of shaly dolomite, and overlain by about 8 feet of harder dolomite, which forms a ledge along the bank of the stream.

LILLEY

Outcrops of the Lilley are numerous throughout a large area in Highland County, extending from the Fayette and Clinton boundaries on the north to the Adams County line on the south, and for varying distances into these counties. It caps low hills in the vicinity of Willettville and Danville and finally disappears below the level of Rocky Fork near Barretts Mills. The most numerous and satisfactory exposures for its study are within a five or six-mile radius of Hillsboro, where many small quarries have been opened in it. Other good sections occur in the valleys farther east. The localities described are only those where it is particularly well exposed or where there are features of unusual interest.

In the eastern margin of Hillsboro there are two quarries mentioned frequently in the descriptions of the Niagaran formations of this vicinity. One of these, located on the Beecher estate on U. S. Route 50, is the "Col. Trimble quarry" of early reports. The other, about half a mile south of this at the west margin of Lilley Hill, is mentioned by Foerste [1] as the "Zink [Zig?] or Corporation quarry." Quoting from description [2] of the latter, "At this quarry, the *Pentamerus* bearing dolomite, correlated with the Cedarville dolomite of the more northern sections in southwestern Ohio, is underlaid by two feet of clay shale, and next by fourteen feet of a bluish, apparently argillaceous limestone, rather massively bedded. Fossils are abundant in the clay shale, much less abundant in the upper part of the massive limestone, and comparatively scarce in the middle and lower parts of this limestone. *Holophragma calceoloides* also is common in the two-foot clay shale, and occurs in moderate numbers in the upper half of the underlying massive limestone . . . *Zaphrentis digoniata* is not rare in the two-foot clay shale and in the upper part of the massive blue limestone . . .".

It is to be regretted that this quarry, long ago abandoned, is now being used as a dumping ground for rubbish, so that the outcrop is in danger of being obscured. The upper part of the Lilley is here more easily accessible than at the Beecher quarry, and it is the best locality for the collection of *Holophragma calceoloides.*

The old quarry on the Beecher estate is also described in the same paper,[3] as follows: "At the Trimble, Beech or Railroad quarry, a third of a mile north of the Zink quarry, the *Pentamerus* bearing dolomite, correlated with the Cedarville dolomite, is underlaid by clay shale, three feet three inches thick. Below this occurs the full section of the blue, massive-bedded limestone seen in the lower part of the Zink quarry. Here its total thickness is 21 feet, and it is underlaid by well-bedded, laminated cherty limestone in which fossils are few. *Holophragma calceoloides*

[1] Foerste, A. F., Notes on Silurian fossils from Ohio and other central States: Ohio Jour. Sci., Vol. 17, pp. 192-193, 1917.

[2] ——— loc. cit.

[3] ——— loc. cit.

occurs here both in the clay shale and in the upper part of the underlying massive limestone, but in much smaller numbers than at the Zink quarry. . . . The two-foot clay shale layer, and the twenty-one-foot massive blue limestone section at the Trimble . . . quarry, . . . contain a fauna quite distinct from that found in the lower third of the West Union formation, northeast of the Bisher Dam. . . ."

The clay shale layer is not present in two quarry sections in the Lilley mentioned by Foerste[1] along the Danville pike, west of Hillsboro, although *Holophragma calceoloides* occurs at both of these outcrops. It was not found by this writer anywhere in the area south or southwest of Hillsboro. Outcrops of the top of the Lilley are rare, however, within this area.

Of the numerous outcrops and sections in other parts of the county, a few of the more typical ones will be described.

West of the bridge across Baker Fork, a mile and a half northwest of Sinking Springs, a quarry and a road cut exhibit the following section:

	Feet	*Inches*
Peebles—		
Light gray, finely crystalline dolomite, bedding indistinct with *Pycnostylus, Favosites, Halysites,* and other corals	12	0
Light brownish gray dolomite, granular crystalline texture, with pockets of asphalt particularly in silicified stromatoporoids	3	0
Light gray dolomite, bedding planes few and indistinct	4	0
Lilley—		
Light gray to gray-drab granular crystalline dolomite, with stromatoporoids	4	0
Heavy-bedded blue dolomite, with *Cladopora* in abundance	12	0
Shell concentrate	..	1
Hard bluish gray dolomite, with *Cladopora*	1	0
Gray dolomite with *Cladopora,* weathers drab	1	0
Gray dolomite, weathers to shaly appearance	..	10
Gray to drab dolomite with *Cladopora, Favosites,* and other corals	2	0
Total thickness of Lilley exposed	20	11

The great abundance of *Cladopora* through a range of 15 feet or more is the most noticeable characteristic of the Lilley at this exposure. None of the layers exposed are noticeably shaly when fresh, but several beds in the lower part of the section weather to a shaly appearance.

Along the highway from Marshall to Sinking Springs, half a mile northeast of Harriett, a part of the Lilley formation is exposed. The coral bed at the base of the Lilley is found in the bed of a small brook just south of the road. (For an analysis from the quarry at this point,

[1] Foerste, A. F., op. cit., p. 193.

see Chapter V.) Numerous silicified stromatoporoids are weathered out along the road gutter, some of them in an excellent state of preservation. Similar beautiful specimens are common on the hilltops of eastern Jackson and western Brush Creek townships.

In a small quarry just south of Fairfax, there is a 20-foot exposure of the Lilley. It is here dark colored from bituminous matter and somewhat more extensively weathered than in other quarries. Fossils are conspicuous, particularly *Halysites, Cladopora,* a small-celled *Favosites,* and abundant crinoid segments. *Holophragma calceoloides* was found in some loose blocks. Irregular bedding and bluish argillaceous lenses or patches show along the road gutter near the quarry. In the dirt road leading southeast from Fairfax, irregular heavy beds form ledges across the road. In this part of the county, the Lilley in many outcrops appears to lack regularly developed bedding planes. Its massive, almost structureless character, together with a moderate abundance of corals, occasionally gives it an appearance similar to that of coral-reef limestones. This is illustrated by a 15-foot exposure along a road turning off to the east, a mile north of Fairfax. The large silicified stromatoporoids are not as common in the soil here as a few miles farther east.

The large hill a mile north of Berrysville is capped by the Lilley, which apparently has a thickness much greater than in other localities. At a quarry a short distance west of the road, the base of the Lilley is, by barometer measurement, a little below 1,055 feet, yet it outcrops as high as 1,125 east of the road, a short distance farther north. This would seem to indicate a thickness of 70 feet, unless there is faulting or a pronounced dip between the two outcrops, less than a quarter of a mile apart. No appreciable dip was noticed, and while a single small displacement appears along the side of the road, its relations to the outcrops in question are such that it can account at most for only a few feet of the unusual thickness of the Lilley. No abrupt departures from the slight eastward regional dip were noticed along the Crab Orchard-Bisher contact near this locality. The section of the lower part of the Lilley, shown in the quarry west of the road, a little over a mile northwest of Berrysville, is as follows:

	Feet	*Inches*
Gray, moderately crystalline dolomite, in even beds, 2 to 6 inches thick	18	0
Gray dolomite, heavy-bedded, coarsely crystalline, crinoidal, porous texture at the surface	3	6
Gray dolomite, even beds, 2 to 4 inches thick, texture finer than above and below. Abundant *Cladopora* from here to top of section	6	6
Gray dolomite, finely crystalline, laminated	2	0
Gray dolomite, crystalline, with *Cladopora* (Base of Lilley)	3	0
Gray, impure dolomite, finely crystalline, slightly laminated; geodes	..	6
Gray, impure, shaly dolomite	3	4

The upper part of the formation, as exposed on the hilltop a quarter of a mile to the northwestward, shows much less perfect stratification and has abundant *Cladopora,* as well as *Favosites* and other corals. The massive, almost structureless character of the rock and the abundance of these fossils suggest that the unusual thickness of the Lilley at this locality may result from the presence of a somewhat reef-like area on the sea-bottom during its deposition.

Although in the Hillsboro region and to the north and west of there the Lilley is generally evenly bedded, as shown in many quarries, at other points it is not uncommonly irregular or indistinct in bedding, with abundant corals and crinoids. Both the lithologic character and the dominant fossils change within relatively short distances. In the vicinity of Beaver Mill, on Rocky Fork, corals of the *Favosites* and *Halysites* types are abundant. Near the point where the road crosses Franklin Branch, half a mile south of Rocky Fork, there are good exposures of the upper Lilley and the base of the Peebles. As at other localities, it is difficult to establish within several feet the exact contact between the two formations. The lowest specimen of *Pentamerus oblongus* and the highest *Cladopora* were found at an elevation of 872 feet, by barometer; stromatoporoids and *Favosites* are abundant at 880, and *Halysites* at about 890. The base of the Peebles is at about 895.

Along Factory Branch south of the site of the old woolen mill, the upper Lilley and lower Peebles are exposed. The lithologic transition between the two is well shown in the following section:

	Feet	*Inches*
Peebles—		
Massive, light gray, finely crystalline dolomite..........	5	0
Light gray dolomite, weathers slightly buff, with *Pentamerus(?), Favosites,* and stromatoporoids..........	2	0
Massive, light gray, crystalline dolomite, with strong cliff-forming tendency..............................	16	0
Lilley—		
Massive crystalline dolomite, with crinoid fragments and small cup corals; lower part buff in color...........	10	6
Thin-bedded, gray to brownish, crystalline dolomite, some beds distinctly laminated, with small concretions and crystals of calcite and pyrite; crinoidal, with small cup corals....................................	7	0

Along Fall Creek, a mile north of New Petersburg, the upper part of the Bisher and the Lilley are well exposed. The irregularity of bedding within the Lilley in this section is in contrast to the distinct, even beds in the quarries near Hillsboro. At several points along this section, the beds are arched over structureless crinoidal masses from one to three yards in diameter and a foot or more in height. Aside from the crinoids, *Cladopora* and other fossils are frequently present in these small structures. Details of the section are as follows:

	Feet	Inches
Brownish crinoidal dolomite, distinct beds, 2 to 6 inches thick	4	0
Massive crinoidal dolomite, not much bedding or joints..	3	0
Covered	4	0
Crystalline, crinoidal dolomite, fairly well stratified.....	8	0
Coarsely crystalline crinoidal dolomite, irregular beds arched over structureless central mass, with crinoids and *Cladopora*	1	6
Crystalline, crinoidal dolomite	7	0
Irregular beds arched over structureless central mass with crinoids and *Cladopora*	1	6
Covered	1	6
Massive, almost structureless crinoidal dolomite	3	2
Covered	2	0
Soft, silty, gray dolomite	2	0
Lens of soft, sandy gray shale	0–2	0
Massive crystalline dolomite with crinoids and corals; bedding indistinct. Base of Lilley	3	6
Brownish crystalline, crinoidal, some beds quite shaly or splitting into thin plates	19	0

The total thickness of the part of the Lilley exposed here is 41 feet.

A ravine north of the Greenfield road, a mile northeast of New Petersburg, yields a fairly complete section of the Lilley. Here the beds appear to be somewhat thinner, partly because of more extensive weathering. The exposure is along the bed of a small stream and does not show the character of the formation as well as the one just given; but in the upper part it has the same irregular and indistinct stratification as along Fall Creek. Small crystals of pyrite were noted at several points in this section.

On the south side of the road, half a mile east of the last, the basal layers of the Lilley form a ledge which is traceable for a quarter of a mile or more. On the west side of Paint Creek north of Rattlesnake Creek, this unit exhibits a cliff-forming tendency comparable to that of the Peebles a few miles farther south.

A quarry on the side road slightly over a mile due south of Samantha gives a section in the upper Lilley which differs markedly in lithology and fossil content from those so far described. It consists of light blue, crystalline, crinoidal dolomite in very even beds from 2 to 4 inches thick.

Pentamerus oblongus is very common throughout the exposure. In addition, *Holophragma, Cladopora, Halysites,* and a small-celled *Favosites* were found.

Not quite half a mile east of this, a ravine section shows the cliff-forming tendency of the upper part of the Lilley, together with the transition of 4 or 5 feet between it and the typical Peebles.

Numerous other quarries have been opened in the Lilley within a radius of seven or eight miles of Hillsboro. Two of these, one a third of a mile south of Fallsville and the other along the New Vienna road three miles and a half southeast of New Vienna, are at the very top of the formation. The latter shows abundant *Cladopora* and *Favosites*. Another quarry at about the same horizon is an old one south of the Wilmington road, two and a half miles northwest of Hillsboro, in which are some crumbled lime kilns, testifying to a former extensive use of this stone.

The quarries near Brick School, five miles northwest of Hillsboro, are also in the upper part of the Lilley. The dolomite here is in moderately thick, even beds, and is unusual in being impregnated with asphalt to a depth of 15 feet or more from the surface. The asphalt is present in the porous rock in sufficient quantity to color it black and make it sticky on fresh surfaces. (For further description of the asphaltic rock, see Chapter V.)

PEEBLES

While the area of outcrop of the Peebles formation in Highland County is relatively large, partly because it caps many rounded hills, good exposures and typical sections are far less numerous than those of the Lilley. Relatively few quarries have been opened in the Peebles, and most of the good sections along streams are at the eastern edge of the county. Considerable areas are concealed under the Wisconsin glacial drift in the northern part.

Although the type locality is at Peebles, in Adams County, the exposures near Hillsboro, and particularly in the old quarry on the Beecher estate, have been well known since the time of Orton's work. In the Beecher quarry only approximately 10 feet of the lower part of the formation is exposed, its base being about 8 (?) feet above the highest shale horizon of the Lilley. The brachiopod *Pentamerus oblongus* is present in abundance and may readily be found in the weathered rock at the top of the north quarry wall. *Megalomus canadensis* is present, but not in great abundance. According to Orton's description,[1] "In Col. Trimble's quarries, 5 or 6 feet of rock heavily charged with Megalomus, occur, in which there is also a sparing distribution of Pentamerus. These beds are overlain by as many feet of which the last named fossil is the principal constituent and the first but rarely met with." The finely crystalline, very light gray dolomite of this exposure is typical of the Peebles. It shows little evidence of stratification.

At the old "Corporation" quarry, on the west side of Lilley Hill, only a few feet of the basal Peebles is present. *Pentamerus oblongus* is fairly common. The thickness given by Orton[2] to this unit at Lilley Hill

---

[1] Orton, Edward, Geology of Highland County: Geol. Survey Ohio, Rept. of Progress in 1870, p. 281, 1871.

[2] Orton, Edward, op. cit., p. 278.

is only 20 feet, which measurement was based on the erroneous assumption that the Hillsboro sandstone as a stratigraphic unit was 30 feet thick. Measured by barometer from its lower contact in the "Corporation" quarry, the thickness of the Peebles is found to be at least 60 feet. On some of the hills in the vicinity of Hillsboro it may be greater.

The Peebles is present in the hills near Boston and northwestward from there to Samantha and beyond. Several small quarries have been opened near Boston, though all of them appear to have been abandoned for many years. One of these, two miles southeast of Boston and three-quarters of a mile south of U. S. Route 50, has *Pycnostylus guelphensis* as well as numerous small brachiopods and gastropods, which are mostly poorly preserved. Another outcrop half a mile farther east yielded a number of good specimens (casts) of *Megalomus canadensis*. The base of the formation shows in the road just west of Boston.

Material encountered in the excavation of a shallow well just south of the road, a mile and a half due north of Boston, consisted of massive dolomite, somewhat weathered near the surface, but compact and dense at a depth of three feet. Several specimens of *Pycnostylus guelphensis*, one of the most characteristic of the Peebles fossils, were found in this exposure.

In the region half a mile to the north of Elton School, northwest of Boston, several Peebles outcrops were found in which *Pentamerus oblongus* was very common. *Pentamerus* was also found in the Lilley in this vicinity; in fact, at one point (a mile and a quarter north and a quarter of a mile west from Elton School), silicified specimens of this fossil were found less than 3 feet above the highest chert layers of the Bisher. A quarry near this point appears to be in the Lilley, yet has abundant *Pentamerus*. As mapped, the hill north of Elton School would appear to have a thickness of 100 feet or more of the Peebles. No higher formation was found in a hasty examination of this hill, but it is possible that the base of the formation is mapped too low on the hillside.

In the region west of Samantha, the Peebles apparently still has a thickness of 80 feet or more, but its lower contact cannot be established with certainty within less than 10 feet. The boundary between Peebles and Greenfield is also difficult to map, as many weathered outcrops show neither fossils nor the true lithologic character of the rock, outcrops are not abundant, and the contact is a very uneven one. On Quaker Hill, west of Samantha, the Greenfield dolomite is present underneath the black shale and may reach a thickness of 20 feet or more at some points. Near a turn in the road, about a third of a mile northwest of Quaker Hill, a small quarry in the upper Peebles has a pocket deposit of black shale in the weathered and fragmental dolomite. Some of the beds of the dolomite are tilted at an angle of 15° locally. Their relation to the black shale is such that they appear to represent weathering and perhaps slumping either before the deposition of the Greenfield or after its erosion and before the deposition of the black shale.

Two miles north of this, on the farm of Charles Smith, a quarry section shows about 60 feet of the Greenfield dolomite without its lower contact appearing. A mile to the eastward, where a secondary road crosses the headwaters of Bridgewater Creek, the approximate base of the Greenfield is shown, with intraformational conglomerate and with a few fossils including small brachiopods, a small cup coral, and ostracods. The elevation at this point is 1,050 feet (by barometer), or less than 60 feet above the base of the Peebles. Thus the Peebles, which has about the same thickness at points along a line from the mouth of Rocky Fork to Samantha and northward from there, decreases about 20 feet in going two miles northeast from Samantha. From the Seven Caves, near the mouth of Rocky Fork, to the hills north of the mouth of Rattlesnake Creek, there is also a considerable decrease in thickness. At the former locality the thickness is over 90 feet, while at the latter it varies from 40 to 60 feet, the upper contact being very irregular.

The irregularity of the contact between the Peebles and the Greenfield is well illustrated in a number of exposures along ravines south of the road which turns east from Route 70 just north of Rattlesnake Creek. On the south side of the hill about a mile east of Route 70, weathered dolomite referred to the upper Peebles occurs in contorted, brecciated beds, tilted in various directions. Above it are the lower laminated beds of the Greenfield, arched over the low undulations in the surface of the brecciated dolomite. Dips in this lower Greenfield range up to 10° or more. Five feet higher on the slope occurs the lowest black shale found at this point; but a short distance farther south black shale was found in place 20 feet below the top of the Greenfield. Other outcrops in the same vicinity show a considerable range in elevation of the Peebles-Greenfield contact, which in general declines to the northward, so that the Peebles has disappeared below the level of Paint Creek at the mouth of Opossum Run.

The most complete and conspicuous section of the Peebles within the county is along the gorge of Rocky Fork, near its junction with Paint Creek. Here a thickness of at least 90 feet is indicated, of which over 70 feet appears in some of the sheer cliffs along the south side of the gorge. The thickness is not uniform for any considerable distance, because of the irregularity of the upper contact. The cliff-forming tendency is illustrated particularly near the Seven Caves,[1] owned by C. G. Chaney. The lower 10 feet of the section is somewhat transitional in character between that of the Lilley and the Peebles formations. At 10 feet above the creek level there is a stromatoporoid horizon, and above it the lithology

[1] For an excellent description, see White, G. W., The Limestone caves and caverns of Ohio: Ohio Jour. Sci., Vol. 26, pp. 104-116, 1926.

is unquestionably that of the Peebles, although the nature of the exposure does not allow any very good opportunity for fossil collecting. Higher up on the cliffs the characteristic large pelecypod, *Megalomus canadensis,* was found at several points. At 54 feet above the creek, in the roof of one of the caves, a number of specimens appear in a single horizon. In the large cave south of the road, called the Dancing Cave, this fossil occurs more than 80 feet above the stream level.

The rock is almost without bedding planes at this locality and is not conspicuously jointed. It weathers to form somewhat rounded and pitted nearly vertical cliffs of uniform gray color. Aside from a number of caves at levels from 50 to nearly 100 feet above the creek, there is one large limestone sink, with one or more smaller ones, on the same rock platform formed by the superior resistance of the Peebles formation.

Another interesting exposure of this formation is found in an old quarry three-quarters of a mile west of the site of Slate Hill School and a mile and three-quarters southeast of Marshall. Specimens of *Megalomus, Pycnostylus, Favosites,* and various gastropods are fairly numerous in this locality, but *Pentamerus oblongus* was not found either here or at the Seven Caves.

A quarry and a road cut west of the bridge across Baker Fork, a mile and a half northwest of Sinking Springs, afford a section of the upper Lilley and lower Peebles. (For details of this section, see p. 106.) The upper part of the section presents the typical lithology of the Peebles, but with numerous asphalt impregnations and cavity fillings. Corals and stromatoporoids are the principal fossils. Aside from *Pycnostylus guelphensis,* these include corals of the *Favosites* and *Halysites* types. The contact between Lilley and Peebles is more readily establishable than at most other points, except for the Hillsboro vicinity.

GREENFIELD

The typical exposure of the Greenfield is in the large quarry in Ross County, just east of Greenfield. The dolomite here is of two separate types of structure: even beds of regular thickness and reef-like mounds or masses of heights up to 20 feet and somewhat greater breadths. These mounds are of soft, crumbling, weathered dolomite, without bedding or lamination, entirely different in lithologic character and fossil content from the well-defined beds overlying them. The dip of the Greenfield beds on the flanks of these arches may be as much as 10° or more locally, though in most of the undulations within the quarry dips are less than 5°. The beds are from 2 to 8 inches in thickness. The laminated character of the formation becomes pronounced 3 or 4 feet above the base. The ostracod *Leperditia* is common throughout most of the extent of the quarry. The carbonaceous partings and laminæ have already been mentioned (p. 80).

Within Highland County, the best exposure for the examination of the Greenfield is in the quarries behind the residence of Charles Smith, on a hill two miles north of Samantha. The section exposed above water level (measured in the dry summer of 1930) is as follows:

	Feet	*Inches*
Top of section, elevation 1,165, by barometer.		
Weathered dolomite, heavy beds, inaccessible..........	15	0
Buff, massive beds, not much jointing, no lamination....	13	0
Fossiliferous horizon—ostracods and poorly preserved brachiopods and corals	..	6
Ripples, 5-inch length, 1 to 1½ inch amplitude.		
Massive layer, lighter gray when fresh than below, and thicker laminations; weathers drab	4	3
Laminated gray-drab dolomite, beds 3 to 8 inches......	2	0
Massive layer	1	6
Laminated gray-drab dolomite, with ostracods; little or no chert	7	6
As above, with chert................................	4	9
Strongly laminated, with chert.......................	2	6
Conspicuous black laminae...........................	..	1
Lenticular fossiliferous chert band....................	..	1
Darker gray-drab dolomite, with black laminae and stylolites; ostracods, poorly preserved brachiopods..	4	0
Water level.	—	—
Total exposed	55	2

According to Mr. Smith, the owner of the quarry, the water is between 12 and 20 feet deep in the quarry. It is possible that the rock quarried out was mostly or entirely within the Greenfield, so that its thickness would be 70 feet or over at this locality, with neither top nor bottom of this member exposed. A mile and a quarter farther east, where the road crosses a headwater of Bridgewater Creek, the approximate base of the Greenfield is exposed at an elevation of 1,050 feet. Thus a thickness of 100 feet or more is suggested, but since the contacts of this unit are very irregular in elevation, such an estimate is not reliable.

Sphalerite in crystalline aggregates weighing up to 10 pounds or more is reported to have been found in the working of both this quarry and the one at Greenfield. None of those seen by the writer were more than 2 or 3 pounds in weight, and none were seen in place which were over an inch in diameter. While these specimens of sphalerite have occasioned a considerable amount of interest locally, it should be remembered that they form an almost negligible proportion of the rock, and show no indication that the zinc will ever be worked commercially. Sphalerite crystals are occasionally found in the Brassfield and in the Niagaran dolomite series.

The undulations in the beds within the lower part of the Greenfield and its uneven lower contact are well shown in an abandoned quarry a mile east of Mr. Smith's farm. Sphalerite and chert nodules are present here.

Negatives of large skeleton crystals of an undetermined mineral were found in the quarry near Mr. Smith's residence by Professor W. H. Bucher in the summer of 1930.

The hill, a mile and a half southeast of Highland, has an old quarry at its north end which is in somewhat weathered dolomite. No fossils were found, and the black carbonaceous laminations typical of the Greenfield were not present, though an indistinct banding was noted in some freshly broken fragments. This rock is here referred to the Greenfield. A thickness of over 30 feet is present between the lowest and highest outcrops of this rock, with no indication that it is anywhere near the total thickness. There is a patch of black shale on the west side of the hill, ranging in elevation from 1,133 to 1,138 feet, while the Greenfield near by occurs at from a little less than 1,120 to nearly 1,150 feet. This illustrates the very irregular character of the contact between the Greenfield and the black shale. No Hillsboro sandstone was found at this locality.

The hill just south of Leesburg is capped by Greenfield dolomite, with very uneven bedding shown in a small quarry near the top.

Aside from those already mentioned, the Greenfield member is present in several other hills rising above the general level of the northeastern part of the county. Among these are hills located as follows: two miles and a half east of Samantha; three miles and a half south of Greenfield, along Route 70; four miles due south of Greenfield; two miles east of New Petersburg; one mile southeast of New Petersburg; and a mile and three-quarters southwest of New Petersburg. At the last two localities it is overlain by or associated with small deposits of the Hillsboro sandstone. The Greenfield is also present at many points in the region northwest of Sinking Springs.

The thickness is extremely variable, even within distances of only a mile or two. For instance, in the hills north of the mouth of Rattlesnake Creek, it is from 5 to 30 feet thick, while four miles north of there it is at least 75 feet thick, and five miles south it is absent altogether.

HILLSBORO

The most important localities at which the Hillsboro sandstone outcrops in Highland County are described in some detail by Carman and Schillhahn.[1] These include Lilley Hill, southeast of Hillsboro, the Samantha region, and Rhoads Corner, three miles northwest of Sinking Springs.

At Lilley Hill, the sandstone is described as consisting of "a remnant of the sheet deposit put down on the post-Greenfield erosion surface, which here was on the Niagaran dolomite," [2] and pocket deposits in the

[1] Carman, J. E., and Schillhahn, E. O., The Hillsboro sandstone of Ohio: Jour. Geology, Vol. 38, pp. 246-261, 1930.

[2] Carman, J. E., and Schillhahn, E. O., op. cit., pp. 250-251.

Niagaran (Peebles) dolomite. In the north road gutter, the sandstone mass is separated from the enclosing dolomite walls by a layer of greenish clay from 1 to 4 inches thick. No sand was found in the dolomite.

On Quaker Hill, west of Samantha, a private road just south of the top of the hill gives a poorly exposed section, with undoubted Niagaran (Peebles) at the base and black shale at the top. Between there is mostly Greenfield dolomite, with masses of Hillsboro sandstone interpreted as cavity fillings. The Hillsboro is not found at all in some old quarries a short distance west of the road.

Just east of the highway, two miles northeast of Samantha, an old quarry in the Greenfield shows a mass of sandstone enclosed in dolomite, with some black shale included. While the sandstone mass is not large, it is obviously a pocket deposit within the dolomite.

The largest deposit of the sheet type is in the vicinity of Rhoads Corner, northwest of Sinking Springs, where Carman and Schillhahn give a thickness of 10 to 20 feet. A geologic map of this section of the county, prepared by Miss Irene Chrisman in the summer of 1923, gives an area of over a square mile of this deposit at this locality. Other smaller areas occur to the northward and westward, particularly west and south of Slate Hill and at North Uniontown.

A hill a mile southeast of New Petersburg has Peebles dolomite outcropping over a considerable area around its base, overlain by the Greenfield, here less than 20 feet thick, with a small amount of Hillsboro sandstone at the top. The sandstone occurs as a thin sheet, at places only a few inches thick, over the irregular surface of the Greenfield, with a few irregular masses lower down which may be cavity fillings. The sheet deposit of sandstone is overlain by a few inches of black shale. A quarter of a mile north of this, along an old dirt road, an irregular mass of sandstone occurs associated with the Peebles.

At the south side of a hill made up of Greenfield dolomite, a mile and three-quarters southwest of New Petersburg, an irregular mass of sandstone occurs associated with weathered Greenfield dolomite in a small quarry. Other masses of the cavity-filling type occur on many of the hills which rise to the approximate level of the top of the dolomite series, but in many cases only a few small fragments are found, so that they cannot confidently be referred to either the sheet type of deposit or the pocket type.

OLENTANGY AND OHIO

The high hills between Sinking Springs and Rocky Fork are made up largely of these two shale formations, generally with a capping of the overlying Waverly. Since the Olentangy grades lithologically into the Ohio, no attempt was made to separate them. In most of the outcrops found, the shale is referable to the Ohio, and no outcrop was noted where a section which could be referred to as the Olentangy could be studied with confidence.

Outcrops of weathered Ohio shale are common on the sides of these hills; in fact, at some points there is little or no soil covering. While the weathered shale is frequently visible on the surface and aids in mapping, exposures showing the character of the unweathered shale in place are limited to ravine sections, as between Irons Mountain and McCoppin Hill, and to artificial cuts. The upper contact is usually well defined in this region, but the lower contact of the shale series is often masked by thick deposits of glacial drift, except in the southern part of this hilly area.

An exposure along the road between Sinking Springs and Cynthiana, a little more than two miles north of Sinking Springs, shows the character of the typical unweathered Ohio shale, which is fissile, nearly black in color, and moderately soft. Large concretions are present, with the bedding of the shale arched over them.

The unevenness of the lower contact of the shale series is well illustrated at many points. In the hills a mile north of the junction of Rattlesnake Creek with Paint Creek, the Greenfield dolomite is thin, at some places as little as 5 feet in thickness, at others apparently absent altogether, and the relief along the lower contact of the shale is often 20 feet between outcrops scarcely a hundred feet apart. Probably the upper surface of the dolomite series is less irregular than this, since some of the lowest occurrences of the shale seem to be as deposits in small cavities within the dolomite. In these pockets the shale retains its usual character except that it is softer than within the main body of the shale formation, and its lamination is apt to be irregular, following the floor of the cavity in which it was laid down. It will be noted that this pocket or cavity-filling type of deposit is similar to the cavity fillings of the Hillsboro sandstone near the top of the dolomite series, and that in one occurrence of the Hillsboro (two miles northeast of Samantha), some black shale is included in the dolomite along with the sandstone. An example of the irregularity of the lower shale contact is shown in the head of a ravine a third of a mile south of the road and a mile and a quarter east of Route 70, north of Rattlesnake Creek. The Peebles-Greenfield is also well shown at this point, as mentioned under the locality descriptions of the Peebles. A small pocket of shale within the Greenfield occurs about 75 feet east of the abandoned road east of this exposure. No shale which could be referred to the Olentangy was found at any of these localities north of Rattlesnake Creek.

At the east end of a hill, half a mile southwest of the mouth of Rattlesnake Creek, the base of the black shale is shown resting on the Greenfield dolomite with blocks of Hillsboro sandstone a few feet lower on the slope. About 40 feet of shale is exposed. The contact between the Peebles and Greenfield was not found, but outcrops of the Lilley 70 feet below the top of the Greenfield indicate that the combined thickness of this and the Peebles is less than 70 feet.

A hill along the county line north of Greenfield is made up of Ohio shale, but neither the top nor the base of the formation is exposed.

Quaker Hill, west of Samantha, has been mentioned in connection with the Greenfield and Hillsboro formations. It is capped by Ohio shale, which has a somewhat irregular lower contact and a maximum thickness of about 30 feet. An old quarry near a turn in the road, half a mile northwest of the cemetery, shows a few feet of weathered Peebles and has a small pocket of black shale at its west end. The Peebles appears to have been weathered, with the development of cavities and perhaps a certain amount of slumping of the beds before the shale was deposited in this pocket, and more slumping since the deposition of the shale (shown by the contortion of the shale and the relation of some of the dolomite blocks to it). The weathered and slumped Peebles has much the appearance of that just beneath the base of the Greenfield north of the mouth of Rattlesnake Creek and in the quarry at Greenfield. Fragmental material which obscures the north end of the shale pocket consists of weathered Peebles dolomite, black shale, and halloysite. A half-inch layer of halloysite is present at the base of the contorted shale in this pocket.

WAVERLY

The Bedford and, in some cases, the Berea are present on the higher hills at the eastern margin of the county south of Rocky Fork. Since no attempt was made to separate the units of the Waverly group in mapping, and since adequate exposures for their study are not numerous in Highland County, the considerable areas of outcrop of these units on Irons Mountain, Long Lick Hill, and Washburn Hill were not examined in detail. Generally loose fragments of buff shaly sandstone on the tops of these hills indicate the approximate nature of the rock. In many cases a noticeable change of slope occurs at the lower contact of the Waverly, and sometimes springs also are present at this horizon.

At the east end of McNary Hill, near its summit, an old quarry in the Bedford formation consists of light gray-buff laminated sandstone, with a banded effect produced by weathering and approximately parallel to the weathered surface. Large blocks of the rock are slumped from in place, giving the appearance of dips up to 10° or more.

On Fort Hill, the thin-bedded sandstone and what soil there was over it were used by the aborigines in the construction of a large embankment extending completely around the summit of the hill. While the removal of so large an amount of material from the ditch within this embankment by means of primitive implements is a feat at which one marvels, it would have been impossible were it not for the thin-bedded nature of the rock itself.

Other hills on which the Waverly is present in varying thicknesses include Butler Hill, Stultz Hill, Reads Hill, Slate Hill, Brown Hill, McCoppin Hill, Spargur Hill, Heads Hill, Barrett Hill, Roundtop, and Jones Hill.

CHAPTER V

ECONOMIC GEOLOGY

SEARCH FOR OIL AND GAS

After the development of the various oil and gas fields in the east-central part of the State from Jackson and Vinton counties north to Cleveland, interest was aroused in other localities and wells were drilled at many points. Often these were located almost at random, and drilling was continued until the owner's or driller's enthusiasm was exhausted. Gas production from the so-called "Clinton" sand was on a commercial basis in Vinton County before 1900, and oil was produced from this and the Berea (Mississippian) sand soon afterwards. The total number of wells drilled in Vinton County up to 1927 was 700, of which "70 per cent have produced oil or gas in paying quantities." [1]

At Waverly, in Pike County, a well was drilled in 1908-09 to a depth of 3,220 feet. According to Bownocker's[2] interpretation of the log of this well, it penetrated from the Ohio shale through the Big Lime, Silurian and Ordovician shales, Trenton limestone, St. Peter sandstone, and various shales to the eastern extension of the Lower Magnesian limestone of Illinois. No appreciable quantity of oil or gas was encountered.

A well was drilled a few years ago on the farm of Frank Stahler, just south of Waverly, which has produced and is still producing enough gas for household use. The depth of this well was approximately 735 feet, of which the lower 300 feet was in the Big Lime. According to Mr. Stahler, water and gas were struck at the Hillsboro sandstone horizon, at 13 feet below the top of the Big Lime, at the base of the Monroe, and in the top of the Niagaran. It is to be noted, however, that these horizons are to be recognized only with great difficulty in a single well section a considerable distance from the outcrop. A sample of the drill cuttings from a depth of about 12 feet below the top of the limestone series, when examined with a microscope, could not be matched with the lithology of any of the formations which appear at the outcrop, but appeared to consist in part of light gray limestone with a finely oolitic texture showing in certain of the fragments. Very small quartz crystals, perhaps geode or cavity fillings, were also present, as well as rounded sand grains.

[1] Stout, Wilber, Geology of Vinton County: Geol. Survey Ohio, 4th Ser., Bull. 31, p. 367, 1927.

[2] Bownocker, J. A., The Bremen Oil Field: Geol. Survey Ohio, 4th Ser., Bull. 12, pp. 46-49, 1910.

In Highland County, several unsuccessful attempts have been made to locate oil or gas in commercial quantities. One of these was a well drilled on the Cope farm, along Big Branch about a quarter of a mile from its junction with Rattlesnake Creek. This well extended several hundred feet into the Cincinnatian rocks and produced a small amount of gas, which, however, has never been used.

Enough gas for household use is reported to have been obtained from a well on the McMullen farm, three or four miles southwest of Dodsonville. This well is said to have been drilled to a depth of 2,000 feet seven or eight years ago. Because of the limited amount of time available for field work in Highland County, it was not visited by the writer.

A well on the farm of Braden Willett, three-quarters of a mile southwest of Berrysville, produces enough gas for household use, for which it appears to be of excellent quality. It was drilled to a depth of 400 feet in May, 1935, most of the gas coming from the Richmond shale at a depth of 356 feet.

Three or four years ago a shallow well (60 feet deep) drilled on the Mock farm just west of Fayetteville yielded a show of gas.

A wildcat well was drilled for oil and gas some years ago within the Serpent Mound cryptovolcanic structure, but without success.

The so-called "Clinton" sand of the drillers is not present as a recognizable horizon at the outcrop within the Silurian series in Highland County. In an attempt to find a horizon which would show traces of sand referable to this unit, specimens were collected at intervals of a few inches to two or three feet throughout the limestone and dolomite series, from which specimens 10-gram samples were dissolved in hydrochloric acid and the insoluble residues washed and examined under the microscope. While small amounts of very fine quartz sand are present in many parts of the section, nothing was found which could be interpreted as a possible correlative of the "Clinton" sand. Further work on the correlation of the drillers sections with the section at the outcrop must await the availability of accurately collected drill cuttings.

LIMESTONES AND DOLOMITES

The limestones and dolomites in Highland County constitute one of its most valuable resources. Formerly used largely for building stones or burned for lime, they now find their greatest use in highway construction and to a less extent as ground limestone for agricultural purposes. The dolomites are a potential source of magnesia as well as lime, while at certain localities there are limestones high in calcium and very low in magnesia, the latter greatly in the minority. Recently the asphaltic dolomites have become important as material for road building.

The occurrence and economic value of these rocks were treated by Orton and Peppel[1] in 1906; but since that time such great changes have taken place in the uses of limestone and other rock products that further description of these formations and their uses seems necessary.

The formations which have been quarried to an important extent include the Brassfield, Bisher, Lilley, Peebles, and Greenfield. More of the quarries are in the Lilley formation than in any other, the Brassfield being second. Fifteen or more quarries, mostly of small or moderate size, have been worked in recent years, with the Lilley as the principal unit used.

In the descriptions of the economic value of the limestones and dolomites by formations, only the larger quarries will be mentioned individually, as the smallest ones are generally used for only a season or two, often during the construction of a particular strip of road. For more detailed descriptions, the reader is referred to Chapter IV, and for further general characteristics of the formations to Chapter III. It will be found most helpful to read all local descriptions with frequent reference to the geologic map accompanying this report, and to the topographic or quadrangle maps obtainable from The Director, United States Geological Survey, Washington, D. C., or from the Geological Survey of Ohio, Columbus, at ten cents each. Highland County includes parts of the Hillsboro, Bainbridge, Sabina, Sardinia, and Greenfield quadrangles, as well as a small area in the southeast part of the Blanchester.

Ordovician Limestones

The limestones of the Richmond group have been used but very little in Highland County for several reasons: The large amount of shale generally interbedded with the limestone, the flatness of topography and generally thick overburden of drift, and the abundance of the better Silurian limestones a few miles to the eastward. These same considerations, particularly the large percentage of shale or clay, make it seem doubtful whether much use will be made of these rocks in the future, except on a small scale. The limestone layers are generally even bedded and easily quarried in small quantities with only the simplest tools.

No chemical analysis of the Ordovician rocks in or near this area was made in connection with the present report. Analyses taken from older publications are listed at the end of the discussion on limestones.

Brassfield Limestone

With the exception of the Lilley formation, more sizable quarries have been opened in the Brassfield in Highland County than in any other unit. Most of these are along the line of outcrop across the county from Sharpsville, east of Lynchburg, to the Adams County line east of Mowrystown. There are few prominent outcrops along this belt, while the area

[1] Orton, Edward, Jr., and Peppel, S. V., Limestone resources and lime industry in Ohio: Geol. Survey Ohio, 4th Ser., Bull. 4, 1906.

of extensive outcrop along the various forks of Ohio Brush Creek has scarcely been touched by quarrymen.

Quarries have been worked at Sharpsville, two miles south of Fairview, at Danville, three and four miles northeast of Mowrystown, and two and a half miles southeast of Mowrystown. Others may have been opened since the completion of the field work for the present report in 1930. At these locations the surface is flat or nearly so, and drainage is poor; consequently much pumping has to be done in most of the quarries. The rock comes out well, and bedding planes are usually from 2 to 6 or 8 inches apart. In some of the quarries there are numerous shaly partings, but the percentage of shale is small. The limestone is usually light blue, crystalline, and fossiliferous. Chert is present in small quantities at Sharpsville. Hematite was not observed in most of these quarries and in none of them more than a trace. At the time they were examined, however, most of these quarries were not being worked, and contained a great deal of water. None of them were sampled for chemical analysis, but two analyses were made from sections sampled at the outcrop. One of these is from two and a half miles east of Belfast, where the lower part of the section is well exposed along Ohio Brush Creek. The section is briefly described as follows:

	Feet	*Inches*
Highest exposed, bluish gray, crystalline limestone, some thinner beds, covered intervals	14	0
Reddish, ferruginous, crystalline limestone	1	6
Mostly covered	18	0
Bluish crystalline limestone, beds 2 to 3 inches	4	0
Bluish crystalline limestone, beds 2 to 6 inches, giant ripples in upper part	8	0
Soft gray Cincinnatian shale	5	0

The thickness of the Brassfield here is about 48 feet. The exposed part was sampled by the writer in August, 1936. The result of the chemical analysis of this sample, made by Downs Schaaf, are as follows:

Silica, SiO_2	4.50
Alumina, Al_2O_3	1.29
Ferric oxide, Fe_2O_3	1.25
Ferrous oxide, FeO	1.44
Pyrite, FeS_2	0.30
Magnesium oxide, MgO	2.07
Calcium oxide, CaO	47.45
Strontium oxide, SrO	none
Sodium oxide, Na_2O	0.03
Potassium oxide, K_2O	0.04
Water, hydroscopic, H_2O-	0.28
Water, combined, H_2O+	0.38
Carbon dioxide, CO_2	40.38
Titanium oxide, TiO_2	0.07
Phosphorous pentoxide, P_2O_5	0.21

Sulphur trioxide, SO_3	<0.01
Manganous oxide, MnO	0.22
Barium oxide, BaO	none
Carbon, organic, C	0.23
Hydrogen, organic, H	0.03

It is to be noted that while the rock shows a reddish hematitic appearance about 30 feet above the base of the formation, the amount of ferric iron is small in relation to the whole composition. The magnesium content is also low.

Another locality at which the Brassfield was sampled is a mile and a quarter east of Folsom. The section is described in detail in the discussion of the Brassfield limestone outcrops in Chapter IV.

The chemical analysis was made by Downs Schaaf, and the results follow:

Silica, SiO_2	7.41
Alumina, Al_2O_3	1.55
Ferric oxide, Fe_2O_3	0.70
Ferrous oxide, FeO	1.20
Pyrite, FeS_2	0.25
Magnesium oxide, MgO	2.70
Calcium oxide, CaO	45.44
Strontium oxide, SrO	none
Sodium oxide, Na_2O	0.15
Potassium oxide, K_2O	0.25
Water, hydroscopic, H_2O-	0.30
Water, combined, H_2O+	0.38
Carbon dioxide, CO_2	39.27
Titanium oxide, TiO_2	0.14
Phosphorous pentoxide, P_2O_5	0.16
Sulphur trioxide, SO_3	0.02
Manganous oxide, MnO	0.15
Barium oxide, BaO	none
Carbon, organic, C	0.09

The irregularity in composition of the Brassfield (formerly called the "Clinton" formation) and the necessity for careful sampling and analysis at any locality to determine its purity were stressed by Orton and Peppel.[1]

Their analyses and others are listed later in this chapter.

Bisher Dolomite

The Bisher formation is variable in physical appearance and character, being at some localities largely made up of silty gray shale with impure dolomite layers, at other places a fairly massive dolomite with smaller amounts of shale. It is often uneven in bedding, particularly in the upper part, and always weathers readily to a brownish color. The

[1] Orton, Edward, Jr., and Peppel, S. V., op. cit., p. 146.

rapidity of its weathering renders it unfit for a building stone, although it was once quarried to some extent for this purpose. Chert is frequently present in considerable quantity, particularly as thin layers or lenses in the upper part of the formation.

At the Carey Brothers quarry at the west edge of Hillsboro both Bisher and Lilley are quarried. The Bisher includes the lower 17 feet of the quarry face and appears more cherty than at most localities. It is here even-bedded and free from shale, and is considered an excellent stone for highway construction, being somewhat harder than the Lilley in the upper part of the quarry. It is doubtful whether the Bisher is as good a stone for quarrying in other parts of the county, although it is present and readily accessible in large areas. Its tendency to weather quickly at the outcrop makes it unattractive in appearance for a good quarry stone.

The Bisher dolomite was sampled in October, 1933, by Wilber Stout, at the quarry of Carey Brothers. Following are the results of the analysis, which was made by Downs Schaaf:

Silica, SiO_2	7.34
Alumina, Al_2O_3	1.59
Ferric oxide, Fe_2O_3	0.40
Ferrous oxide, FeO	0.51
Pyrite, FeS_2	0.47
Magnesium oxide, MgO	18.92
Calcium oxide, CaO	27.20
Strontium oxide, SrO	none
Sodium oxide, Na_2O	0.10
Potassium oxide, K_2O	0.11
Water, hydroscopic, H_2O-	0.29
Water, combined, H_2O+	0.51
Carbon dioxide, CO_2	42.25
Titanium oxide, TiO_2	0.09
Phosphorous pentoxide, P_2O_5	0.05
Sulphur trioxide, SO_3	0.04
Manganous oxide, MnO	0.04
Vanadium pentoxide, V_2O_5	<0.01
Barium oxide, BaO	none
Zinc oxide, ZnO	<0.01
Carbon, organic, C	0.25
Hydrogen, organic, H	0.03

This analysis and most of the others were calculated by Wilber Stout in terms of mineral contents, and the results given in a table on page 138.

A sample of chert was taken from the Bisher at this quarry by R. A. Schoenlaub of the State Highway Department. The results of the analysis, which was made by Downs Schaaf, are as follows:

Silica, SiO_2	95.11
Alumina, Al_2O_3	0.14
Ferric oxide, Fe_2O_3	0.40
Ferrous oxide, FeO	0.44
Pyrite, FeS_2	0.21
Magnesium oxide, MgO	0.71
Calcium oxide, CaO	1.11
Sodium oxide, Na_2O	<0.01
Potassium oxide, K_2O	0.01
Water, hydroscopic, H_2O-	0.43
Water, combined, H_2O+	0.25
Carbon dioxide, CO_2	1.38
Titanium oxide, TiO_2	0.03
Phosphorous pentoxide, P_2O_5	0.01
Sulphur trioxide, SO_3	<0.01
Manganous oxide, MnO	0.01
Zinc oxide, ZnO	<0.01
Carbon, organic, C	0.05
Hydrogen, organic, H	<0.01

A section northeast of Bates School, three miles and a quarter northeast of Hillsboro, was sampled along the bed of a small brook. The description of the section appears among the Bisher localities as given in Chapter IV. The analysis, made from samples collected in 1930 for the purpose of studying insoluble residues, follows. Analyst, Downs Schaaf.

Silica, SiO_2	24.92
Alumina, Al_2O_3	1.82
Ferric oxide, Fe_2O_3	0.66
Ferrous oxide, FeO	0.40
Pyrite, FeS_2	0.16
Magnesium oxide, MgO	14.70
Calcium oxide, CaO	22.32
Strontium oxide, SrO	none
Sodium oxide, Na_2O	0.03
Potassium oxide, K_2O	0.04
Water, hydroscopic, H_2O-	0.36
Water, combined, H_2O+	0.42
Carbon dioxide, CO_2	33.82
Titanium oxide, TiO_2	0.18
Phosphorous pentoxide, P_2O_5	0.10
Sulphur trioxide, SO_3	<0.01
Manganous oxide, MnO	0.11
Barium oxide, BaO	none
Carbon, organic, C	0.08

The Bisher was sampled along the railroad cut west of the village of Peebles for the purpose of examination for insoluble residues. The thickness sampled was about 35 feet, consisting of silty dolomite, weathered to a yellow color, with some grayish shaly layers. The results of the analysis follow, Downs Schaaf analyst.

Silica, SiO_2	18.38
Alumina, Al_2O_3	3.92
Ferric oxide, Fe_2O_3	0.04
Ferrous oxide, FeO	1.95
Pyrite, FeS_2	0.33
Magnesium oxide, MgO	12.80
Calcium oxide, CaO	25.75
Strontium oxide, SrO	none
Sodium oxide, Na_2O	<0.01
Potassium oxide, K_2O	<0.01
Water, hydroscopic, H_2O-	0.28
Water, combined, H_2O+	0.89
Carbon dioxide, CO_2	35.40
Titanium oxide, TiO_2	0.22
Phosphorous pentoxide, P_2O_5	0.07
Sulphur trioxide, SO_3	0.04
Manganous oxide, MnO	0.07
Barium oxide, BaO	none
Carbon, organic, C	0.10

A quarry at West Union, sampled in 1933 by Wilber Stout, showed a product with the following composition. Analyst, Downs Schaaf.

Silica, SiO_2	13.40
Alumina, Al_2O_3	1.80
Ferric oxide, Fe_2O_3	0.72
Ferrous oxide, FeO	2.16
Pyrite, FeS_2	0.63
Magnesium oxide, MgO	16.52
Calcium oxide, CaO	24.47
Strontium oxide, SrO	none
Sodium oxide, Na_2O	0.10
Potassium oxide, K_2O	0.11
Water, hydroscopic, H_2O-	0.42
Water, combined, H_2O+	0.57
Carbon dioxide, CO_2	38.50
Titanium oxide, TiO_2	0.14
Phosphorous pentoxide, P_2O_5	0.05
Sulphur trioxide, SO_3	0.08
Manganous oxide, MnO	0.06
Vanadium pentoxide, V_2O_5	<0.01
Barium oxide, BaO	none
Zinc oxide, ZnO	<0.01
Carbon, organic, C	0.38
Hydrogen, organic, H	0.05

The Bisher was not sampled for analysis at the type locality because of the weathered character of the outcrop there, and because of the nearness to the Carey Brothers quarry at Hillsboro, where the upper part of it was well sampled. The same holds true for the Lilley, of which the typical exposure is now obscured by dumping of rubbish.

Lilley Formation

Without question, the Lilley formation is at present the most important quarry stone in the county. As was noted under the general description of the formation, it varies widely in its characteristics between different localities within Highland County, but is everywhere distinguishable from the Bisher below and the Peebles above, though the actual contacts may be in doubt. Probably with more detailed study of fauna, facies, and lithologic character, this unit will be subdivided.

Quarries have been opened in the Lilley at one time or another at many localities, only a few of which can here be mentioned. The old Corporation and Trimble quarries in Hillsboro used this unit mainly; it was burned for lime two miles northwest of Hillsboro and at other localities; and within recent years its use in highway construction has become so important that quarries have been opened at numerous points. Various ones of these have been owned or operated by John Cashman and son, of Wilmington, and by the Carey Brothers, of Hillsboro.

Localities where sizable quarries have been operated include those near Brick School, five miles northwest of Hillsboro (operated by Mr. Cashman and later by the Ohio Asphaltic Limestone Co.); Fallsville, west of Samantha; a mile and a quarter south of Samantha; Hillsboro; north of Berrysville; and three and one-half miles northwest of Hillsboro, on the New Vienna road. Others are three miles south of New Vienna; half a mile south of Hoagland; two miles and a half north of Sugartree Ridge; at Fairfax; a mile and a half east of Hillsboro; a mile west of Elmville; half a mile northeast of Harriett; and a mile and a half northwest of Sinking Springs.

At the Carey Brothers quarry, in the west edge of Hillsboro, the upper 16 feet of the quarry face belongs to the Lilley formation.. The section was sampled by Wilber Stout in October, 1933, and described as follows:

		Feet	
Sample No. 8......	Lilley	16	Dolomite, bluish gray, massive layers, no flint.
Sample No. 9......	Bisher	17	Dolomite, blue, massive, with thin widely spaced chert layers.

An analysis of the Lilley formation from this quarry was made by Downs Schaaf with the following results:

Silica, SiO_2	6.55
Alumina, Al_2O_3..................................	1.72
Ferric oxide, Fe_2O_3..................................	0.36
Ferrous oxide, FeO..................................	0.51
Pyrite, FeS_2..................................	0.51
Magnesium oxide, MgO	19.00
Calcium oxide, CaO	27.34
Strontium oxide, SrO	none

Sodium oxide, Na_2O	0.10
Potassium oxide, K_2O	0.12
Water, hydroscopic, H_2O-	0.32
Water, combined, H_2O+	0.55
Carbon dioxide, CO_2	42.50
Titanium oxide, TiO_2	0.09
Phosphorous pentoxide, P_2O_5	0.02
Sulphur trioxide, SO_3	0.07
Manganous oxide, MnO	0.04
Vanadium pentoxide, V_2O_5	<0.01
Barium oxide, BaO	none
Zinc oxide, ZnO	<0.01
Carbon, organic, C	0.41
Hydrogen, organic, H	0.06

A sample taken by Wilber Stout at Beaver Mill in 1933 included both the upper part of the Lilley and the lower part of the Peebles. Following are the results of the analysis, which was made by Downs Schaaf.

Silica, SiO_2	5.79
Alumina, Al_2O_3	1.31
Ferric oxide, Fe_2O_3	0.21
Ferrous oxide, FeO	0.44
Pyrite, FeS_2	0.16
Magnesium oxide, MgO	19.31
Calcium oxide, CaO	28.20
Strontium oxide, SrO	none
Sodium oxide, Na_2O	<0.01
Potassium oxide, K_2O	<0.01
Water, hydroscopic, H_2O-	0.32
Water, combined, H_2O+	0.45
Carbon dioxide, CO_2	43.51
Titanium oxide, TiO_2	0.09
Phosphorous pentoxide, P_2O_5	0.035
Sulphur trioxide, SO_3	0.015
Manganous oxide, MnO	0.07
Vanadium pentoxide, V_2O_5	<0.01
Barium oxide, BaO	none
Zinc oxide, ZnO	<0.01
Carbon, organic, C	0.16
Hydrogen, organic, H	0.025

At a quarry operated by John Cashman on the farm of Mrs. Elizabeth Bryant, a mile and a quarter northwest of Berrysville, the Lilley is thicker than at other localities and has a reef-like aspect. A sample was taken by Wilber Stout, and the analysis was made by Downs Schaaf. Following are the results:

Silica, SiO_2	6.68
Alumina, Al_2O_3	1.78
Ferric oxide, Fe_2O_3	0.44
Ferrous oxide, FeO	0.55

Pyrite, FeS_2	0.27
Magnesium oxide, MgO	18.94
Calcium oxide, CaO	27.23
Strontium oxide, SrO	none
Sodium oxide, Na_2O	0.11
Potassium oxide, K_2O	0.14
Water, hydroscopic, H_2O-	0.55
Water, combined, H_2O+	0.56
Carbon dioxide, CO_2	42.35
Titanium oxide, TiO_2	0.11
Phosphorous pentoxide, P_2O_5	0.02
Sulphur trioxide, SO_3	0.08
Manganous oxide, MnO	0.02
Vanadium pentoxide, V_2O_5	<0.01
Barium oxide, BaO	none
Zinc oxide, ZnO	<0.01
Carbon, organic, C	0.24
Hydrogen, organic, H	0.04

The section is briefly described as follows:

	Feet
Weathered dolomite, massive	5
Dark bluish gray, hard, medium to massive layers (sampled)	28
Water level covered, floor of pit	3

A quarry along the road at Baker Fork, northwest of Sinking Springs, was sampled by Wilber Stout in 1933. This sample is from a fresh pit and is representative of the Lilley. The section follows:

	Feet
Dolomite, weathered, drab, not sampled	15
Dolomite, hard, bluish, with light-colored markings, sampled	21
Dolomite and covered	32
Stream level, Baker Fork, 790.	

The analysis was made by Downs Schaaf with the following results:

Silica, SiO_2	7.01
Alumina, Al_2O_3	1.64
Ferric oxide, Fe_2O_3	0.53
Ferrous oxide, FeO	0.56
Pyrite, FeS_2	0.14
Magnesium oxide, MgO	19.08
Calcium oxide, CaO	27.17
Strontium oxide, SrO	none
Sodium oxide, Na_2O	0.16
Potassium oxide, K_2O	0.12
Water, hydroscopic, H_2O-	0.35
Water, combined, H_2O+	0.49
Carbon dioxide, CO_2	42.47
Titanium oxide, TiO_2	0.09
Phosphorous pentoxide, P_2O_5	0.04

Sulphur trioxide, SO_3	0.14
Manganous oxide, MnO	0.05
Vanadium pentoxide, V_2O_5	<0.01
Barium oxide, BaO	none
Zinc oxide, ZnO	<0.01
Carbon, organic, C	0.25
Hydrogen, organic, H	0.04

A very unusual development of the Lilley is found half a mile northeast of Harriett, in a quarry operated by Carey Brothers. It is a nearly pure limestone, with only 1.45 per cent of magnesia. The quarry is on the land of Harlan Skeen. A sample was taken by Wilber Stout in 1933. The following measurements were made:

12748

	Feet
Limestone, weathered	5
Hard, light colored, coarsely crystalline, porous, massive limestone	16
Floor of pit.	

The floor of the quarry is 16 feet above the base of the Lilley.

The analysis was made by Downs Schaaf. The results follow:

Silica, SiO_2	1.42
Alumina, Al_2O_3	0.33
Ferric oxide, Fe_2O_3	0.21
Ferrous oxide, FeO	0.22
Pyrite, FeS_2	0.35
Magnesium oxide, MgO	1.45
Calcium oxide, CaO	52.70
Strontium oxide, SrO	none
Sodium oxide, Na_2O	0.01
Potassium oxide, K_2O	0.01
Water, hydroscopic, H_2O-	0.18
Water, combined, H_2O+	0.10
Carbon dioxide, CO_2	43.10
Titanium oxide, TiO_2	0.02
Phosphorous pentoxide, P_2O_5	0.015
Sulphur trioxide, SO_3	0.02
Manganous oxide, MnO	0.04
Vanadium pentoxide, V_2O_5	<0.01
Barium oxide, BaO	none
Zinc oxide, ZnO	<0.01
Carbon, organic, C	0.08
Hydrogen, organic, H	0.01

The upper part of the Lilley formation is exposed in the Carey Brothers quarry at Fallsville. This was sampled in 1936 by the writer. Following is the section:

12750

	Feet
Peebles—Light gray dolomite with cavities and asphalt impregnations	10
Transition zone — Light gray dolomite, weathers light drab	3
Lilley—Light bluish gray dolomite, hard, porous, some crinoids	7

The results of the chemical analysis, which was made by Downs Schaaf, follow:

Silica, SiO_2	0.77
Alumina, Al_2O_3	0.04
Ferric oxide, Fe_2O_3	0.04
Ferrous oxide, FeO	0.40
Pyrite, FeS_2	0.17
Magnesium oxide, MgO	20.77
Calcium oxide, CaO	30.53
Strontium oxide, SrO	none
Sodium oxide, Na_2O	<0.01
Potassium oxide, K_2O	<0.01
Water, hydroscopic, H_2O-	0.20
Water, combined, H_2O+	0.02
Carbon dioxide, CO_2	47.10
Titanium oxide, TiO_2	0.015
Phosphorous pentoxide, P_2O_5	0.02
Sulphur trioxide, SO_3	<0.01
Manganous oxide, MnO	0.02
Barium oxide, BaO	none
Carbon, organic, C	0.09
Hydrogen, organic, H	....
Zinc sulphide, ZnS	....

ASPHALTIC PHASE OF THE LILLEY FORMATION

While asphalt impregnations are common in the dolomites of the Lilley, Peebles, and Greenfield formations in many parts of the county, up to date the asphaltic rock is of economic importance only in an area extending from a mile north of Hillsboro northwestward nearly to Willettville. The richest rock occurs, so far as now known, in the Lilley formation, mostly in its upper part, where it is porous. Further development may reveal its presence in important quantities at other horizons or in other localities.

Although the presence of asphalt in the rock has been known for a long time, and the property north of Brick School, four and a half miles northwest of Hillsboro, was leased for development many years ago, the rock did not become economically important until the last three or four years. Mr. Cashman, operating the quarry on the east side of the road, north of Brick School, was the first to market the rock; and later this quarry has been operated by Mr. Cashman and the Ohio Asphaltic

Limestone Company. Another quarry west of the road is operated by the Ohio Rock Asphalt Company. The asphaltic rock is quarried here to a depth in some places approaching 20 feet, but below this depth the rock is harder, compact dolomite with little or no asphalt.

Two samples collected by Wilber Stout in 1933 from the Ohio Asphaltic Limestone Company's quarry were analyzed. Following is a section of the rocks where the first sample was taken:

1275

	Feet
Black, mottled dolomite, porous, massive, highly saturated with bitumen	19
Dolomite, light, medium crystalline, massive, hard	11
Floor of pit.	

The other sample was from crushed rock taken from the upper eight feet of the quarry. Both analyses were made by Downs Schaaf.

	Quarry	*Stock pile*
Silica, SiO_2	0.20	0.48
Alumina, Al_2O_3	0.10	0.17
Ferric oxide, Fe_2O_3	0.20	0.03
Ferrous oxide, FeO	0.19	0.33
Pyrite, FeS_2	0.01	0.14
Magnesium oxide, MgO	21.21	21.01
Calcium oxide, CaO	29.70	29.31
Strontium oxide, SrO	none	<0.01
Sodium oxide, Na_2O	<0.01	<0.01
Potassium oxide, K_2O	<0.01	<0.01
Water, hydroscopic, H_2O-	0.40	0.48
Water, combined, H_2O+	0.07	0.06
Carbon dioxide, CO_2	46.61	46.29
Titanium oxide, TiO_2	0.01	0.01
Phosphorous pentoxide, P_2O_5	0.05	0.02
Sulphur trioxide, SO_3	0.015	0.02
Manganous oxide, MnO	0.035	0.03
Vanadium pentoxide, V_2O_5	<0.01	....
Barium oxide, BaO	<0.01	....
Carbon, organic, C	1.27	1.61
Hydrogen, organic, H	0.22	0.23

In 1936 a third quarry has been opened, by the American Rock Asphalt Company, two and a half miles northwest of Hillsboro. This is also in porous, crinoidal upper Lilley, working to a depth of about 20 feet. The rock appears to be somewhat thinner-bedded and softer than at the other quarries, but perhaps more uniformly impregnated with asphalt.

Peebles Dolomite

Two widely different types of quarry stone are found in the Peebles formation: a "marly" phase, soft, easily crumbled, and readily quarried; and a hard, dense, massive gray dolomite, very difficult to quarry.

The "marly" phase occurs only in the unglaciated southeastern part of the county, near Sinking Springs, where it is quarried and where it has been used in surfacing several of the roads. The first analysis here given is from the pit worked by L. C. Kessler on the property of Simpson West. The part sampled consists of "marly" dolomite, light colored, partially disintegrated, 23 feet of which is exposed, covered by soil and "marl." The second analysis is from the pit on the land of Samuel Henise, a quarter of a mile east of Locust Grove, Adams County, where 22 feet of soft, light-colored "marl" was sampled by Wilber Stout. Analyst, Downs Schaaf.

	Sinking Springs	*Locust Grove*
Silica, SiO_2	0.33	0.24
Alumina, Al_2O_3	0.12	0.11
Ferric oxide, Fe_2O_3	0.36	0.21
Ferrous oxide, FeO	0.14	0.20
Pyrite, FeS_2	0.09	<0.01
Magnesium oxide, MgO	21.35	21.40
Calcium oxide, CaO	30.03	30.18
Strontium oxide, SrO	none	none
Sodium oxide, Na_2O	<0.01	<0.01
Potassium oxide, K_2O	<0.01	<0.01
Water, hydroscopic, H_2O-	0.11	0.14
Water, combined, H_2O+	0.07	0.06
Carbon dioxide, CO_2	47.15	47.34
Titanium oxide, TiO_2	0.006	0.006
Phosphorous pentoxide, P_2O_5	0.05	0.02
Sulphur trioxide, SO_3	none	none
Manganous oxide, MnO	0.01	0.01
Vanadium pentoxide, V_2O_5	<0.01	<0.01
Barium oxide, BaO	none	none
Zinc oxide, ZnO	<0.01	<0.01
Carbon, organic, C	0.40	0.36
Hydrogen, organic, H	0.05	0.04

Throughout most of its extent in Highland County, the Peebles is a hard, light gray, finely crystalline dolomite, generally massive, without conspicuous bedding or jointing. The surface is often weathered to a drab color and softer than the unweathered rock, but only to a depth of a few feet. Small quarries have been opened at several places in parts of the county where the Lilley or Greenfield formations were not available, but there are no large quarries completely within the Peebles. The upper 10 feet of the ledge of the Carey Brothers quarry at Fallsville, two miles west of Samantha, is the Peebles. This was sampled by the writer, August, 1936, and the following analysis was made by Downs Schaaf:

Silica, SiO_2	0.95
Alumina, Al_2O_3	0.14
Ferric oxide, Fe_2O_3	0.05
Ferrous oxide, FeO	0.40
Pyrite, FeS_2	0.15
Magnesium oxide, MgO	20.85
Calcium oxide, CaO	30.11
Strontium oxide, SrO	none
Sodium oxide, Na_2O	<0.01
Potassium oxide, K_2O	<0.01
Water, hydroscopic, H_2O-	0.20
Water, combined, H_2O+	0.04
Carbon dioxide, CO_2	46.84
Titanium oxide, TiO_2	0.02
Phosphorous pentoxide, P_2O_5	0.09
Sulphur trioxide, SO_3	<0.01
Manganous oxide, MnO	0.03
Barium oxide, BaO	none
Carbon, organic, C	0.32
Hydrogen, organic, H	0.04
Zinc sulphide, ZnS	0.07

The rock at this quarry, both Lilley and Peebles, is hard and durable, making a good stone for highway purposes. It contains enough asphalt to be noticeable on the quarry face, but does not compare in richness with the asphaltic area between Hillsboro and Willettville.

The Peebles stone was sampled at two other localities by Wilber Stout: at a quarry on the property of John Shivener, a mile and a quarter east of Lynx, Adams County, and from the cliff along the road near the mouth of Plum Run, Paint Township, Highland County. The section measured east of Lynx follows:

12688

	Feet
Dirt	1
Weathered stone	4
Dolomite, sugary, with bitumen, "curly" texture, sampled	34
Base of section at elevation of 720 feet and top not far below base of Ohio shale.	

The section measured at Plum Run is given below:

12882

	Feet
Dolomite, poorly exposed. Massive, sugary dolomite, slightly weathered, sampled	32
Base of part sampled at elevation of 780 feet.	

Analyses were made by Downs Schaaf, and the results follow:

	Lynx	*Plum Run*
Silica, SiO_2	0.77	0.33
Alumina, Al_2O_3	0.27	0.09
Ferric oxide, Fe_2O_3	0.20	0.09
Ferrous oxide, FeO	0.43	0.33
Pyrite, FeS_2	0.24	0.02
Magnesium oxide, MgO	21.10	21.07
Calcium oxide, CaO	29.72	30.75
Strontium oxide, SrO	none	none
Sodium oxide, Na_2O	<0.01	<0.01
Potassium oxide, K_2O	<0.01	<0.01
Water, hydroscopic, H_2O-	0.20	0.14
Water, combined, H_2O+	0.11	0.10
Carbon dioxide, CO_2	46.81	47.07
Titanium oxide, TiO_2	0.03	0.015
Phosphorous pentoxide, P_2O_5	0.03	0.05
Sulphur trioxide, SO_3	<0.01	none
Manganous oxide, MnO	0.045	0.08
Vanadium pentoxide, V_2O_5	<0.01	<0.01
Barium oxide, BaO	none	none
Zinc oxide, ZnO	<0.01	<0.01
Carbon, organic, C	0.33	0.10
Hydrogen, organic, H	0.04	0.015

Greenfield Dolomite

Long recognized as one of the most desirable limestones for quarrying in the region, the Greenfield affords many desirable quarry locations, but has not been worked to any large extent within the limits of Highland County. The Cincinnati Quarries Company's quarry at Greenfield is just beyond the county line in Ross County. It has been well known for a long time and is still actively worked. In it are typically shown both the even-bedded dolomite, with gray and drab laminations and carbonaceous partings, and the structureless, reef-like masses also characteristic of this formation. On account of the difficulty of quarrying, the latter have to some extent limited the opening up of the quarry in certain directions, although they have been produced and used. Samples of both types were collected, the even-bedded stone being sampled through a 41-foot section as follows:

	Feet
Weathered rock near top of cliff	6
Even-bedded dolomite, slightly weathered	16
Weathered, hard, gray to drab dolomite, base at water level	19

The reef-like mass is 19 feet above water level.

12810

Analyses of both phases follow. Analyst, Downs Schaaf.

	Even-bedded dolomite	Reef-like dolomite
Silica, SiO_2	3.10	1.77
Alumina, Al_2O_3	0.03	0.04
Ferric oxide, Fe_2O_3	0.03	0.21
Ferrous oxide, FeO	0.40	0.30
Pyrite, FeS_2	0.19	0.03
Magnesium oxide, MgO	20.51	20.62
Calcium oxide, CaO	29.20	30.29
Strontium oxide, SrO	<0 01	none
Sodium oxide, Na_2O	0.10	0.01
Potassium oxide, K_2O	0.11	0.01
Water, hydroscopic, H_2O-	0.15	0.10
Water, combined, H_2O+	0.08	0.02
Carbon dioxide, CO_2	45.65	46.62
Titanium oxide, TiO_2	0.06	0.015
Phosphorous pentoxide, P_2O_5	0.17	0.03
Sulphur trioxide, SO_3	0.03	<0.01
Manganous oxide, MnO	0.03	0.02
Barium oxide, BaO	none	none
Carbon, organic, C	0.35	0.11
Hydrogen, organic, H	0.03	0.01

Rock here referred to as Greenfield, but perhaps sometimes including a higher member of the Monroe group as well, occurs at the higher elevations in parts of Madison, Fairfield, Penn, and Paint townships. A good section is found in the quarry on the farm of Charles Smith, a mile and a half south of Highland. The rock is even bedded but dips unevenly near the floor of the quarry, probably arching over structureless masses below. A section of this quarry is described on page 114. Following are the results of the analysis, which was made by Downs Schaaf:

Silica, SiO_2	1.65
Alumina, Al_2O_3	0.02
Ferric oxide, Fe_2O_3	0.04
Ferrous oxide, FeO	0.34
Pyrite, FeS_2	0.06
Magnesium oxide, MgO	20.95
Calcium oxide, CaO	29.68
Strontium oxide, SrO	<0.01
Sodium oxide, Na_2O	0.12
Potassium oxide, K_2O	0.16
Water, hydroscopic, H_2O-	0.17
Water, combined, H_2O+	0.10
Carbon dioxide, CO_2	46.51
Titanium oxide, TiO_2	0.04
Phosphorous pentoxide, P_2O_5	0.05
Sulphur trioxide, SO_3	0.02
Manganous oxide, MnO	0.015
Barium oxide, BaO	none
Carbon, organic, C	0.29
Hydrogen, organic, H	0.03

This analysis is probably less representative than that at Greenfield because the rock appears to be more weathered.

MINERAL CONTENT AS CALCULATED FROM ANALYSES

The analyses of samples collected by Wilber Stout have been calculated by him in terms of mineral content, as given in the following table. The localities and formations from which these samples were collected are:

1. Peebles "marl"—Simpson West property, north of Sinking Springs.
2. Lilley dolomite—Baker Fork, northwest of Sinking Springs, Martha Crum property.
4. Peebles dolomite—John Shivener pit, one mile east of Lynx.
5. Peebles "marl"—Locust Grove quarry.
6. Peebles dolomite—Near mouth of Plum Run, Paint Township, Highland County.
7. Lilley and Peebles—Beaver Mill, Brush Creek Township, Highland County.
8. Lilley dolomite—Carey Brothers quarry, Hillsboro.
9. Bisher dolomite—Carey Brothers quarry, Hillsboro.
10. Lilley dolomite—Property of Mrs. Bryant, northwest of Berrysville.
11. Bisher dolomite—Quarry at West Union, Adams County.
12. West Union—Near head of Stout Run, Adams County.
13. Lilley formation—Quarry of Carey Brothers on land of Harlan Skeen, northeast of Harriett.
14. Lilley formation—Ohio Asphaltic Limestone Company quarry, northwest of Hillsboro.

These calculations are summarized in the following table:

Mineral Content as Calculated from Analyses

		1	2	4	5	6	7	8	9	10	11	12	13	14
Sericite $(NaK)_2O.3Al_2O_3.6SiO_2.2H_2O$		0.00	2.99	**0.00**	0.00	0.00	0.00	2.25	2.16	2.53	2.16	1.47	0.00	0.00
Kaolinite, $Al_2O_3.2SiO_2.2H_2O$		0.30	1.16	0.69	0.28	0.23	3.31	2.13	1.87	2.00	2.41	0.47	0.84	0.26
Quartz, SiO_2		0.19	5.08	0.45	0.11	0.22	4.25	4.52	5.47	4.57	11.28	2.58	1.03	0.08
Limonite, $2Fe_2O_3.3H_2O$		0.42	0.62	0.23	0.25	0.11	0.25	0.42	0.47	0.51	0.84	0.85	0.25	0.23
Pyrite, FeS_2		0.09	0.14	0.24	0.00	0.02	0.16	0.51	0.47	0.27	0.63	0.04	0.35	0.01
Rutile, TiO_2		0.006	0.09	0.03	0.006	0.015	0.09	0.09	0.09	0.11	0.14	0.07	0.02	0.01
Apatite, $3CaO.P_2O_5$		0.11	0.09	0.07	0.04	0.11	0.075	0.04	0.11	0.04	0.11	0.11	0.035	0.11
Gypsum, $CaO.SO_3.2H_2O$		0.00	0.30	0.00	0.00	0.00	0.035	0.15	0.09	0.18	0.18	0.035	0.04	0.035
Dolomites or Limestones — Main components	$MgO.CO_2$	44.65	39.90	44.13	44.76	44.07	40.38	39.74	39.57	39.61	34.55	40.53	3.03	44.36
	$CaO.CO_2$	53.49	48.23	52.97	53.83	54.78	50.24	48.67	48.39	48.46	43.46	51.92	94.01	52.88
Dolomites or Limestones — Parts in solid solution	$FeO.CO_2$	0.23	0.90	0.69	0.32	0.53	0.71	0.82	0.82	0.89	3.48	1.20	0.35	0.31
	$MnO.CO_2$	0.02	0.08	0.08	0.02	0.13	0.11	0.07	0.06	0.03	0.10	0.10	0.06	0.055
Water, hydroscopic, H_2O		0.11	0.35	0.20	0.14	0.14	0.32	0.32	0.29	0.55	0.42	0.32	0.18	0.40
Hydrocarbons, C_nH_{n+2}		0.45	0.29	0.37	0.40	0.115	0.185	0.47	0.28	0.28	0.43	0.50	0.09	1.49
Unbalanced parts CO_2 and H_2O		0.20	0.11	0.18	0.16	—0.22	—0.02	0.07	0.05	0.08	—0.03	—0.08	—0.04	0.06
Total		100.266	100.33	100.33	100.316	100.25	100.095	100.27	100.19	100.11	100.16	100.115	100.245	100.29

Analyses of Highland County Rocks Reported By Edward Orton, Jr. and S. V. Peppel in 1906.[1]

Locality	Lexington	Leesburg	Greenfield	Hillsboro				Sinking Springs
Description of Sample	Pope's Quarries Niagara	Wright's Quarries Niagara	Wright's Quarries Lower Helderburg	Rucker's Quarries Lower Helderburg	"Lower Cliff" or West Union Stone	Trimble's Quarries Guelph Beds	Trimble's Quarries Blue Cliff or Cedarville Stone	Water Lime or Lower Helderburg
Silica	3.57	1.60	4.35	2.44	2.60	13.30	0.40	0.70
Alumina	0.90	2.20	1.00	1.30	3.20	2.00	1.80	1.50
Carbonate of calcium	49.76	54.10	49.70	53.67	62.60	35.57	54.25	52.87
Carbonate of magnesium	45.77	41.77	44.87	42.42	31.32	49.00	43.23	42.94
Total	100.00	99.67	99.92	99.83	99.72	99.87	99.68	98.01

[1] Orton, Edward, Jr. and Peppel, S. V., Limestone resources and lime industry in Ohio: Geol. Survey Ohio, 4th Ser., Bull. 4, p. 75, 1906.

ANALYSES OF GREENFIELD DOLOMITE[1]

Locality	*Greenfield*		*Highland*	*Leesburg*
Carbonate of lime	53.67	49.70	54.10	49.76
Carbonate of magnesia	42.42	44.87	41.77	45.77
Alumina and iron	1.30	1.00	2.20	0.90
Silicates of lime and magnesia	1.44	2.98	....	2.88
Silica	1.00	1.45	1.60	0.69
Total	99.83	100.00	99.67	100.00

SAND AND GRAVEL

Hillsboro Sandstone

The Hillsboro formation is a fine, white, friable sandstone which may at some future date have an economic value. Its occurrence is irregular and limited in quantity, and while its color is white when fresh, its tendency to acquire a reddish brown stain upon weathering indicates a considerable percentage of iron and perhaps other impurities.

GLACIAL DEPOSITS

The more important sand and gravel deposits of the county are largely glacial in origin: for the most part, they were laid down in water at or near the margin of the ice-sheet or as outwash carried away from it. Sand does not usually occur in these deposits without a certain amount of gravel intermixed or interstratified with it; in some cases coarse gravel is found with relatively little fine material. Screening or washing is generally necessary where uniformity of size is desired, but much of the gravel used for road material is applied without any sorting whatsoever. The clean unweathered sand and gravel generally have an overburden of red, "sticky" oxidized gravel in which limestone pebbles, if present at all, are apt to be of chalky consistency. In the case of the poorly drained deposits of the Illinoian age there may also be a zone of gumbo in which are present only the most resistant pebbles, such as cherts and quartzites.

The majority of deposits of gravel are here considered to be of Illinoian age, although those indicated on the map as of doubtful age may later be found to belong to the early Wisconsin stage. The Illinoian of the flat Till Plains was not examined as closely as that of the hilly region, but at several points it has gravelly phases in which pits have been opened. One of these, from which a considerable amount of gravel has been removed by means of a dragline, is located just west of the highway, a mile and a half southeast of Danville.

The kame-morainic hills, particularly those of the central part of the Hillsboro quadrangle and near Beaver Mill in the Bainbridge quadrangle,

[1] Orton, Edward, Geology of Highland County: Geol. Survey Ohio, Report of Progress in 1870, p. 287, 1871.

furnish an inexhaustible supply of gravel, ranging in coarseness from sand to small boulders, but frequently of fairly even size in certain parts of a single deposit. Of these, one of the westernmost is the group of small hills cut through by the highway and the railroad about a mile and a half southwest of Hillsboro, from which a considerable amount of gravel has been removed. A little over a mile south of this a larger group of hills affords an enormous supply of gravel which appears to be of excellent quality, although locally cemented into ferruginous and possibly manganiferous conglomerate. In both of these occurrences, the clean gravel has only a slight overburden of 0 to 3 feet of weathered material. To the west and south of these, other lower hills appear to have considerable thicknesses of gravelly drift, but no large deposits of gravel of as good quality as those mentioned. Numerous small gravel pits have been opened in this vicinity.

South of Hillsboro, between Rocky Fork and the old Cincinnati and Chillicothe road, there are many small hills of gravel as well as some thick valley fillings. Some of these deposits have the limestone pebbles leached out to a depth of 8 or 10 feet and are oxidized to a greater depth, while others, where erosion has been active, show fresh gravel at the surface. An example of the latter is found in certain of the knolls west of South Fork, about a mile northwest of the former site of Mt. Washington school. A group of kames, west of the Belfast road just south of Rocky Fork, has furnished a considerable amount of gravel, some of which, however, is cemented into conglomerate masses.

Similar gravel knolls of unquestioned Illinoian age occur on the west side of the ridge followed by the road, approximately three miles northwest of Belfast. A small pit opened in one of these affords a good grade of gravel, although there is usually an overburden of weathered gravel to a depth of several feet. East of this, in the valley of Elm Run, there are extensive terrace-like deposits of gravel, which is generally not of as good quality as the last.

Various gravel hills and terrace-like deposits occur west and north of Marshall. Some of the smaller hills appear to be made up entirely of gravel, as for instance the one a mile and a half east of Carlyle School; others have a veneer of gravel over bedrock.

Along the highway for two miles and a half northwest of Carmel there are gravel hills, the northern ones of which line up to form a ridge parallel to the road. At one point along this ridge, a pit has been opened and a considerable amount of gravel removed for road material. There are many large lumps of cemented gravel, or conglomerate, which are worthless and a hindrance to the removal of the unconsolidated material.

At the west margin of the Beech Flats there is a thick filling of more or less gravelly drift, with some small gravel hills rising above its general level, such as the ones east of Roundtop and southeast of Heads Hill.

Considerable deposits of gravel also occur west and northwest of the junction of Rocky Fork and Paint Creek, where several small gravel pits have been opened.

A relatively small deposit of gravel on the hilltop, a mile northwest of Hillsboro, is referred with considerable doubt to the Illinoian. In freshness of appearance and in its comparatively shallow zone of weathering, it resembles the Wisconsin, but this is also true of other gravel hills farther south, as pointed out in the description of the Illinoian drift.

Within the drift of unquestionable Early Wisconsin age there are only a few gravel deposits of any importance. The Cuba moraine, where it enters the county southwest of New Vienna, is somewhat gravelly in nature, but has not been worked for gravel. At Samantha the Early Wisconsin drift also contains a considerable percentage of fine gravel. Four miles and a half east of Samantha, north of Rosebush School, there is a small deposit of gravel, which contains but little coarse material and which has in the past been worked to a small extent. A prominent kame about a mile west of New Petersburg has been opened at several places for gravel; the material here is heterogeneous in character, some of the boulders being over a foot in diameter.

The Middle Wisconsin deposits of the northeastern part of the county include numerous occurrences of gravel, particularly along the south side of the valley of Rattlesnake Creek. The morainic system, which extends with interruptions from the vicinity of Leesburg to the mouth of Plum Run, consists mainly of gravel hills and somewhat irregular gravel deposits on the bedrock slopes of the valley. A few pits have been opened at various points, and most of the material removed has been used on near-by roads. Aside from the morainic gravel, terrace deposits occur at many points along the valleys of Rattlesnake Creek and Paint Creek, particularly southeast of Centerfield and south of Greenfield. In addition, there are various localities where the Middle Wisconsin drift itself is gravelly, as along the railroad two miles west of Greenfield.

STREAM DEPOSITS

Many streams have gravel in their beds to a considerable amount, such, for instance, as the South Fork of Rocky Fork. Here the chief source of supply appears to have been from the wasting away of the surrounding hills. Stream gravels in many parts of the county have been used locally on the secondary roads.

INDEX

A

B

C

D

I

J

K

L