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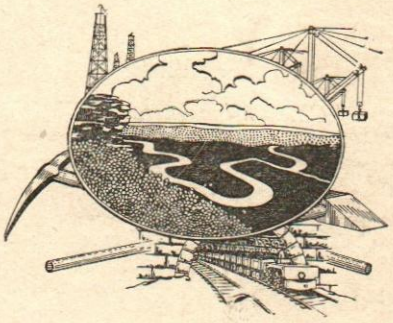
Stratigraphy and Correlation of the Devonian of Western Tennessee

By CARL O. DUNBAR.



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PREFACE

The Devonian strata exposed along the Western Valley of the Tennessee River have for more than half a century offered one of the most inviting fields to the stratigrapher and paleontologist. Not only are they replete with finely preserved fossils, but the long sequence —especially the presence of the typical upper Oriskany—will make it the standard section for the Lower Devonian of the entire Mississippi basin. Nevertheless, in spite of their significance, these strata have received only the scantiest attention and they have remained the last important area of Lower Devonian rocks in America to be adequately described.

The present study of these strata was begun in the summer of 1916, when the writer spent two months in the field, making a large collection of fossils and gathering data which formed the basis for a dissertation presented in 1917 in partial fulfillment of the requirements for the degree of doctor of philosophy at Yale University. The problem proved so fruitful of interesting results that through the interest of the late Doctor A. H. Purdue, the Tennessee State Geological Survey enabled the writer to spend five additional weeks in the field during the summer of 1917, and to prepare the present monograph.

The original study was made possible through the kindness of Professor Charles Schuchert, and all the work on the faunas and the preparation of this manuscript has been done in the paleontological laboratories of the Peabody Museum at Yale University, under his constant supervision. It is a pleasant duty to acknowledge the writer's indebtedness to Professor Schuchert for the criticisms and suggestions which have given to this study much of whatever value it may have.

Thanks are due to Doctor Ray S. Bassler of the United States National Museum for the identification of part of the bryozoa, and to Doctor Frank Springer, of the same institution, for the identification of the crinoids. The writer is, in addition, especially indebted to Doctor Bruce Wade, who generously shared his knowledge of the geology of the Western Valley of Tennessee and donated a number of collections of fossils.

Stratigraphy and Correlation of the Devonian of Western Tennessee

CHAPTER I

General Relations of the Devonian Formations

AREA OF OUTCROP

The Devonian rocks of Tennessee are exposed in numerous small, irregular areas along the Western Valley of the Tennessee River and certain of its tributaries in Benton, Decatur, Perry, and Hardin counties. Important sections are afforded by Indian and Horse creeks in Hardin County, while more extensive outcrops occur along Birdsong and Cypress creeks and on the lower course of Big Sandy River in Benton County. This narrow belt crossing the State from north to south embraces practically all the Devonian strata of Tennessee, save for the widespread Chattanooga shale. The exceptions to be noted are small outcrops of the Lower Devonian in the Wells Creek basin near Cumberland City and little exposures of a thin formation of Middle Devonian limestone near Pegram and Newsom, a few miles west of Nashville. A small occurrence of the Helderbergian is also known near Sneedville in the mountains of East Tennessee. The latter, however, belongs to the Appalachian province and was not included in the present study. (See Fig. 1.)

INTRODUCTION AND GENERAL RELATIONS

Location and Extent.—The area covered by this investigation coincides approximately with the Western Valley of the Tennessee River. In its reflex course northward across the State, this great stream lies in a relatively narrow valley, "remarkable for its broken and varied surface," and hemmed in on either side by table-like highlands that have an average altitude of 500 to 600 feet above the river. Limited by the line where, in general, the bordering highlands break away, this area forms an irregular belt extending entirely across the State from south to north, varying in width from perhaps 5 to 20 miles, but averaging about 10 or 12 miles. Its area is, therefore,

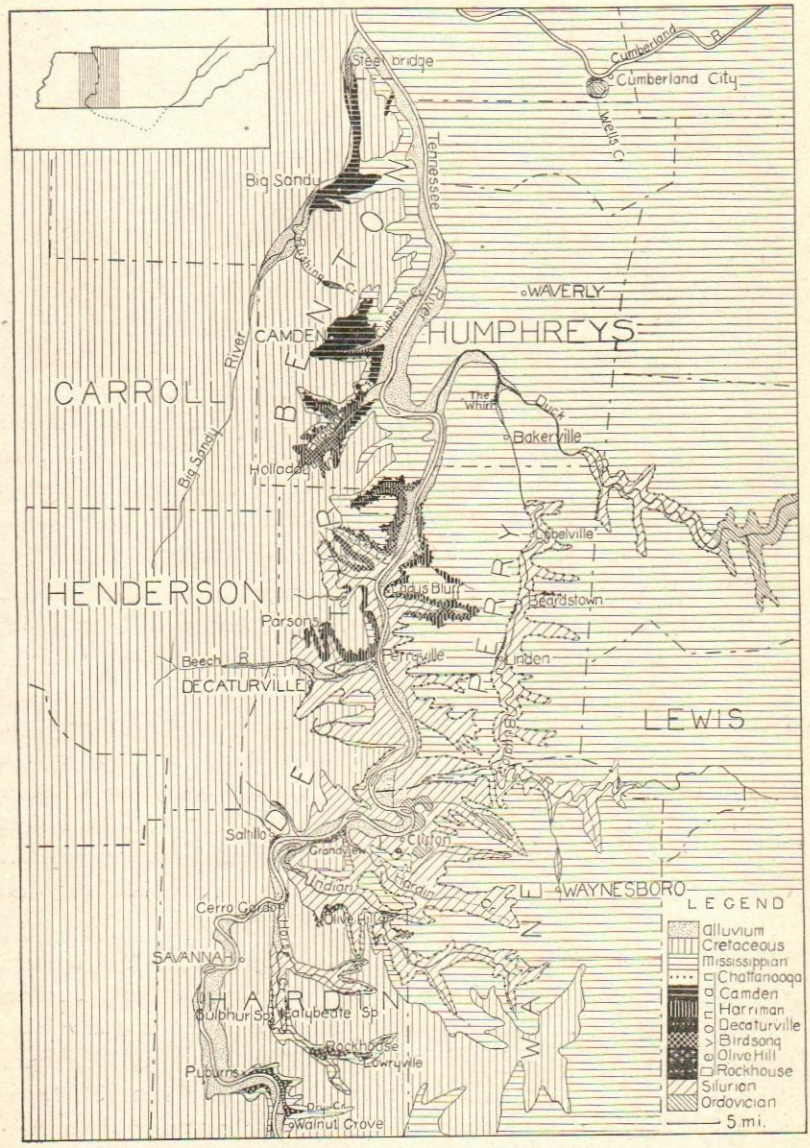

FIGURE 1.—Geological map of the Western Valley of Tennessee and vicinity.

approximately 1,200 square miles, and although it forms so small a portion of the State, it is nevertheless one of the natural physiographic subdivisions of the same. It includes much of Benton, Decatur, and Hardin counties and portions of Wayne, Perry, Humphreys, and Henry counties.

Towns.—The largest town in the area under consideration is Savannah, the seat of Hardin County, which has a population of about 2,000, and is important as a cotton-buying center. The second in size is Parsons, a town of 800 inhabitants, located on a branch line of the Nashville, Chattanooga & St. Louis Railway in Decatur County. Camden, the seat of Benton County, is on the main line of the same railroad, while Clifton, the chief town of Wayne County, is situated on the bank of the Tennessee River. Camden and Clifton each have about 700 inhabitants. Of the smaller towns and villages along the valley, ranging in population from 300 to 500, should be mentioned Saltillo in Hardin County; Decaturville, the seat of Decatur County; Linden, the seat of Perry County; and Big Sandy, a small town on Big Sandy River in the northern portion of Benton County.

Railroads.—The Western Valley is directly crossed in its northern portion by two railroads; the Nashville, Chattanooga & St. Louis Railway, running through Camden, and the Louisville & Nashville Railroad, crossing at Big Sandy. In addition, a branch line of the former road comes into the center of the valley from the west and terminates at Perryville, a village on the bank of the river in east central Decatur County. The southern half of the valley, on the other hand, suffers for the lack of such an outlet, and is, in fact, a part of the largest area in the State still untouched by a railway. A new line to cross Hardin County has been proposed, however, and if built will be a great boon to this region.

A great natural highway of traffic is provided for the Western Valley by the Tennessee River, for the deep unobstructed channel of this noble stream makes it one of the greatest of our navigable rivers. Two large freight steamers of the Mississippi and Tennessee River Packet Company make the round trip weekly from St. Louis down the Mississippi and up the Tennessee to some point in Alabama, stopping at the many landings which are distributed every few miles along the river.

Climate.—The Western Valley of Tennessee is characterized by a mild climate, with only moderate extremes of temperature or of moisture. During midsummer, the days are rather hot, but the nights are generally cool, and the winters are rather mild and open, with an average snowfall of less than 5 inches. The greatest recorded extremes of temperature are 107° F. for summer and —23° F. for winter, but the mean temperature for the hottest summer month is 79° F., and for the coldest winter month 40° F.

The last killing frost in spring generally comes the first week in April and the first killing frost of the fall about the last week in October, so that a long growing season is given to crops. The average annual rainfall is about 50 inches, and this is so uniformly distributed throughout the year that growing crops are not likely to suffer either excessive drought or moisture.

Physiography.—The Western Valley is deeply incised between two plateaus which lie at an altitude of 750 to 1,000 feet above sea-level. To the east lies the Highland Rim, formed of the resistant Mississippian limestones, cherts, and shales, while in the opposite direction, stretching out toward the Mississippi Valley, is the western plateau slope, composed of Cretaceous sands and clays. Through the more resistant Mississippian strata and into the underlying Devonian, Silurian, and Ordovician rocks, the river has incised itself to a depth of 400 or 500 feet in its meandering course. Its valley, in consequence, is surprisingly narrow and rough for so great a stream. Lying between the highlands which overlook it from either side, the valley averages only 10 to 12 miles in width, while the river's flood plain seldom exceeds a width of 2 or 3 miles. Spurs, fringing outward from where the highlands begin to break away, frequently extend out to the river, overhanging in precipitous cliffs 100 feet and more in height. Many small tributaries to the Tennessee flow between these spurs in deep narrow valleys that subdivide headward into a myriad of little ramifying branches, each of which begins in a small gorge where it in turn is working headward into the highland. Practically the entire surface of the valley has thus been reduced to narrow-topped ridges and slopes. This rough and varied topography has provided many good natural exposures of the rock strata and thus afforded an excellent opportunity for the study of the stratigraphy of the Western Valley.

TABLE OF GEOLOGIC FORMATIONS OF THE WESTERN VALLEY OF TENNESSEE

SYSTEMS		FORMATIONS	THICKNESS	CHARACTER OF FORMATIONS	ECONOMIC PRODUCTS	DISTRIBUTION OF FORMATIONS
QUATERNARY		ALLUVIUM		GRAVEL, SAND, SILT	VERY FERTILE SOIL	NARROW BELT ALONG STREAMS
		TERRACE GRAVEL	0-30'	WATER-WORN CHERT GRAVEL	ROAD METAL	SCATTERED REMNANTS OF OLD RIVER TERRACES
		UNCONFORMITY				
CRETACEOUS	UPPER	EUTAW FORM.	0-50'	RED SANDS AND LESSER AMOUNTS OF VARICOLORED SANDS		WIDESPREAD IN HARDIN CO.; BORDERING W. SIDE OF THE VALLEY FURTHER NORTH
		TUSCALOOSA FORM	0-150'±	WATER-WORN CHERT GRAVEL, SOME SAND AND CLAY	ROAD METAL	A CHAIN OF OUTLIERS CAPS RIDGES ALONG EAST SIDE OF VALLEY BEST DEVELOPED IN HARDIN AND WAYNE COUNTIES
		UNCONFORMITY				
MISSISSIPPIAN	UPPER	ST. LOUIS LS.	0-200'	GRAY CHERTY LS., EXPOSED AS RESIDUAL CHERTY RUBBLE	FERTILE SOIL	CRESTS OF HILLS AND RIDGES BORDERING THE VALLEY ON THE EAST
	LOWER	FT. PAYNE CHERT	0-200'	DARK CALCAREOUS CHERT, WEATHERING YELLOW	ROAD METAL	MIDDLE AND HIGHER SLOPES ALONG SIDES OF THE VALLEY
		RIDGETOP SH. MEMBER	0-150'	GRAY TO BLACK SILICEOUS SH.	BRICK SHALE	FT. PAYNE CHERT BEST DEVELOPED IN SOUTHERN HALF OF THE VALLEY
		UNCONFORMITY				
DEVONIAN	UPPER	CHATTANOOGA SH.	0-20'	BLACK FISSILE SHALE HARDIN SS. LAYER AT BASE	OIL PHOSPHATE	WIDESPREAD. NARROW OUTCROP BORDERING THAT OF THE MISSISSIPPIAN
		UNCONFORMITY				
	MIDDLE	PEGRAM LS.	0-6'±	PURE WHITE LIMESTONE		ONE SMALL OUTCROP, MOUTH BUFFALO RIVER
		CAMDEN NOV.	0-200'±	WHITE, BUFF-WEATHERING FOSSILIFEROUS NOVACULITE	ROAD METAL	CONFINED TO N. HALF OF VALLEY. WIDELY EXPOSED ABOUT CAMDEN AND BIG SANDY
	LOWER	HARRIMAN NOV.	0-55'	NOVACULITE SIMILAR TO THAT ABOVE	ROAD METAL	WELL DEVELOPED IN CENTRAL DECATUR CO. REMNANTS FROM CERRO GORDO TO NORTH STATE LINE
		QUALL LS.	0-10'±	LIGHT GRAY SILICEOUS LS.		SMALL OUTCROPS IN HARDIN CO.
		DECATURVILLE CH.	0-10'±	POROUS GRAY CHERT	ROAD METAL	MANY SMALL SCATTERED OUTCROPS
		BIRDSONG SH.	0-70'	BLUISH CALCAREOUS SHALE AND SHALY LIMESTONE		WELL DEVELOPED FROM PERRYVILLE NORTHWARD. OUTCROPS ALONG CREEKS
		FLAT GAP LS.	0-55'	PURE, MASSIVE, WHITE LS.	LIMESTONE	LOCAL REMNANTS IN HARDIN CO.
		BEAR BRANCH FORM	0-45'	LIMESTONE AND OOLITIC HEMATITE	IRON-ORE	LOCAL REMNANTS BETWEEN OLIVE HILL AND CLIFTON
		ROSS LS.	0-80'	DARK, COMPACT, THIN-BEDDED, CHERTY LIMESTONE	BUILDING STONE	WELL EXPOSED ALONG CREEKS IN HARDIN CO.
		ROCKHOUSE SH.	0-26'	GREENISH BLUE CALCAREOUS SHALE		SMALL EXPOSURES ON UPPER PART OF HORSE CREEK
		UNCONFORMITY				
SILURIAN	MIDDLE	DECATUR LS.	0-70'	HEAVY-BEDDED, LIGHT GRAY, RATHER PURE LS.	LIMESTONE	EXPOSED ALONG STREAM COURSES IN CENTRAL AND SOUTHERN PART OF REGION
		LOBELVILLE FORM.	0-75'	THIN-BEDDED SHALY LS. AND VARIEGATED SHALES		EXTENSIVELY EXPOSED ALONG LOWER PORTIONS OF STREAM COURSES IN SOUTHERN DECATUR AND IN PERRY CO.
		BOB FORM.	0-75'	MASSIVE PURE LIMESTONE AND VARIEGATED SHALE	LIMESTONE	
		BEECH RIVER FORM	0-106'	CALCAREOUS SH. AND SHALY LS. WITH CHERT	PHOSPHATE	
		DIXON LS.	0-44'	ARGILLACEOUS RED LS. AND RED AND PURPLE SHALES		EXPOSURES CHIEFLY CONFINED TO STREAM COURSES NORTH OF SAVANNAH AND SOUTH OF PERRYVILLE
		LEGG LS.	0-46'	COMPACT, LIGHT GRAY, SUBCRYSTALLINE LS.	LIMESTONE	
		WALDRON SH.	0-4'	LIGHT GRAY SHALY LS.		
		LAUREL LS.	0-28'	MASSIVE, PURPLE AND REDDISH LS.	LIMESTONE	
		OSGOOD LS.	0-15'	THIN-BEDDED, REDDISH, ARGILLACEOUS LS.		
	L.	*UNCONFORMITY* BRASSFIELD LS.	0-1'	WHITE AND BROWN CHERTY LS.		
		UNCONFORMITY				
ORDOVICIAN	UPPER	FERNVALE FORM.	0-35'	BLUISH SHALE AND COARSE-GRAINED, GRAY, PHOSPHATIC LIMESTONE	IRON ORE, MARBLE	SMALL EXPOSURES ALONG THE STREAMS IN THE VICINITY OF CLIFTON
		ARNHEIM FORM.	0-3'	COARSE-GRAINED PHOSPHATIC AND CHERTY LS.		
		UNCONFORMITY				
	MIDDLE	HERMITAGE FORM	0-70'+	DARK GRAY, COMPACT, ARGILLACEOUS LS., INTERBANDED WITH BLUE SH.	NATURAL CEMENT	

N. B.—Numerous unconformities of only local significance, between the several Devonian and Silurian formations, are omitted from the table.

Geologic Formations.—The deep dissection of the valley of the Tennessee has brought to light a wide range of geologic formations, several of which are not elsewhere exposed in the State. This is true of the higher Silurian formations (the Brownsport group and the Decatur limestone), as well as of the Linden group and the Harriman and Camden cherts of the Devonian. These groups of formations thin out as a great wedge to the eastward on the flank of the Nashville dome, so that they are absent where their horizon comes to the surface along the margins of the Central Basin of Tennessee. On the preceding page is shown the formations recognized in the Western Valley, the table being partly compiled from the works of Foerste,[1] Pate and Bassler,[2] Wade,[3] and Drake.[4]

Structure.—All the rocks of this region are sedimentary strata which were deposited in flat and essentially horizontal layers. In general, they still maintain this attitude, but in detail they are in many places thrown into low open folds, on the limbs of which the dip may reach a maximum of 8 or 10 degrees. In the southern half of the valley, faulting is not uncommon and the throws range from a few to perhaps 150 feet. The strongest disturbance observed is in the vicinity of Clifton, where the structure is transected and beautifully shown along the Tennessee River. The town is located on the crest of an anticline from which the rocks dip very gently away to the east and west for a mile in either direction. The height of the arch, if restored, would be fully 250 feet, and the south limb is broken down by a fault which has a throw of about 125 feet, bringing the mid-Ordovician Hermitage limestone up in contact with the mid-Silurian Dixon. Just below Grandview, the river cuts across another low arch some 2 miles wide and fully 100 feet high at its crest, while the preserval of the big Devonian section at Olive Hill is due to a syncline of similar magnitude. Considerable faulting has occurred just below Cerro Gordo, where a section of the bluff 200 or 300 yards long, composed of Devonian limestone dipping 8 or 10 degrees to the north, intervenes between bluffs formed of horizontal mid-Silurian strata. Faulting is also seen in the bluff

[1]Foerste, A. Silurian and Devonian Limestones of Western Tennessee. Jour. Geology, vol. 11, 1903, pp. 554-583.

[2]Pate, W. F., and Bassler, R. S. The Late Niagaran Strata of West Tennessee. Proc. U. S. Nat. Mus., vol. 34, 1908, pp. 407-432.

[3]Wade, Bruce. The Geology of Perry County and Vicinity. Res. Tenn., vol. 4, 1914, pp. 150-181.

[4]Drake, N. F. Economic Geology of Waynesboro Quadrangle. *Ibid.*, pp. 99-120.

above Pyburns. Just below the mouth of Bluff Creek the strata dip westward at an angle of about 8 degrees and the top of the Devonian is over 50 feet above water level. The dip decreases and the strata are nearly horizontal half a mile to the west, where the bluff drops away to the valleys of Anderson's and Johnson's branches; and the top of the Devonian is but little above water-level. West of these valleys the previous section is repeated, the dip being to the west again, and the top of the Devonian about 50 feet above the river. A fault with a throw of between 25 and 50 feet, therefore, occurs somewhere in the intervening valley.

While the dips are invariably slight and the folds broad and low in the limestone and shale formations of the valley, the hard brittle Camden and Harriman cherts are extremely fractured and frequently crumpled by small sharp folds with dips at all angles up to vertical. It is characteristic of these chert formations that the bedding planes are seldom horizontal for more than a short distance, even though the underlying shales and limestones bear no appearance of disturbance. This character is well shown at the boat landing at Saltillo, which is situated on a rather sharp syncline. Above the landing the massive Decatur limestone may be seen dipping downstream at an angle of about 25 degrees. Some 200 yards below, it appears again, dipping upstream at an equal angle. Aside from the dip, the limestone shows no obvious results of its deformation. The Harriman chert formation, which succeeds the Decatur, is well exposed by a ravine which enters the river at the landing. The chert is thoroughly fractured and crumpled into a series of small sharp folds with dips frequently reaching 80 degrees or more. Some of the folds are broken and others slightly overturned. Since the older limestones and shales could not have escaped the same compressive stresses to which the chert has been subjected, the contrast in their structure must be attributed to their different physical characters. The heavy limestones were stout and tough enough to carry the stresses into broad open folds, while the shale was soft and weak enough to yield by mashing and to accommodate itself between the harder formations. The thin-bedded chert, on the contrary, being too hard to yield by mashing and too brittle to carry the strain into broad folds, has been thoroughly fractured and crumpled.

Although there is some irregularity, the axes of the folds, so far as observed by the writer, tend to have an alignment a little east of north and west of south.

Most of the deformation can not be accurately dated, since all the strata present, except the Cretaceous, are involved. Local unconformities between the several formations, nevertheless, show that more or less warping of a gentle nature went on during the Devonian, and more especially during the Middle Devonian, since the greatest discordance occurs between the Chattanooga shale and the older formations. At Olive Hill, for example, this shale unconformably overlies a low arch in the Helderbergian limestone, truncating 50 feet of the latter within a distance of half a mile. The faulting, however, and all the stronger folding is of a younger date, involving Mississippian as well as Devonian strata. Thus the deformation observed at Pyburns Bluff affects the Mississippian Ridgetop shale as much as the Lower Devonian limestone; the Chattanooga shale is equally involved in the folding on Bear Branch near Olive Hill; while the sharp syncline at Saltillo preserves an inlier of the black shale (probably Chattanooga) which is absent from both its limbs. At this locality the overlying Cretaceous seems not to be involved, and since, in fact, it was not seen to be involved elsewhere in the deformation, the age of the major disturbance may be placed between the Mississippian and the Cretaceous. As the Pennsylvanian also is faulted in Illinois, it seems probable that the deformation is of Permian time, when the entire Appalachian Mountains were elevated.

ECONOMIC RESOURCES

The Western Valley possesses a wide variety of economic resources, and though none of them offer promises of great and quickly earned wealth, nevertheless they will reward proper development with an enduring and substantial return.

Soils.—Taken as a whole, the Western Valley is not a great agricultural region. A large percentage of its surface, especially of the southern half, is too rough and broken to be suitable for cultivation and is still covered with timber. It is highly desirable that it should be left so, since to deforest the steeper slopes would only cause the rapid removal of the soil which now mantles them. Nevertheless, portions of the region are well suited to cultivation. The belt of alluvium

which borders the Tennessee and its larger tributaries, forming the "bottoms," has been built up by the overflows of the streams and makes a deep and exceedingly fertile soil. This belt of alluvial soil has an average width of about 2 miles along the Tennessee River and decreases from a mile in width to much less along the valleys of the larger tributary creeks. The total area of tillable bottom land in the valley may, therefore, be put at approximately 250 square miles, and practically all of this land may be highly producitve. It is well adapted to the growth of corn. In Perry County this type of soil has been found very suitable for the growth of peanuts, while in the southern portion of the valley in Hardin County much cotton is grown.

The residual rock formed from the weathering of the older rock formations vary, of course, with the nature of the several formations. In general, however, these upland soils, though easily tillable, are only moderately fertile. Some of them could doubtless be much improved by liming, or by the use of various types of fertilizers. A soil survey could determine these problems and would be of great service to the farmers of the region.

Wherever the upper Niagaran or Brownsport group of formations outcrops, it forms "glades" or "barrens," so called because vegetation will scarcely grow upon them. These formations form many barren hillside exposures in central and southern Decatur County, where they are covered only with scattered scrubby cedar trees.

Forests.—One of the most valuable resources of this region is its timber. Except where it has been put under cultivation, almost the entire surface is covered by a luxuriant growth of trees, including a large variety of hardwoods such as oak, hickory, poplar, elm, birch, and cherry. Yellow pine is in abundance in Hardin County and parts of Wayne and Perry counties, but is not common in the valley further north. Since the Tennessee has always provided easy shipping facilities for lumber, the heaviest of the virgin timber in the valley has already been cut, but its place is being taken by the second-growth timber. There are still many small sawmills in the region which provide lumber for local consumption. At the present time, cross-ties form the most important forest product for export, and in the southern half of the valley, especially, the cutting of cross-ties forms a part-time occupation for a large percentage of the inhabitants. This furnishes a market for much timber which is too small

or knotty for saw logs, but unless a careful policy of conservation is adopted, is likely to prove highly detrimental to the forests of the region, since it offers a temptation to cut the young trees that should be left to grow into logs. Only the culls of the timber should be cut into cross-ties, yet it is the straight young growing trees that yield the best ties for the least labor and too many of the latter are being cut by short-sighted timber men.

Road Material.—The Western Valley is fortunate in having a variety and unlimited abundance of easily available road material. Doctor Ashley has already pointed out the excellent qualities of the Camden "chert" as a road metal.[1] This fine-grained siliceous rock, technically known as a novaculite, possesses two highly important qualities for a good road material, namely, it is hard so that it does not readily crumble or wear to dust, and it packs together or "bonds" well so as to maintain a firm surface under traffic. The underlying Harriman novaculite has exactly the same characters as the Camden, and these two formations are widely exposed in the northern half of the valley, as may be seen from the geologic map (p. 9). Not only are they thus easily available, but the rock is so thoroughly fractured where it outcrops that quarrying is a very simple process and but little crushing is required. A "pike" made of this material connects Decaturville and Parsons. Chert quarries are located on the Nashville, Chattanooga & St. Louis Railway at Camden, Parsons, and Perryville.

In the southern portion of the valley, where these novaculites are absent, the overlying Mississippian cherts frequently outcrop, and excellent roads may also be made of this material. In addition to these solid rock formations, deposits of water-worn gravels are widely scattered over the region. These occur either as modern stream deposits, as the more ancient and elevated terrace gravels, or as deposits in the Cretaceous (Tuscaloosa) formation. These gravels, because they are rounded, are not so easily compacted as the novaculite, nevertheless they make enduring roads.

In spite of the unusual opportunities here offered for good road building, there are but very few macadamized roads in the entire 1,200 square miles embraced in this province. As exceptions to this

[1]Ashley, G. H. The Camden Chert—an Ideal Road Material. Res. Tenn., vol. I, 1911, pp. 34-43.

statement, it should be mentioned that a very excellent pike connects Clifton and Waynesboro, and that only recently work has been started on the Memphis to Bristol Highway, which crosses the valley through Waverly and Camden. In general, however, the roads in the Western Valley are very bad, even in summer, and in winter many of them are well-nigh impassable. That such need not be the case was recently demonstrated in a most commendable way by the inhabitants about Olive Hill. Previous to 1917 the 10 miles of road which separated that village from the Waynesboro pike had always been notoriously bad. By neighborhood co-operation, each man donating a team and wagon for three or four days' work, this extremely bad road was transformed into a first-rate one—all within a couple of weeks' time and without the expenditure of any capital. The procedure was first to grade the road with a grader, on which four teams were used, and then to cover the road bed by a thick coating of river gravel which was ready at hand in the fords of Hardin and Indian creeks. This should be an example to other communities. Certainly no other part of the State has the facilities for building good roads so cheaply as the Western Valley.

Cement.—Cement is made by fusing mixtures of the oxides of calcium, aluminum, and silicon, and then finely grinding the clinker thus formed. These materials may be mixed in the proper proportions to make artificial or Portland cement, or, on the other hand, certain limestones containing a high percentage of clay or shale may supply all these ingredients in the right proportions so that they may be quarried and fused without any additions. Cements made of such limestones are termed natural cements. Such a limestone is the Hermitage formation exposed in the river bank at Clifton, which was used for making cement in the days before the Civil War, and is said to have produced a good grade. Its quality could be proved by a little investigation, and if this is found to be satisfactory, Clifton might be a very favorable site for a cement plant, since it is so conveniently located for the river transportation. This is the most promising formation for cement manufacturing exposed in the valley.

Limestone.—Limestone may serve two important uses in this region —as a building-stone, and, upon being ground or burnt, as correcting the acidity of soils deficient in lime. The demands for building-stone are not extensive, and an abundant supply of good quality is

to be had in many localities. The Lego and Laurel limestones are suitable for quarrying, because they are fairly pure and even, but not too heavily bedded for handling. The Bob and Decatur limestones, though rather massive to work easily, are compact and solid and would doubtless make a good quality of stone. Further south, in Hardin County, the Ross limestone would also be suitable for building-stone.

Limestones of fairly pure quality to use on the soils are within easy reach of most communities in the valley. At the extreme southern end of the region the pure white Flat Gap limestone outcrops at Dry Creek schoolhouse near Walnut Grove, while further north in Hardin County it is exposed in the bluff facing Olive Hill. The Decatur limestone could be used at various localities where it is exposed along Horse and Indian creeks in Hardin County, and at many places in Decatur and Perry counties. It comes to the surface as an extremely pure white coral-reef limestone on Wolf Creek near the ford east of Holladay in southern Benton County, and is exposed again at the Allen's Mill locality on Birdsong Creek.

Phosphate.—Deposits of phosphate rock occur in several localities in Perry and Decatur counties, but none of them are now being exploited. Two types of deposits may be distinguished, which differ not only in appearance but in origin and geologic associations. These are (1) black phosphate and (2) white rock phosphate. The black phosphate occurs in nodular or bedded deposits at the base of the Chattanooga shale. It is a primary deposit which accumulated at the same time as the enclosing sediments. This type is rather widespread, but so thin that it does not appear to be of economic importance.

The white rock phosphate is a secondary deposit formed by percolating waters. It is generally associated with the top of the Decatur limestone, though in the White's Creek locality in southern Decatur County it is found in the older Beech River limestone, and in the Terrapin Creek locality in northern Perry County it occurs in the younger Mississippian cherty limestones. It occurs, according to Hayes, either as a replacement of or a filling of caverns in the limestone, or as the matrix of a residual breccia of chert or novaculite directly overlying the limestone.

The white rock phosphates have been prospected along Beech River and White Creek in Decatur County, and along Toms, Red Bank, and Terrapin creeks in northern Perry County. These deposits have been the subject of special investigation by Hayes,[1] Maynard,[2] and Hook,[3] to whose works the reader is referred. As regards the origin of these deposits, there is general agreement that the phosphate was leached from other and higher formations during an erosion interval, and carried to its present position by the percolating waters. The exact time of this concentration has not been determined, but there seems to be no doubt that it was later at least than the deposition of the Birdsong shale of Lower Devonian age. This fact may have some significance in prospecting for the phosphate. The Decatur limestone would normally be succeeded by the Birdsong shale, and above this would be the Harriman novaculite, which in turn is succeeded by the Camden novaculite. These several formations were separated by erosional intervals, so that in portions of the region under discussion the Birdsong shale is absent by erosion and the novaculites, one or the other, rest directly on the Decatur. The novaculites are much fractured and offer ready passage to ground-water, but the Birdsong formation, of which 25 or 30 feet is shale, is rather impervious. If the phosphate, therefore, was laid down after the deposition of the Birdsong shale, the phosphate-bearing solutions would readily have reached the pure Decatur limestone, which seems to have favored the deposition of the phosphate in only those localities where the Birdsong shale is absent. So far as the writer's observations go or as far as he can learn from published reports, no deposits of phosphate occur beneath the shaly Birdsong.

A new locality for phosphate was observed by the writer on Wolf Creek near Holladay, where the Harriman novaculite locally rests on the Decatur. It appeared to be only a small deposit, though of rather high-grade lamellar or travertine-like phosphate. Several years ago a carload of white phosphate was mined at Eva, Benton County.

Iron Ore.—Iron ore of the red hematite variety occurs near Clifton and further southwest in Hardin County. It is found in the Bear

[1]Hayes, C. W. The Tennessee Phosphates, U. S. Geol. Survey, 16th Ann. Rept., pt. IV, 1895, pp. 610-630; 17th Ann. Rept., pt. II, 1896, pp. 536-550; 21st Ann. Rept., pt. III, 1901, pp. 473-485.

[2]Maynard, T. P. White Rock Phosphate of Decatur County, Tennessee. Res. Tenn., vol. 3, 1914, pp. 161-169.

[3]Hook, J. S. The White Phosphates of Tennessee, *Ibid.*, vol. 5, 1915, pp. 21-33.

Branch member of the Linden (Lower Devonian) group of which several small and isolated remnants occur between Clifton and Olive Hill. The ore is the oolitic hematite of the Clinton ores type and is discussed further in Chapter 2 where the Bear Branch formation is described (pp. 44, 45). This ore was mined before the Civil War at a locality about 1½ miles southeast of Clifton, but none of the deposits are large or rich enough to meet the present competition of the greater iron-producing regions. In the future, especially with a railroad crossing Hardin County, some of these deposits may become of economic value.

Oil and Gas Possibilities.—The structure along the Western Valley of the Tennessee appears favorable for the accumulation of oil, but unfortunately the majority of the formations present are not suitable to serve as oil reservoirs. The prospects for obtaining oil in paying quantities in this region are therefore not very promising. All the formations that underlie the region as deep down as the Middle Ordovician are brought to the surface at one place or another along the valley, so that their character is known. An examination of the table of formations (p. 12) will reveal the fact that sandstones are conspicuously absent. The limestones present are generally fine-grained, but a few are coarse-grained, and might form favorable oil reservoirs. The series is dominantly shales, shaly limestones, and limestones up at least to the Devonian cherts. None of the formations below the Chattanooga shale are of a carbonaceous nature. This shale, it is true, is petroliferous, being one of the great mother rocks of oil. Either the underlying Devonian or the succeeding Mississippian cherts where locally perhaps porous or in a fractured condition might possibly serve as a small reservoir for oil. Within the Western Valley, however, these are among the highest formations, and they are not under sufficient cover to have prevented the escape of oil if it were ever present. To the east under the Highland Rim, these formations are under sufficient cover. If oil-bearing formations should occur deeper down below the formations exposed,* the low anticlines, which are common and some of which are transected and clearly shown by the Tennessee River, would be favorable places to prospect. The structual

*The oil from the Pob's Bar well, in Pickett County, came from a limestone of Ordivician age about 270 feet below the Chattanooga ("black") shale. Formations of this age occur below the Western Valley of the Tennessee River.—Wilbur A. Nelson.

section on page 25 shows conditions as they exist along the Tennessee River.

Water Power.—The larger of the creeks tributary to the Tennessee could be utilized for water power to operate grist mills at many points. These streams, though small, maintain a steady flow even in the driest weather, for their headwaters, cutting deeply into the steep front of the bordering highlands, are fed by many springs. As a result, a reservoir is not required and it is only necessary to construct a low dam which will give the streams a fall of a few feet. Such mills are in operation at several points along the larger streams and some of them date back to the early days when the country was first settled. Others could be built in several places, but in recent years, since the advent of the gasoline engine, some of those already in operation have been abandoned. In the future, however, as fuel oils become more expensive, the latent water power of these small streams is certain to become more valuable.

In the smaller, more rapidly descending branches along the borders of the valley, many excellent opportunities are offered to farmers with a little ingenuity to utilize the water power to operate small farm machinery, such as the churn, the washing machine, the pump, or the corn sheller.

OUTLINE OF DEVONIAN GEOLOGIC HISTORY

A brief review of the Devonian geologic history of western Tennessee may make the discussion of its stratigraphy more easily understood. At the beginning of Devonian time, the region was a low, flat country but little above sea-level. There was no Tennessee River and, therefore, no Western Valley. Even the Appalachian Mountains were yet to be formed where the lowlands continued far away to the east. Before long, however, during Keyser (early Devonian) time came the first spreading of the Devonian sea, which was repeated in late Coeymans time, when gentle warping of the land spread the waters northward from the Gulf, covering this region with a broad shallow sea, in character somewhat like Hudson Bay or the Baltic Sea of to-day. The rivers from the low surrounding lands poured forth into this inland sea their sediments of limy mud, which the waves and tides spread out in broad flat layers over the sea floor, to become, later on, the strata of limestone and shale. At its maximum spread this sea reached northward beyond Cairo, Illinois, and while a western

arm extended to the Arbuckle Mountains of Oklahoma, its eastern margin overlapped on the flank of a broad low arch, the Nashville dome, which then occupied central Tennessee. The extent of this Gulf embayment in New Scotland time is shown on Figure 2. The more or less gentle warping which accompanied the successive advances and retreats of this pulsating Helderbergian sea changed and shifted its boundaries, the earliest advance being recorded only in the southern portion of the valley, while subsequent deposits cover the northern half. With each retreat of the sea, moreover, a portion of the sedi-

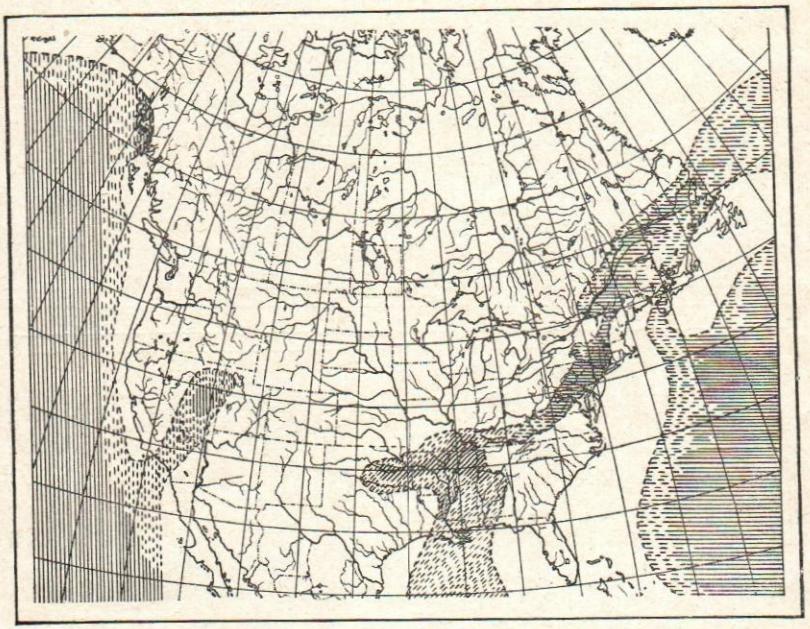

FIGURE 2.—Paleogeographic map of New Scotland time. The known extent of the seas is shown by solid lines, and the conjectural expanse by broken lines. After Schuchert.

ment previously laid down was subjected to erosive forces. In consequence the various members of the Linden or Helderbergian group are irregular in their distribution, and their thicknesses vary in successive exposures.

Early in Becraft time the waters withdrew completely from the region of western Tennessee and dry land conditions obtained until upper Oriskany time. The Oriskany invasion, however (see Fig. 3A), came from the great Appalachian trough which then occupied the

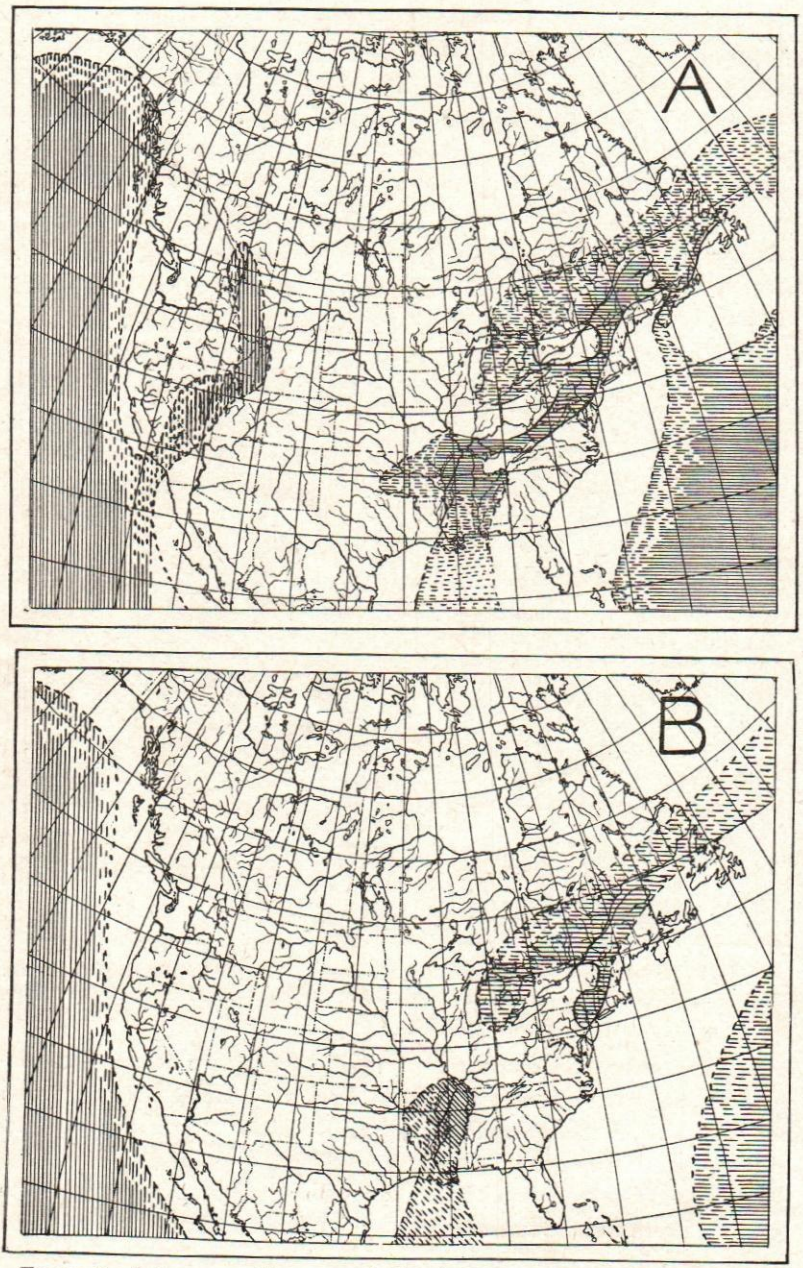

FIGURE 3.—Paleogeographic maps of (A) Oriskany and (B) Onondaga time.

present site of the Appalachian Mountains, the waters arriving from the northeast across middle Kentucky. For a short period, dry land conditions followed this inundation, but at the beginning of Middle Devonian time the waters once more spread northward from the Gulf. This, the Camden sea (Fig. 3B), occupied almost the same region that the earlier Helderbergian embayment had covered. Just before its withdrawal, the Onondagan coral fauna, which is so finely developed at the falls of the Ohio, had reached Tennessee, and for a brief period was spread as far east as Nashville. the dry land conditions which ensued and prevailed throughout the remainder of the Middle Devonian were possibly interrupted only very briefly in Hamilton time, for a few inches of Hamilton shale has been identified near Pegram station. During this long interval the strata were more or less elevated, gently warped, and partially eroded away. Finally in Upper Devonian time, the black-mud Chattanoogan sea spread very widely over Tennessee, depositing carbonaceous shale. While this ended Devonian deposition, the sea again covered the region during much of Mississippian time, when other black shales and finally great thicknesses of chert were deposited. Following this marine invasion, land conditions

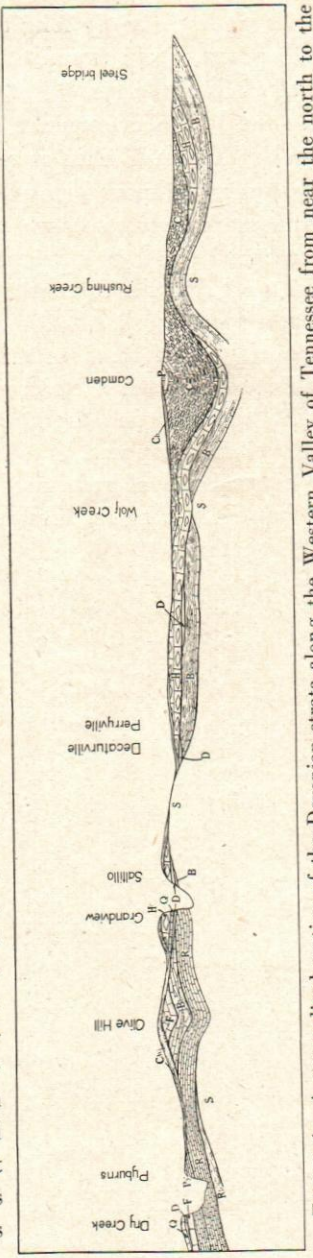

FIGURE 4.—A generalized section of the Devonian strata along the Western Valley of Tennessee from near the north to the south edge of the State. B, Birdsong shale; Eb, Bear Branch limestone; C, Camden chert; Ch, Chattanooga shale; D, Decaturville chert; F, Flat Gap limestone; H, Harriman novaculite; P, Pegram limestone; Py, Pyburn limestone; Q, Quall; R, Ross limestone; Rh, Rockhouse shale; S, Middle Silurian or Niagaran formations.

ensued for an exceedingly long time, until finally in Cretaceous time the Gulf waters again inundated the region and covered it with a mantle of sands and clays.

Since the Devonian sequence in the Western Valley is broken by so many land intervals when erosive forces were active, the formations vary greatly in thickness from place to place, and some of them have been reduced to isolated remnants. The local thicknesses of the Devonian are not great. A maximum exposed at any single locality is about 150 feet, but the composite section amounts to nearly 500 feet. (See Fig. 4.)

In general, the formations thicken westward, but are soon lost to observation beneath the Cretaceous cover—they may be seen, at most, but a few miles beyond the river—while toward the east they thin out rapidly and disappear.

For convenience of reference the following synoptic table is inserted, showing the names, sequence, and general characters of the various formations:

GENERALIZED DEVONIAN SECTION OF WESTERN TENNESSEE

Series	Group	Formation	Thickness Feet	Character
Neodevonian	Chautauquan	Chattanooga shale Hardin sandstone member	20±	Black fissile carbonaceous shale Thin basal sandstone
	Senecan	*Break*		
Mesodevonian	Erian			
	Ulsterian	Pegram limestone	10±	Heavy-bedded white limestone
		Break		
		Camden chert	0-200±	Thin-bedded buff colored novaculite
		Break		
Paleodevonian	Oriskanian	Harriman chert	30-55	Heavier bedded white and buff novaculite
		Break		
		Quall limestone	10±	Heavy-bedded cherty gray limestone
		Break		
	Helderbergian or Linden	Decaturville chert	6±	Porous gray chert
		Break		
		Birdsong shale	35-65	Bluish shaly limestone and shale
		Break		
		Olive Hill form.: Flat Gap	0-53	Massive pure limestone
		Olive Hill form.: Bear Branch—Pyburn	0-45	Massive limestone and oolitic hematite in north—impure cherty limestone in south
		Olive Hill form.: Ross	0-60±	Impure thin-bedded cherty limestone
		Break		
		Rockhouse shale	0-26	Bluish green calcareous shale

PREVIOUS DEVONIAN STUDIES IN TENNESSEE

The first geologist to discuss the stratigraphy of western Tennessee was Troost, the pioneer state geologist of Tennessee (1831-1850). He classified the rocks, however, only in the broadest way, including all the strata of the Tennessee valley below the base of the "black" shale in one unit, and there is no evidence that he actually discriminated here the Devonian rocks.

The first real contribution to the stratigraphy of this region was written by Safford in 1851.[1] It included a geologic map and a table of formations which is incorporated in the correlation chart at the end of this chapter. Safford embraced all the strata of the Western Valley beneath the "black" shale in a single unit, the Harpeth or Tennessee River group, though he stated that it no doubt included both Upper Silurian and Devonian strata. It is worthy of note that he had already grasped the significant relations of this group, which he says is confined to the western side of the Nashville dome, and which he describes as a "great wedge" thickening to the west and thinning out around the margin of the Central Basin.

Safford's first biennial report as state geologist, which appeared in 1856, was accompanied by a new geologic map and a more detailed table of formations. For the first time the presence of the Helderbergian rocks in Tennessee was made known, and it is interesting to note that Safford here correctly referred them to the Devonian, a reference not followed in America for many years later. The "black" shale was now placed in the Sub-Carboniferous.

Eight years before this (1848) the French stratigrapher, de Verneuil, had visited America expressly to see if the faunal sequence which had been established for Europe also held here. Previous to his visit the Portage had been considered by the New York geologists as the base of the Devonian. In de Verneuil's report, published in 1846-1847 and reviewed by James Hall in 1848-1849,[2] it was shown by comparison of American and European faunas that the Hamilton and Onondaga were clearly Devonian and with some hesitation he

[1]Safford, J. M. The Silurian basin of Middle Tennessee, with notices of the strata surrounding it. Amer. Jour. Sci., vol. 12, pp. 352-361.

[2]Verneuil, E. de. Sur le parallelisme des roches, des dépots paléozoiques de l'Amérique septentrionale avec ceux de l'Europe, etc. Bull. Soc. Géol. France, vol. 4. 1846-1847, pp. 646-709. Review in Amer. Jour. Sci., vol. 5, 1848, pp. 176-183, 359-370; vol. 7, 1849, pp. 45-51, 218-231.

also included the Oriskany. This reference of the Oriskany to the Devonian was based on the fact that the seas had widely changed between this time and the Helderbergian, and because the Oriskany Spirifers resembled those of the Lower Devonian of the Eifel. The Helderbergian, however, he placed without question in the Silurian. This classification was at once adopted by the New York State Geological Survey, and after its appearance in Hall's *Paleontology of the Lower Helderberg and Oriskany*,[1] it was generally accepted in America for over a quarter of a century, and in all of Safford's later writings the Helderbergian rocks were included with the Niagaran in the Silurian.

In a review of Roemer's *Die Silurische Fauna des westlichen Tennessee*, Safford in 1861[2] took occasion to point out the fact that the Helderbergian was also present on some of the glades of the Western Valley. He noted the variable thicknss of the Helderbergian formation and ascribed it chiefly to subsequent erosion but in part to the Helderbergian sea having advanced over an uneven surface. In this paper he gave a list of Helderbergian fossils and a new table of formations for the Western Valley.

Safford's masterpiece, *The Geology of Tennessee*, which appeared in 1869, devoted seven pages of fine print to the Helderbergian, giving a list of exposures and several geologic sections, also a list of forty-two species of which nine were figured. The heavy chert formations about Camden and Perryville, which have subsequently been recognized as Devonian, were not yet distinguished from the more widespread Mississippian cherts and on the geologic map are marked as Carboniferous. The black shale, now the Chattanooga and the Ridgetop, was again referred to the Devonian.

During the next year a controversy arose concerning the validity of the Helderbergian group of formations. At the Troy meeting of the American Association for the Advancement of Science in 1870, Worthen, the state geologist of Illinois, read a paper the essence of which was that the Lower Helderbergian series was the time equivalent of the Niagaran; that a single formation in Illinois carried Niagaran fossils in northern and western Illinois, while in southern Illinois its fossils were Helderbergian; and that in Wayne, Perry, and Decatur counties in Tennessee beds occupying the same position carried

[1]Hall, James. Nat. Hist. N. Y., Pal., vol 3, 1859, pp. 32-39.

[2]Safford, J. M. The Upper Silurian beds of western Tennessee; and Dr. F. Roemer's monograph. Amer. Jour. Sci., vol. 31, pp. 205-209.

a promiscuous mingling of both Helderbergian and Niagaran fossils. He concluded that the Lower Helderbergian, having no real existence as a distinct formation, was superfluous and should be dropped from the nomenclature.

This provoked a characteristically vigorous defense from the upholder of the Lower Helderbergian group. At the Portland meeting of the same society in 1873, Hall traced the exposures of both Niagaran and Lower Helderbergian, and presented a map showing their known distribution in America. He correctly showed how the Niagaran thins eastward in New York but thickens westward and extends into Illinois and Iowa as a dolomite, and how it can be traced southward around the western side of the Cincinnati dome into Kentucky and Tennessee, always with Niagaran fossils. Then he showed how the Helderbergian thins westward, but can be traced from Gaspe to Tennessee down the Appalachian trough, always with characteristic fossils. He stated emphatically, as a result of his own observations, that the two faunas are not mingled in southern Illinois and Missouri, and on Professor Safford's word, that they are not mixed in Tennessee, except where found in talus heaps.

In 1876, Safford and Killebrew published *An Elementary Geology of Tennessee,* in which, for the first time, the name Linden was applied to the strata of Helderbergian age in Tennessee.

The Devonian age of the Camden chert was first made known by Safford and Schuchert in 1899.[1] Safford recounts that in his travels on horseback he had many times observed chert fragments above the Helderbergian but, without close examination, always supposed them to be a part of the Mississippian chert. One day in 1884 he saw fossils in the chert near Camden. Dismounting to examine them, he discovered that the chert was Devonian. In 1897 he showed the fossils to Schuchert, then of the United States National Museum. The latter recognized their close relation to a fauna described by Worthen from the Clear Creek chert of Illinois. He went to Tennessee to secure a larger collection of fossils, and in the following year wrote the joint paper with Safford. The fauna was a new one, not represented in the standard geologic sections, but an analysis of it seemed to show the closest relations to the Oriskany. The absence of all the big brachio-

[1]Safford, J. M., and Schuchert, C. The Camden chert of Tennessee and its lower Oriskany fauna. Amer. Jour. Sci., vol. 7, pp. 429-432.

pods which characterize the upper Oriskany led the writers to the conclusion that the Camden chert represented lower Oriskany time.

The last edition of the *Elements of the Geology of Tennessee* by Safford and Killebrew, in 1900, added little to our knowledge of the Devonian. The Helderbergian was still placed in the Silurian, and the Chattanooga shale was included with the Camden chert in the Devonian.

About this time, however, the Devonian age of the Helderbergian began to receive general acceptance in America. Eleven years earlier Clarke[1] had analyzed the Helderbergian fauna and set forth in the clearest manner its Devonian relations. He pointed out the fact that European geologists already generally made this reference of the Helderbergian. Nevertheless, the change was not adopted by the New York Gological Survey until 1899.[2] However, in the following year the matter was finally clinched by Schuchert's elaborate comparison of all the known Lower Devonian faunas in a paper entitled *The Lower Devonic Aspect of the Lower Helderberg and Oriskany Formations.*[3]

In 1901, Foerste[4] defined the Pegram limestone and described its occurrence in central Tennessee. The most important contribution of this time to the Devonian studies in this region, however, is Foerste's *Silurian and Devonian Limestones of Western Tennessee,*[5] in which he describes several of the best Devonian sections along the western valley and proposes a subdivision of the Linden into two formations. His conclusions regarding the Linden are quoted in the discussion of these formations.

Savage's paper on *The Lower Paleozoic Stratigraphy of Southwestern Illinois*, published in 1908,[6] directly affected the correlation of the Camden chert of Tennessee. Near Grand Tower, Illinois, Savage found the top layers of the Clear Creek chert to interfinger with the basal layers of the succeeding Onondagan. He, therefore, concluded that the former was not broken from the Onondagan, but must be highest Oriskany instead of lower Oriskany, as it had been previously

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[1]Clarke, J. M. The Hercynian question. 42d Rept., N. Y. State Mus., 1889, pp. 408-437.

[2]Clarke, J. M., and Schuchert, C. The nomenclature of the New York series of geological formations. Science, n. s., vol. 10, pp. 874-878.

[3]Schuchert, C., Bull. Geol. Soc. America, vol. 11, 1900, pp. 241-332.

[4]Foerste, A. F. Silurian and Devonian limestones of Tennessee and Kentucky. Ibid., vol. 12, pp. 395-444.

[5]Foerste, A. J. Jour. Geol., vol. 11, 1903, pp. 554-583, 697-715.

[6]Savage, T. E., Bull. 8, Illinois Geol. Survey, pp. 103-116.

classified. The correlation of the Clear Creek and Camden cherts was clearly established, and therefore Schuchert, in 1910,[1] placed the Camden chert at the top of the Oriskany.

In 1914, Wade[2] published an important account of the geology of Perry County and vicinity, which described the nature of the Devonian formations in these their most eastern outcrops. His geologic map is the first detailed map of any portion of the valley.

The various classifications of the Devonian formation of Tennessee are arranged in the following table:

[1]Schuchert, C. Paleogeography of North America. Bull. Geol. Soc. America, vol. 20, pp. 427-606.

[2]Wade, B. The geology of Perry County and vicinity. Resources of Tenn., vol. 4, No. 4, pp. 150-181.

CORRELATION TABLE

Safford 1851	Safford 1869	Safford & Killebrew 1900	Foerste 1903	Pate & Bassler 1908	Ulrich 1911	Dunbar 1918				
							Mississippian			
Black shale	Chattanooga sh.	Chattanooga sh. Hardin ss.	Chattanooga sh. Hardin ss.	Chattanooga sh. Hardin ss.	Maury sh. Chattanooga sh. Hardin ss.	Chattanooga sh. Hardin ss.		Upper	Middle	Devonian
			Pegram ls.		Pegram ls.	*Great break* Pegram ls. *Break*	Scholarie-Onondaga	Ulsterian		
		Camden chert	Camden chert	Camden chert	Camden chert	Camden ch.				
						Break Harriman ch. *Break* Quall ls.	Upper	Oriskanian	Lower	
Harpeth ls.						*Break* *Break* Decaturville ch.	Lower			
						Break	Beecraft	N. Scotland	Helderbergian	
	Lower Helderbergian	Linden	Linden: Pyburn, Ross	Linden	Linden	Birdsong sh. *Break* Olive Hill: Flat Gap ls., Bear Branch Pyburn li, Ross ls.	Coeymans Keyser			
						Rockhouse sh. *Great break*	Niagaran	Niagara	Mid-Silurian	Silurian
	Meniscus	Clifton	Brownsport	Decatur	Decatur	Decatur ls.				

CHAPTER II

STRATIGRAPHY AND CORRELATION

INTRODUCTION

In the following pages the several Devonian formations will be described in sequence, beginning with the lowest. It will be necessary, however, to briefly describe first the highest of the Silurian formations in order to establish the base of the Devonian and determine the nature of the Siluro-Devonian contact in Tennessee. Throughout the discussion frequent reference will be made to the detailed geologic sections in Chapter III, which embody the evidence for many of the statements regarding the stratigraphic relations.

The generalized geologic map here presented (see Fig. 1) is modified from the state map published in 1913, since it was not the purpose of the present study to map the formations. Such work must await the completion of adequate base maps. Nevertheless, future changes in the present map will, it is thought, be only a matter of minor details.

The stratigraphic relations of the several formations are shown in the generalized north-south section along the valley shown in Figure 4. The section is necessarily more or less diagrammatic, and the vertical scale much exaggerated, so that the dips are all too steep, but at the same time care was taken to keep the vertical and horizontal scales as uniform as possible.

LATEST SILURIAN FORMATIONS

The retreat of the widespread Middle Silurian seas from western Tennessee left it a low and almost featureless landscape. During the long interval of dry land which ensued, the region was disturbed only by the gentlest warping, and when finally the seas again returned in early Devonian time they spread out over an extremely flat limestone country, depositing newer limestones on the older. There appears accordingly but little physical evidence of the long land interval and the break in the sequence which occurred in later Silurian time, for the Silurian and Devonian strata appear conformable to one another in almost every exposure, and when, as is frequently the case (Fig. 5) the contact is between massive limestones, it may be located only with difficulty. The exposure at Perryville, in fact, may well be

ranked with that in the famous Bear Grass quarries of Louisville, Kentucky, as an example of a great invisible break or disconformity.

The difficulty in locating the base of the Devonian is further increased by the fact that the massive Decatur limestone, which is generally the latest Silurian formation present in the Western Valley, is almost unfossiliferous.

FIGURE 5.—Disconformable contact of the Silurian and Devonian in a quarry on the Tennessee River one-half mile north of Perryville. The Birdsong formation, one of the higher members of the Linden (Lower Devonian), is resting on the Middle Silurian Decatur limestone. The contact is along the dashed line. The beds are perfectly conformable in the quarry face and along the bluff where the contact is well exposed for about one-half mile down stream.

DECATUR LIMESTONE

(See Sections 7, 12-15, 18, 19, 21-28.)

This is a massive, light gray, generally unfossiliferous limestone ranging in thickness from 50 to 70 feet. It is made up of heavy layers, some of which are rather coarsely crystalline, while others are more fine grained and dense. Some appear to be more or less magnesian. The formation is typically developed and well exposed in central Decatur County. While it becomes reddish in color or variegated with red bands in the northern part of this county (section 13), yet its normal gray color is maintained southward into Hardin County. At Olive Hill it is well exposed above the Lobelville coral zone, and at the

"big rock swimming hole," one-half mile north of Lowryville, it forms a precipitous bluff very similar to that of its type section at Decaturville.

The unconformable relations of the Decatur to the older Silurian strata are more evident than its discordance with the Devonian, notwithstanding the fact that the break is considerably greater above than below the Decatur. In successive sections of central Decatur County the limestone overlies different members of the Brownsport group. At Lady's Bluff it succeeds the bryozoan zone of the Lobelville, while only four miles up the Tennessee River, near Perryville, it rests with erosional unconformity upon the much older Beech River horizon, where both Lobelville and Bob formations are absent, due to interformational erosion. At Decaturville, about seven miles further southwest, a distinct angular unconformity separates the Decatur and Beech River formations, while at Brownsport Furnace, only six miles south of Perryville, both Lobelville and Bob are present and measure 60 feet in thickness. On the contrary, the disconformable contact of the Linden and the Decatur, typically illustrated in Figure 5, is duplicated in successive sections wherever their contact is exposed in Decatur County.

Of its fossils, the most conspicuous one in the Decatur limestone is a bulbous chambered crinoid root known as *Camarocrinus*—a type of fossil which is, however, more characteristic of the succeeding Devonian limestones. The dominance of this fossil and the scarcity of others, combined with the stratigraphic relations noted above, inclined the writer, in his preliminary studies of the formation, to the belief that this limestone belonged with the Devonian. After further field studies, however, and the accumulation of more faunal evidence, the Silurian age is clearly established.

In defining the Brownsport formation, Foerste[1] included as its upper member this massive limestone, from which he cited two very diagnostic Silurian sponges, *Astraeospongia meniscus* and *Caryomanon stellatum-sulcatum*. Later on, however, Pate and Bassler[2] removed this limestone form the Brownsport and defined it as the Decatur formation. These authors also considered it of mid-Silurian age, and added to its known fauna *Uncinulus stricklandi, Wilsonia saffordi, Pachydictya crassa* and *Penniretepora* sp. Springer in the meantime

[1]Op. cit., 1903, pp. 569-583.

[2]Pate, W. F., and Bassler, R. S. The late Niagaran of western Tennessee. Proc. U. S. Nat. Mus., vol. 34, 1908, pp. 425-426.

had secured many crinoids from the upper part of the formation at Perryville, and among them were such diagnostic Silurian genera as *Lecanocrinus, Pisocrinus, Eucalyptocrinus, Marsipocrinus, Clonocrinus, Desmidocrinus* and *Gazacrinus*. He kindly informed the writer of this in a letter and added: "Although *Lecanocrinus* and *Eucalyptocrinus*, while typical Silurian, with one species each pass upward into the Devonian, the other genera are strictly Silurian and the whole facies decidedly so."

Elsewhere in America *Camarocrinus* is usually confined to Helderbergian rocks, and therefore has frequently been considered as a "guide fossil" for the Devonian. The only exception is the rare occurrence in the Manlius at Schoharie, New York. Nevertheless, it was known long ago from the Silurian in Bohemia, and its association with the above mentioned array of diagnostic Silurian fossils shows that in America the genus began in the Silurian. Unfortunately these crinoid roots are generalized structures, and Springer is not able to point out characteristics of value for specific differentiation between those of the Silurian and the Devonian.[1]

So far as the writer is aware, *Camarocrinus* does not appear in earlier members of the Silurian, though it has been found in almost every exposure of the Decatur. This fact, together with the stratigraphic relations noted above, supports the removal of this limestone by Pate and Bassler from the Brownsport.

LOWER DEVONIAN SERIES

Linden or Helderbergian Group

The name Linden was applied to the Helderbergian rocks of western Tennessee by Safford and Killebrew in 1876.[2] The term was an unfortunate choice, since only a small portion of one member of the group is present at Linden, and even that is poorly exposed. These authors, however, applied it to the thicker sections of strata exposed further west, which they treated as a single formation. This usage prevailed until Foerste divided the Linden into two members, the Ross and the Pyburn limestone. That writer's conclusions regarding the stratigraphy of these beds is summed up in the following paragraph:[3]

[1]Springer, F. On the crinoid genus *Scyphocrinus* and its bulbous root *Camarocrinus*. Smithson. Inst., Pub. 2440, 1917, pp. 26-27.
[2]Safford and Killebrew. Elementary geology of Tennessee, pp. 146-148.
[3]Op. cit., 1903, p. 685.

"As far as may be judged from the few sections so far studied, *Camarocrinus* is abundant in the lower half of the Linden bed, and is either much rarer or altogether absent in the upper half. The upper half, on the contrary, appears to contain a greater quantity of softer, clayey material, which weathers readily. It appears to give rise to the greater number of exposures at which the Linden bed fossils may be collected free from the rock. It appears possible to divide the Linden bed into two subdivisions, a lower, Camarocrinus or *Ross Limestone*, and an upper, or *Pyburn limestone*. The exposures at Perryville, Linden, and Cumberland City appear to belong to the upper or Pyburn horizon. The upper bed appears to have a greater eastward extension than the lower, overlapping the latter. Very little attention has been given so far to the stratigraphy of the Devonian in western Tennesese."

In the following pages are described thick and very important sections of the Linden, not previously studied, which with other facts show that the Linden is a much more complex group of strata than even Foerste believed. Four distinct formations are here recognized, each separated by unconformities or disconformities representing longer or shorter periods of erosion.

ROCKHOUSE SHALE

(See Sections 26-28.)

Definition.—Heretofore the Ross limestone has been regarded as the lowest member of the Linden and its base as the beginning of the Devonian sequence in Tennessee. Near the southern edge of the State, however, a still lower, undescribed formation of fossiliferous shales comes in like a wedge between the Ross limestone and the massive Decatur limestone. It thickens to the south, where it goes permanently below drainage, but thins out northward and disappears without reaching the center of Hardin County. A maximum thickness may be seen at Rockhouse, a hunter's clubhouse on Horse Creek, five miles northwest of Lowryville, and because of this good exposure the formation will be called the Rockhouse shale. It is a glade-forming, calcareous shale of greenish gray color, interbedded with occasional thin bands of light gray, crystalline limestone. Toward the base of the shale, the bands of the limestone become thicker and closer set, so that the formation appears to grade into the underlying Decatur. Of the many finely preserved fossils which weather out of

the shale, *Camarocrinus* is most conspicuous, and some of the bands of limestone are practically made up of these crinoid bulbs.

Distribution.—South of Rockhouse the formation is below drainage, and its thickness is unknown, but to the north its depth rapidly decreases. On the Ross farm, five miles southeast of Savannah, it forms a small glade near the sulphur spring, and here it is perhaps 10 or 15 feet thick, though no accurate measurement can be made. Another small exposure occurs about one mile north of here at the bend in Horse Creek just below the chalybeate spring. In the good sections further north, on the contrary, at Olive Hill, Cerro Gordo, Grandview, etc., the formation is entirely absent.

While there are probably other small outcrops in the vicinity of Rockhouse, the three just described constitute the known exposures of the formation, and to this circumstance may be ascribed the fact that it has not been previously studied. The contacts of the shale were observed only at Rockhouse and near the chalybeate spring. The latter section reveals the base of the shale resting disconformably on the Decatur limestone. At Rockhouse its layers are likewise accordant with those of the Decatur, and its limy base appears to grade into the latter. At the top its contact with the Ross limestone can be seen for only a short distance, and here, although the lithologic change from the one formation to the other is abrupt, the beds also appear conformable.

Fauna.—Although the fauna of the Rockhouse shale is prolific in individuals, only thirty-five species have been identified. Brachiopods easily hold first place with nineteen species, but the occurrence of seven species of gastropods in so small a fauna is especially worthy of note. One-third of the fauna consists of new species. Some of them, as *Pleurodictyum trifoliatum*, are very primitive expressions of characteristic Devonian stocks, and others, as *Dictyonella subgibbosa*, are equally suggestive of characteristic Silurian ancestors. Taken as a whole, the fauna is an unusual mingling of forms suggestive of both Silurian and Devonian—a circumstances which can only indicate that it holds a position near the Siluro-Devonian boundary line.

The species included in the fauna of the Rockhouse shale are:

Hindia sphæroidalis Duncan
Edriocrinus adnascens Dunbar
" *pocilliformis* Hall
Camarocrinus saffordi Hall

Scyphocrinus sp.
Enterolasma waynense Safford
Pleurodictyum trifoliatum Dunbar
Favosites sp.
Dalmanella rockhousensis Dunbar
" *macra* Dunbar
Rhipidomella oblata Hall
" *preoblata* Weller
" *saffordi* Foerste
Bilobites bilobus Linnæus
Leptæna rhomboidalis Wilckens
Strophonella sp.
Leptænisca adnascens Hall & Clarke
Dictyonella subgibbosa Dunbar
Uncinulus sp.
Eatonia fissicosta Dunbar
Atrypina imbricata Hall
Atrypa reticularis Linnæus
Delthyris cyrtinoides Dunbar
Nucleospira concentrica Hall
Merista tennesseensis Hall
Meristina maria-roemeri Foerste
Anoplotheca concava Hall
Phacops sp.
Gastropoda 7 sp.

Correlation.—The Rockhouse formation lies between Middle Silurian and Lower Devonian limestones, being separated from either by a disconformity, so that its known stratigraphic relations are noncommittal as to its Silurian or Devonian age. The writer has, therefore, seriously considered the possibility that the formation belongs to the Upper Silurian instead of the Lower Devonian, but for a number of reasons this hypothesis was rejected as untenable. The evidence in point may be stated as follows:

1. The general paleogeographic conditions of the Upper Silurian favor the Devonian age of the Rockhouse shale. The Decatur limestone, the highest of the recognized Silurian strata in Tennessee, is generally referred to the mid-Silurian, the most distinctive evidence of its age being that of the crinoids which Springer characterizes as "simon pure Niagaran." After the withdrawal of this sea, no later Silurian deposits are known in the whole Mississippi Valley province, unless the Rockhouse be such. But the Upper Silurian was a time of marked restriction of the seas in North America, as is recorded in

the red shales and the salt deposits of the Salina. While the Rockhouse shale was being deposited, on the contrary, the sea must have spread widely across the lower Mississippi Valley from Tennessee to Oklahoma, since the Rockhouse fauna is also distinctively developed in the Arbuckle Mountains. This epiric sea most probably came in from the Gulf region, since the formation thickens southward and since it is not known anywhere to the north and east of Tennessee. While such a wide inundation of the Mississippi Valley is out of harmony with all the known conditions of the Upper Silurian, the succeeding Devonian seas of about middle Helderbergian time unquestionably occupied the same region as the Rockhouse, and the latter is therefore most probably an earlier invasion of the Helderbergian sea.

2. If the Rockhouse shale be Lower Devonian, it is separated from the overlying Ross limestone by only a short interval of erosion; but if it be of Silurian age the hiatus is greatly lengthened and the chances for erosion increased. The preserval of so thin and easily eroded a formation in both Tennessee and Oklahoma, where it is overlain by Helderbergian strata, strongly supports the former assumption.

3. Finally, a preponderance of the faunal affinities are with the Devonian, and with this fact should be borne in mind the principle, generally recognized by paleontologists, that the heralders of new faunas are of more significance in the age of a formation than straggling holdovers from a previous time.

The Devonian affinities of the fauna may be summed up as follows: One-fourth of the species are gastropods. In the Silurian faunas there are only two or three species of gastropods present in any one—the entire 300 feet of highly fossiliferous Brownsport strata have yielded but five. On the contrary, gastropods are usually plentiful in the Lower Devonian, the New Scotland of Maryland having eight species and that of New York thirteen, while the Oriskany has yielded over twenty.

Of scarcely less significance is the deployment of the orthids among the brachiopods, for here we find six species, or over 16 per cent of the fauna, belonging to this group. Orthids are generally present in the Silurian faunas, but nearly always only two or three at a time, whereas they burst out in the Lower Devonian with many species. *Rhipidomella oblata* in particular is suggestive of Devonian faunas, as it attains a size of more than an inch across. Likewise, the new species *Dalmanella macra* closely resembles the Helderbergian *D.*

subcarinata. Against these forms, however, must be weighed the many small Rhipodomellas which are referred to *R. preoblata,* and the little sinuated *R. saffordi* which also occurs in the Silurian. These latter forms give the fauna an earlier aspect. The genus *Edriocrinus* is characteristic of the Lower Devonian, and the two species here identified continue into the succeeding Linden formations, but no representatives of the genus have ever been reported from the Silurian.

The genus *Pleurodictyum* is likewise confined to the Devonian, *P. lenticulare* being especially common in the Linden. That species is commonly composed of eight to thirteen corallites, and succeeding species of the Middle and Upper Devonian greatly increase the number and become spheroidal colonies. The interesting little *P. trifoliatum,* which reaches its maturity in a three-celled stage, indicates the primitiveness of this Devonian fauna. *Delthyris cyntinoides* is very similar to the characteristic *D. perlamellosa* of the Helderbergian. The former, on the other hand, is much larger and more closely lamellose than any of the known Silurian progenitors of its line.

Leptænisca adnascens is a common fossil in Linden and New Scotland formations, but it has never been recorded from the Silurian. It should be noted, nevertheless, that the writer has seen this little fossil thickly adhering to many specimens of Silurian corals in the Yale collection from the Hunton formation of Oklahoma, and unless the corals were exposed on the floor of the invading Devonian sea so as to form resting places for these sessile brachiopods, the species seems also to occur in the Silurian.

While, on the other hand, the genera *Camarocrinus, Scyphocrinus, Eatonia,* and *Phacops* occur in both the Silurian and Devonian, they are each much more at home in the latter, and although they may have little significance in the present case, they are at least in harmony with the inferred Devonian age of the fauna.

To be weighed against these Devonian affinities, must be noted especially the presence in the fauna of *Dictyonella subgibbosa, Nucleospira concentrica,* and *Merista tennesseensis.* The latter two species, although belonging to genera which have their best development in the Devonian, cannot be distinguished from the Silurian species, and therefore have a distinctly Silurian import. *Dictyonella subgibbosa,* although a new species, belongs to a genus which in America has heretofore not been seen above the Silurian. In Europe, however,

Barrande long ago described a similar species from the Middle Devonian of Bohemia, so the genus did persist into the Devonian.

The species of *Bilobites* in the Rockhouse shale is smaller and more deeply lobed than is characteristic of the Helderbergian *Bilobites varicus*, agreeing with the Silurian *Bilobites bilobus*, though many specimens of the former species might be selected from the Linden faunas which could not be distinguished from those of the Rockhouse, *B. varicus* being less robust in Tennessee than it usually is in the Appalachian province.

The remaining species, either because of their imperfect condition or long range, have little stratigraphic significance.

Taken as a whole, the faunal evidence is, therefore, seen to be predominantly Devonian, but that the formation is near the Siluro-Devonian boundary line is shown by the presence of Silurian holdovers and the pricitive expression of such species as *Pleurodictyum trifoliatum* and *Rhipidomella preoblata*. This circumstance, combined with the fact that the Rockhouse shale is succeeded by a long Helderbergian section of Coeymans and New Scotland age, leads to the conclusion that this fauna is probably of the same age as some part of the Keyser formation of Maryland. However, there is little direct faunal affinity with that formation, and the Mississippian embayment seems not to have been in communication with the Appalachian trough.

OLIVE HILL FORMATION

(See Sections 20, 21, 24-30.)

Definition and Subdivisions.—This, the second of the Linden formations, is well developed in Hardin County and the adjacent portions of Alabama and Mississippi. However, because of the deep erosion which it suffered in later Devonian time, and the subsequent covering by Mississippian and Cretaceous deposits, its remnants are now exposed only in small and scattered areas. The thickest section, and one that may be considered the type exposure for the formation, is well exposed at Olive Hill (section 25). Here it consists of three rather distinct lithologic units. These are, in descending order, the Flat Gap, Bear Branch, and Ross limestone members.

The Flat Gap member is a heavily bedded, coarsely crystalline or granular limestone of white or pinkish color. It is very sparingly fossiliferous, but toward the top *Rhipidomella oblata* and *Spirifer*

cycloptera are common and *Delthyris perlamellosa* and *Dalmanites pleuroptux* very rare.

The Bear Branch member consists of more impure, coarse-grained limestone and oolitic hematite. At this locality the lower half of the member is disposed in layers 2 to 12 inches thick, varying in color from gray to dark red as the composition varies from impure limestone to low grade ore with 20 to 30 per cent iron. The iron is a pri-

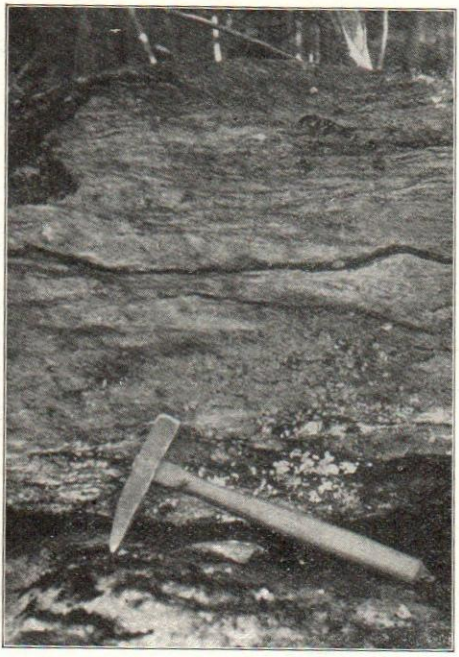


FIGURE 6.—Upper portion of the Bear Branch member of the Olive Hill formation. The darker lines which show the uneven bedding are red streaks of oolitic hematite. Only a trace of ore is present in these layers.

mary deposit, having accumulated along with the limestone, and its character is the same as that of the well-known Clinton iron ore. Near the middle of the member is a 5-foot zone of thin-bedded, muddy and cherty limestone without an appreciable quantity of iron. These layers are highly fossiliferous. The succeeding half of the formation is heavy-bedded and rather pure limestone with a small amount of oolitic iron forming reddish streaks and lines, which show up as irregular or

slight cross-bedding in the heavy layers (see Fig. 6). At the next locality, two miles south of Olive Hill on Bear Branch—whence the member takes its name—the cross-bedding is coarser and more marked, and here a thickness of 20 feet, exposed in a low bluff along the stream, is made up entirely of low-grade ore, average samples of which yield from 20 to 26 per cent iron. It is this same bed which supplied the iron mined before the Civil War at a locality about 1½ miles southeast of Clifton (section 20). Here it caps a rounded hill about one-fourth of a mile west of the toll gate on the Clifton-Waynesboro pike. The surface of the exposure and the old mining pits are now covered by a deep red regolith of clay and cherty fragments of stone. Nevertheless, the near association of highly fossiliferous layers of the subjacent Ross limestone, which outcrops on the hillside 30 feet below, makes the reference of the ore to the Bear Branch member quite certain. It is not, therefore, a replacement deposit as Drake[1] supposed, but a sedimentary one, though secondary enrichment may and probably has occurred during the process of weathering. The ore is of too low a grade to be successfully exploited at present. It is, however, interesting, its occurrence being, so far as the writer is aware, the largest deposit of this type of sedimentary ore yet found in the Devonian.

The lowest or Ross limestone member of the Olive Hill formation was defined by Foerste in 1903.[2] It is an impure, dark gray, siliceous and cherty limestone disposed in thin layers usually 2 to 5 inches thick, and where partly weathered these often appear to be separated by softer shaly layers along the bedding planes. The limestone is extremely hard, tough, and compact, and commonly forms cliffs and bluffs. The silica is so finely disseminated that it may not appear as chert even where the rocks analyze over 20 per cent SiO_2. In its more southern exposures, the formation contains thin bands of bluish chert varying in thickness from 1 to 10 inches and disposed at irregular intervals, usually a few feet apart. These layers of chert do not appear in the more northern exposures.

The fresh rock is bluish gray in color and hard and dense. Upon exposure the surface turns brown and with deep weathering the lime is leached out and the residue of insoluble silica forms a soft porous

[1]Drake, N. F. Economic geology of the Waynesboro quadrangle. Resources of Tenn., vol. 4, No. 3, 1914, p. 10.
[2]Op. cit., p. 685.

shaly sandstone which is colored rusty brown by the hydration of a trace of iron occurring in the limestone. Secondary chert is also formed at the surface during weathering. On a weathered outcrop, chunks of the rotten sandstone if broken will frequently be found to

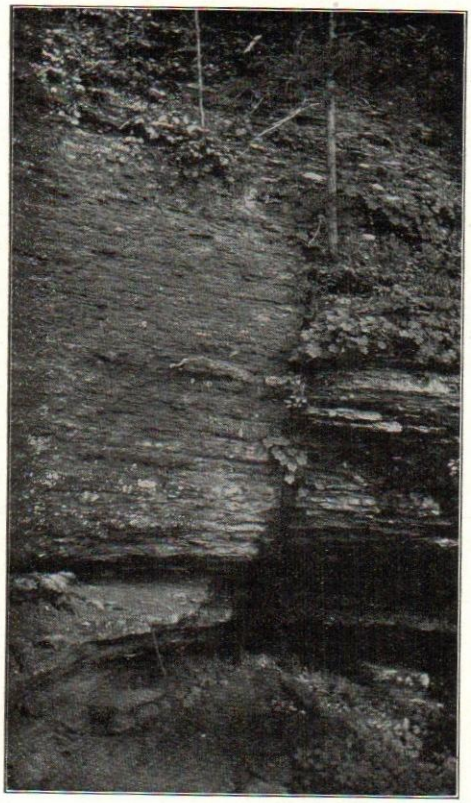


FIGURE 7.—Typical section of the Ross limestone at the chalybeate spring on the Ross farm, five miles southeast of Savannah, where it forms a bluff along Horse Creek. Height of exposure about 50 feet.

have a center of unaltered bluish gray limestone with concentric bands showing various degrees of weathering.

In the numerous sections of the Lower Devonian within a radius of twenty miles to the northwest, west, and south of Olive Hill, only this lower or Ross member of the formation is present, the higher members having been removed by subsequent erosion during Devonian

time. The Ross member is well exposed in the bluffs along the river at Grandview, and again a short distance below Cerro Gordo. It also outcrops east of the latter place along Smith's Fork and the lower course of Indian Creek. It is again typically developed along Horse Creek, on the Ross farm, five miles southeast of Savannah at the chalybeate spring (see Fig. 7). Here it is about 60 feet thick. It was this section which gave the limestone its name. Other exposures occur on the upper course of Horse Creek for a distance of two or three miles about Rockhouse.

The large bluff along the Tennessee for over a mile above Pyburns exposes between 80 and 100 feet of impure cherty limestone, which Foerste divided into the Ross limestone below and the Pyburn limestone above. Lithologically the whole thickness is much alike, the separation being made by Foerste on faunal grounds and in particular on the circumstance that *Camarocrinus*, which everywhere characterizes the Ross limestone, does not appear in the upper half of the section here exposed. The base of the formation is not exposed at this locality, and Springer's studies of the Scyphocrini and Camarocrini of these beds have led to the conclusion that the lower zone of the Ross with *Scyphocrinus pratteni* is below drainage if present here.

There does not seem to be a break in sedimentation between the Ross and Pyburn members. The latter consists of thin-bedded, impure, dirty and cherty limestone, with occasional bands of chert from 2 to 10 inches thick. The lower part is somewhat softer, but the upper 14 feet or more heavy-bedded and lithologically closely resemble the Ross limestone.

Foerste tentatively correlated this limestone with the far more widely spread shale formation described beyond as the Birdsong shale, but at that time he was not aware of the very significant Devonian sections in northern Hardin County, for he states that "The chief results of the writer's efforts have been the conclusion that the Linden bed is absent in a large part of the territory east of the Tennessee River once believed to contain it. It is not known to occur anywhere between Rise mill, New Era, Bath Springs, Economy and Martin's mill." That his conclusion was erroneous will be shown below.

The Pyburn limestone is now seen to hold the stratigraphic position of the Bear Branch member of the Olive Hill formation, which is seen over twenty miles to the northeast, and it appears to be equivalent to more or less of the latter. That the iron-bearing layers of the

PLATE 1.

Characteristic Linden Fossils.

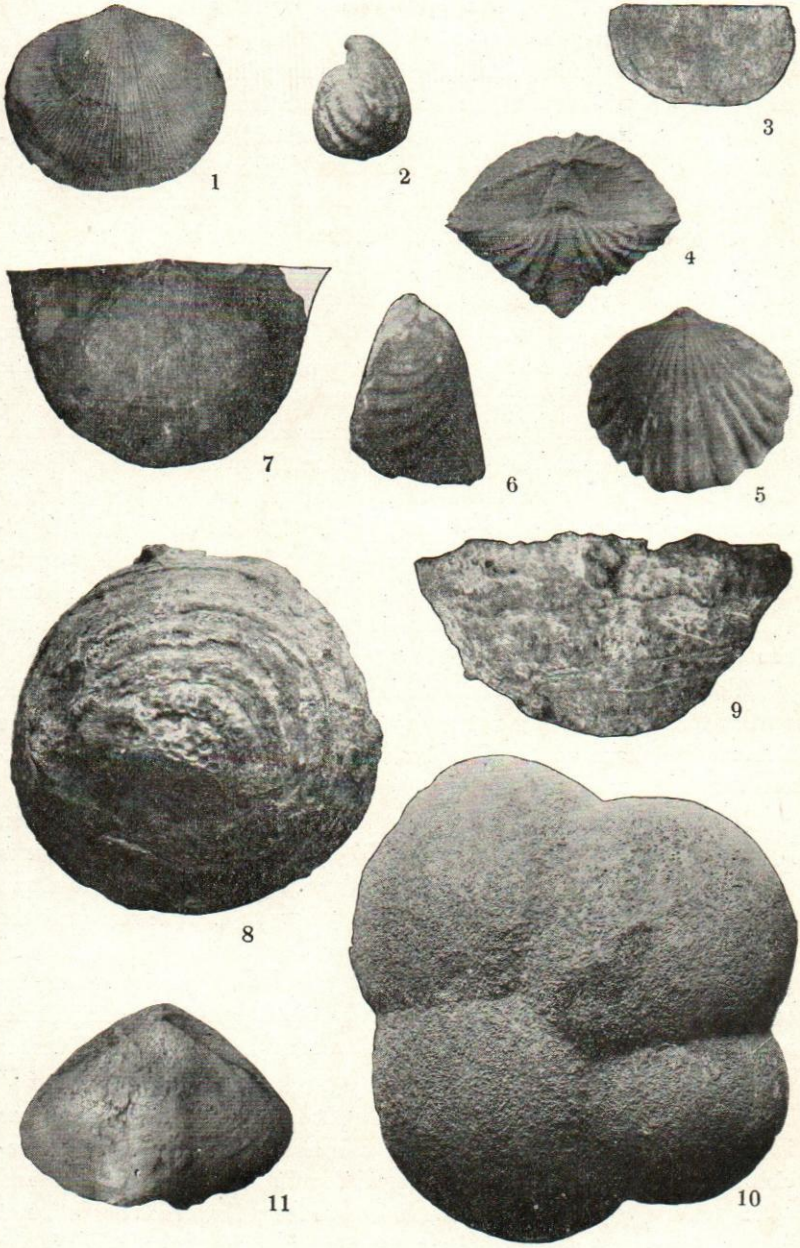
1. *Rhipidomella oblata* (Hall). Common throughout the Linden group.
2. *Delthyris octocostata* mut. *tennesseensis* Dunbar.
3. *Chonostrophia lindenensis* (Dunbar). Confined to the Ross member of the Linden.
4. *Delthyris perlamellosa* (Hall). A variety with a very high cardinal area, occurring in the Ross limestone.

5-6. *Eatonia eminens* Hall. Dorsal and lateral views. Confined to the Bear Branch formation.

7. *Brachyprion purduei* Dunbar.

8-9. *Favosites foerstei* Dunbar. Basal and lateral views. A characteristic Linden fossil.

10. *Camarocrinus*, the bulbous root of the crinoid *Scyphocrinus pratteni* McChesney. (×½.) This crinoid and its conspicuously large bulb are confined to the lower part of the Ross limestone.
11. *Meristella atoka* Girty. A large, broad type characteristic of the Ross limestone.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Bear Branch member are a local development is indicated by the marks of shallow-water deposition such as the cross-bedding and the development of oolite, and by the rapidity with which the richness of the ore varies within the short distance from Olive Hill to the locality on Bear Branch. It is supposed that if interformational erosion had not removed them from central Hardin County these layers would become impure dirty limestone toward the south, grading into the Pyburn. Nevertheless, the two names, Pyburn and Bear Branch limestones, will both be of service, since the lithology is distinctly different and they occupy different regions, and, furthermore, their exact equivalence is for the present not established with certainty.

Distribution.—In addition to the exposures mentioned above, the Olive Hill formation extends further southward into the edge of Alabama and Mississippi, where it goes below drainage, apparently with unreduced thickness. A thick section on Dry Creek near Walnut Grove shows the top of the Pyburn limestone becoming more sandy and irregularly bedded, and succeeded by 25 feet of massive light-colored crystalline limestone which has but few fossils and is tentatively referred to the Flat Gap member of the formation. The latter is here separated from the Pyburn limestone by a slight erosional unconformity.

Along Horse Creek the Ross limestone rests on the Rockhouse shale; south of here its base is not exposed, but to the north it overlies the Decatur limestone of the Silurian, in all observed cases with a disconformable contact.

The thick section at Olive Hill was only preserved from later erosion by down-warping. Although fully 150 feet thick at this locality, it is rapidly truncated toward the north and northwest, only the Ross and a part of the Bear Branch members extending to Clifton and only the Ross reaching to Grandview and Cerro Gordo, while it is entirely absent in the vicinity of Saltillo. At this latter locality occurs an outlier of the younger and southwardly overlapping Birdsong shale, with its *Eospirifer macropleura* fauna, resting largely on the Decatur limestone.

Fauna.—In the lower member, the Ross limestone, *Camarocrinus* is the most conspicuous fossil, and calyces of three species of associated Scyphocrini may occasionally be found. Although common and often extremely abundant in the Ross member, *Camarocrinus* has not been observed in either of the succeeding members, the Pyburn, the

Bear Branch, or the Flat Gap limestones. Brachiopods occur plentifully in the Ross limestone, being distributed throughout the rock in the more northern exposures, where they weather out as free pseudomorphs in silica, but in the southern exposures they are for the most part confined to the layers of chert.

The fauna of the Bear Branch member contains fewer species, 16 in all, but these are all found below in the Ross limestone, excepting *Eatonia eminens, Chonetes wadei,* and *Platyceras gibbosum,* which were found in the cherty band near the middle of this member. The latter two species are known here from only a single specimen each.

The fauna of the Flat Gap member embraces only four common Linden species which were mentioned above and all of which occur in the Ross limestone.

The fauna of the Pyburn limestone is a continuation of that of the Ross, except for the absence of Camarocrinus and the Scyphocrini.

Some of the characteristic fossils of this complex formation are figured in Plate 1 and others in Plate 2. In the following correlation table, the fauna of this formation is compared with that of the succeeding Birdsong shale and with related formations in Oklahoma, Maryland, and New York.

Faunal Table.

B =Becraft C =Cceymans K =Keyser M=Manlius O =Oriskany c =common cc=very common r =rare rr=very rare x =Denotes occurrence	Linden			Haragan, Okla.	New Scot.		Below N. Scotland	Above N. Scotland
	Birdsong	Ross	Bear Branch		N. Y.	Md.		
Hindia sphæroidalis Duncan	rr	rr		x	x	x	C	
Aulopora schohariæ Hall	r	r			x			B
Pleurodictyum lenticulare (Hall)	c	r			x	x	C	O
Enterolasma strictum (Hall)	cc	c		x	x	x		B
Duncanella rudis Girty	c			x	x			
Amplexus sp.	rr							
Striatopora 2 n. spp.	c							
Favosites conicus Hall	cc	r		x	x	x		B, O
Favosites foerstei Dunbar	cc	r						
Favosites helderbergia Hall	c	c	r		x	x	C	
Favosites n. sp.		rr						
Codaster loræ Dunbar	rr							
Edriocrinus pocilliformis Hall	rr	r			x	x		B

Faunal Table—Continued

B =Becraft
C =Coeymans
K =Keyser
M=Manlius
O =Oriskany
c =common
cc=very common
r =rare
rr=very rare
x =Denotes occurrence

	Linden				Scot. New			
	Birdsong	Ross	Bear Branch	Haragan, Okla.	N. Y.	Md.	Below N. Scotland	Above N. Scotland
Edriocrinus adnascens Dunbar	c							
Edriocrinus pyramidatus Springer MS.	r							
Stereocrinus sp.	rr							
Phimocrinus sp.	rr							
Scyphocrinus pyburnensis Springer	rr	c						
Scyphocrinus pratteni (McChesney)		c						
Scyphocrinus mutabilis Springer	r	c						
Camarocrinus	r	cc		x		K	M	
Ascodictyon siluriense Vine	c						K	
Rhopalonaria n. sp.	c							
Corynotrypa cf. *inflata* (Hall)	c							
Phænopora tenuis (Hall)	c				x			
Eridotrypa corticosa (Hall)	c				x	x		
Orthopora rhombifera (Hall)	cc				x	x		
Lioclema ponderosum (Hall)	c				x			
Lioclema cellulosum (Hall)	c				x			
Hallopora perelegans (Hall)	cc			x	x			
Monotrypa tabulata (Hall)	c				x	x		
Crania pulchella Hall & Clarke	rr				x			
Crania agaricina Hall & Clarke	rr				x			
Crania n. sp.	rr							
Pholidops ovata Hall	r				x		K	
Orthostrophia strophomenoides (Hall)	rr			x	x	x		
Dalmanella planoconvexa (Hall)	rr	rr			x	x		B, O
Dalmanella subcarinata (Hall)	cc	r	x	x	x			
Dalmanella perelegans (Hall)	c				x	x	C	B
Dalmanella pygmæa Dunbar	c							
Dalmanella concinna (Hall)	rr						K	
Dalmanella eminens (Hall)	rr				x			
Rhipidomella oblata (Hall)	cc	cc	cc	x	x	x	K	B
Rhipidomella emarginata (Hall)	cc	rr		x			K	
Bilobites varicus (Conrad)	cc	r		x	x			
Leptæna rhomboidalis Wilckens	cc	c	c	x	x	x	x	x
Leptostrophia beckii (Hall)	c	c			x	x		B
Leptostrophia beckii var. tennesseenisis Dunbar	rr	rr						
Leptostrophia planulata Hall		rr		x	x	x	C	B
Stropheodonta varistriata (Conrad)	rr	rr		x			C	
Brachyprion purduei Dunbar	r	r	c					
Pholidostrophia lindenensis Dunbar	rr							
Strophonella punctulifera (Conrad)	c	c		x	x	x	C	B
Strophonella punctulifera var. hoiladayi Dunbar	rr							

Faunal Table—Continued

B =Becraft
C =Coeymans
K =Keyser
M=Manlius
O =Oriskany
c =common
cc=very common
r =rare
rr=very rare
x =Denotes occurrence

	Linden				Scot. New			
	Birdsong	Ross	Bear Branch	Haragan, Okla.	N. Y.	Md.	Below N. Scotland	Above N. Scotland
Strophonella lineolata Dunbar	r	r						
Leptænisca adnascens Hall & Clarke	cc	r			x			
Leptænisca concava (Hall)	rr			x	x	x	C	
Schuchertella woolworthana (Hall)	c	c	c	x	x	x	C	B
Anoplia helderbergiæ Rowe	rr			x		x		
Chonostrophia lindenensis Dunbar		r						
Chonetes wadei Dunbar			rr					
Scenidium insigne (Hall)	r			x	x			
Anastrophia verneuili (Hall)	cc	rr	rr	x	x			
Gypidula multicostata Dunbar	cc	r						
Gypidula coeymanensis Schuchert	rr	rr			x		C	
Eatonia eminens Hall			c					
Eatonia tennesseensis Dunbar	c							
Camarotœchia transversa (Hall)	cc	r		x	x			
Camarotœchia bialveata Hall	c			x	x			
Uncinulus lindenensis Dunbar	cc	c						
Uncinulus vellicatus? (Hall)		r						
Uncinulus cf. *nucleolatus* (Hall)	rr							
Uncinulus swaynensis Dunbar	rr							
Wilsonia wadei Dunbar	c	r						
Rensselœrina medioplicata Dunbar	cc	r	rr	x				
Atrypina imbricata (Hall)	cc			x	x	x		
Atrypa reticularis (Linnæus)	cc	cc		x	x	x	x	x
Eospirifer macropleura (Conrad)	cc				x	x		
Delthyris perlamellosa (Hall)	cc	cc	r	x	x	x	C	
Delthyris octocostata mut. *tennesseensis* Dunbar	c	r						
Spirifer cycloptera Hall	c	c	c	x	x	x	C	B
Cyrtina dalmani (Hall)	c	r		x	x			
Rhynchospira formosa (Hall)	cc	r		x	x			
Rhynchospira globosa (Hall)	c	rr		x	x		K	
Trematospira simplex Hall	rr				x			
Trematospira costata Hall	rr			x	x			
Nucleospira ventricosa (Hall)	cc	cc		x	x	x	C	
Meristella arcuata (Hall)	cc	cc			x	x		B
Meristella atoka Girty	cc	cc	c	x				
Meristella lævis (Hall)	rr	rr	c	x			C	
Anoplotheca concava (Hall)	cc	rr		x	x	x		B
Spirorbis laxus Hall	c				x			
Cornulites chrysalis Hall	c				x			
Cornulites n. sp.	r							
Tentaculites aculus Hall	r				x			O
Platyceras multisinuatum Hall	r	r			x	x		

Faunal Table—Continued

B =Becraft C =Coeymans K =Keyser M=Manlius O =Oriskany c =common cc=very common r =rare rr=very rare x =Denotes occurrence	Linden				Scot. New			
	Birdsong	Ross	Bear Branch	Haragan, Okla.	N. Y.	Md.	Below N. Scotland	Above N. Scotland
Platyceras tenuiliratum Hall	r	r		x	x	?		
Platyceras spirale Hall	rr	rr		x	x	x		
Megambonia sp.	rr	rr						
Actinopteria textilis (Hall)	rr				x	x		
Phacops logani Hall	rr	rr	c	x	x	x		
Phacops hudsonica Hall	r	rr		x	x			
Dalmanites retusus Dunbar	c							
Dalmanites purduei Dunbar		r						
Dalmanites pleuroptyx (Green)	r	r	r		x			
Orthoceras pauciseptatum Hall	rr				x		C	
Orthoceras rude? Hall	rr				x			
Conularia huntiana Hall		rr						

Correlation.—The fauna of the Olive Hill formation as fully developed in the Ross limestone member shows very close relations to the succeeding Birdsong formation. Of its fifty-eight species, fifteen are indigenous to Tennessee, while twenty elsewhere occur in both the Coeymans and the New Scotland formations, and twenty-one others are elsewhere confined to the New Scotland and one to the Coeymans. While related to both these formations, therefore, it has more decidedly the impress of the former. At the same time it does not contain a number of significant species such as *Dalmanella perelegans, D. eminens, Orthostrophia strophomenoides, Camarotœchia bialveata,* and especially *Eospirifer macropleura,* all of which are very distinctive of the New Scotland and do occur in the succeeding Birdsong formation. The latter formation is the more exact equivalent of the typical New Scotland, and since, therefore, the Olive Hill formation is considerably older, as shown by the interval of erosion which separates these formations, it seems better to refer it to late Coeymans time.

BIRDSONG FORMATION

(See Sections 1-3, 7-11, 13-16, 18, 19, 23.)

Definition.—This is the well-known shaly member of the Linden group, characterized by many beautifully preserved fossils. Foerste[1] tentatively correlated it with the Pyburn limestone and it has since passed under that name. On the contrary, both the faunal and stratigraphic evidence adduced from the present study indicate that such a correlation is erroneous. Even though it were correct, a distinct name for this shaly formation would have been desirable, since the Pyburn limestone is separated by a distance of thirty miles from the nearest section of this formation (excepting only a small outlier of the latter at Saltillo), and, moreover, the section at Pyburns is neither typical nor representative, in fauna or lithology, of this much more widely spread formation.

Because of the good development of these strata along the valley of Birdsong Creek and its tributaries in Benton County, they are named the Birdsong formation. In this vicinity the strata are about 45 feet thick and embrace all between the Decatur limestone and the Decaturville chert, and to these beds should be added an additional 20 feet of similar shaly strata which only comes in further north along the lower course of Big Sandy River.

The Birdsong formation begins with a few feet (8-10) of heavy-bedded, rather pure, coarsely crystalline limestone. Above this it passes into interbedded bluish shale and thin bands of crystalline limestone and then into softer, calcareous, blue shale, constituting the upper half to three-fourths of the formation. Harder calcareous laminae and thin bands or lentils of limestone occur throughout the shale. When fresh the latter is partly indurated by its large percentage of calcium carbonate, but it weathers into bluish clay and a rubble of small limy fragments forming barren hillsides slopes or "glades," of which a very characteristic one is shown in Figure 8. Because of the absence of vegetation, such glades are fine places to collect the fossils which weather out free from the clay. These Devonian glades are smaller, but by no means inferior to the Silurian ones which have achieved fame as a "happy hunting ground" for paleontologists.

Distribution.—The Birdsong shale is well developed west of the Tennessee River and north of Perryville, especially in northern De-

[1]Op. cit., 1903, p. 685.

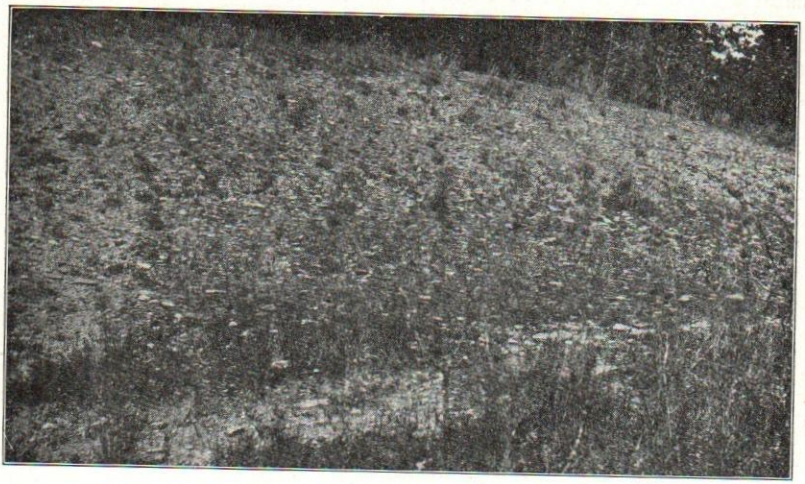


FIGURE 8.—Typical glade exposure of the Birdsong formation, on the Holladay-Cis Mundy road near the home of Mr. Will Love, four and one-half miles north of Holladay.

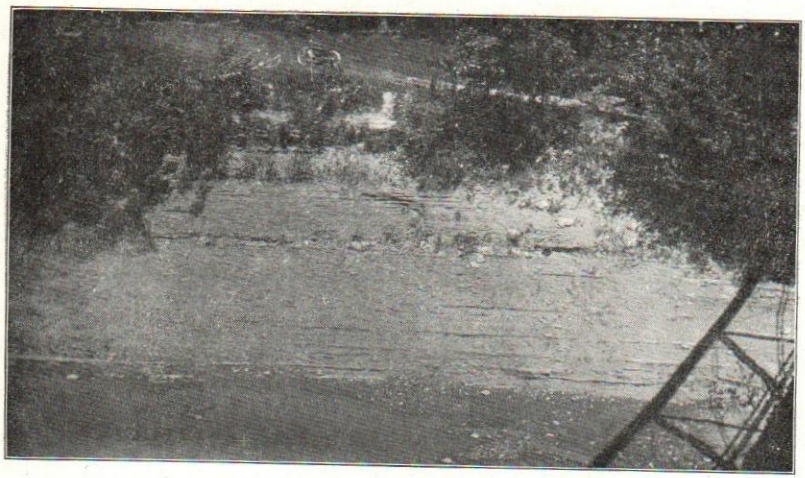


FIGURE 9.—Upper portion of the Birdsong formation at the steel bridge, four miles above the mouth of Big Sandy River, Henry County, Tennessee. A characteristic exposure of the formation.

catur and southern Benton counties. The section at Perryville is typical for the lower 35 feet of the formation and the same strata continue northward with but little change either lithologically or faunally. They are best exposed along Big Lick and Birdsong creeks and the tributaries of the latter about Holladay (sections 9, 11, 13).

North of Birdsong Creek the formation is generally buried by younger strata, but Rushing Creek cuts into its upper layers about halfway between Camden and Big Sandy. On the lower course of Big Sandy River higher layers of the shale appear which are not present farther south. These are well exposed at the steel bridges (see Fig. 9) and at the old Swayne's mill site (section 1). A part of the lower shale is also exposed at the latter locality, but the total thickness of the formation in this part of the country is unknown. Adding the thickness of 22 feet of strata exposed at the steel bridge to the sections on Birdsong Creek gives a total thickness for the formation of about 65 feet.

While it goes under cover of younger strata to the north without any evidence of decreasing thickness, the formation thins out rapidly to the south of Perryville. Only a few feet of the lower portion is present at Decaturville, and in the sections farther south it is absent entirely, except that at Saltillo a few feet of strata, which seem to be referable to the southwardly overlapping upper part of this formation, rest on the Decatur limestone.

East of the Tennessee River the formation is thin and usually absent by erosion. At the bridge over Buffalo River, east of Linden, the more limy base of the formation, about 10 feet thick, is overlain by the Hardin sandstone at the base of the "black" shale. About a mile north of the village the base of the formation may be seen again in an old quarry in the timber about one-fourth mile northeast of Mr. Ledbetter's house. It consists of coarsely crystalline, rather pure limestone characterized by *Rhipidomella oblata, Leptæna rhomboidalis, Leptostrophia beckii,* and *Strophonella punctulifera.*

Small exposures of the basal layers of the formation may be seen at various places along the roadside for a distance of two or three miles north of Linden. At the roadside about three-fourths of a mile south of Beardstown there is a small outcrop of the same limestone crowded with *Leptostrophia beckii* and also containing *Rhipidomella oblata, Strophonella punctulifera, Uncinulus cf. nucleolatus, Meristella atoka,* and *Camarocrinus.* These strata are clearly referable to the

base of the formation. A section of 20 feet of the Linden is exposed in the lower part of the bluff, at Mr. Hinson's mill on Cane Creek, about two and one-half miles east of Beardstown. It succeeds the Lobelville division of the Silurian and is unconformably overlain by the Chattanooga black shale. The lower 5 feet of limestone is impure and more or less sandy and cross-bedded. It is disposed in courses 2 to 10 inches thick and is only slightly fossiliferous. The succeeding 15 feet, to the base of the "black" shale, is heavily bedded and rather coarsely crystalline limestone, of which the lower 10 feet is very fossiliferous. Slender ramose bryozoa are abundant in a 2-foot zone near the center of the formation.

The Birdsong extends as far northeast as Cumberland City, where there are small exposures in the Wells Creek basin. The best of these outcrops occurs in the bank of the Cumberland River about one mile southwest of the city. The 10 feet exposed here consists of thin-bedded and somewhat cherty limestone, with the usual fossils of the brachiopod zone. The heavy-bedded limestone which generally forms the base of the formation seems not to be present in the Wells Creek basin. It appears, therefore, that there is an overlap in this direction so that layers well above the base of the Birdsong formation rest on the Dixon formation of the Silurian.

Fauna.—Excepting the heavy limestone at its base, the Birdsong formation is very richly fossiliferous and the remarkable preservation of its fossils is scarcely duplicated in the whole Lower Devonian of America. Brachiopods overwhelmingly predominate, except in one limited zone, which is replete with bryozoa. Crinoidal material is abundant, but calyces are rarely preserved. *Camarocrinus*, which is so abundant in the Ross limestone, persists throughout the Birdsong, although it is not common except in the limestone at the base. Of corals, four species—two tetracorals and two favosites—are common, while on the other hand pelecypods, gastropods, and cephalopods are almost nil. Three major faunal zones and a number of faunal subzones can be recognized. The most conspicuous of these is the bryozoa zone, which forms the top of the formation on Birdsong Creek. For a thickness of 5 or 6 feet the shale is replete with ramose, massive, and incrusting forms of bryozoa, which are so abundant that they may be swept up by the handful wherever these layers outcrop. The 35 or 40 feet of the formation below the bryozoa zone may be called the brachiopod zone. The higher portion of the formation exposed on

the lower course of Big Sandy River also contains many brachiopods, but is characterized by an abundance of trilobites and may, therefore, be designated the trilobite zone.

Beginning at the base of the brachiopod zone, the lower 9 or 10 feet is rather heavy limestone in which fossils occur only sparingly. *Camarocrinus* is associated with *Rhipidomello oblata, Delthyris perlamellosa, Atrypa reticularis,* and *Dalmanites retusus.* The succeeding 6 or 8 feet of interbedded shale and limestone is characterized by *Leptostrophia beckii,* which is most aboundant at this horizon and is associated with *Strophonella punctulifera, Eospirifer macropleura, Dalmanites retusus,* and other Linden fossils. The following 25 feet of softer shale up to the bryozoa zone is replete with brachiopods and has yielded most of the Linden fossils in paleontological collections. The very rare little blastid, *Codaster lorœ,* occurs near the middle of this zone.

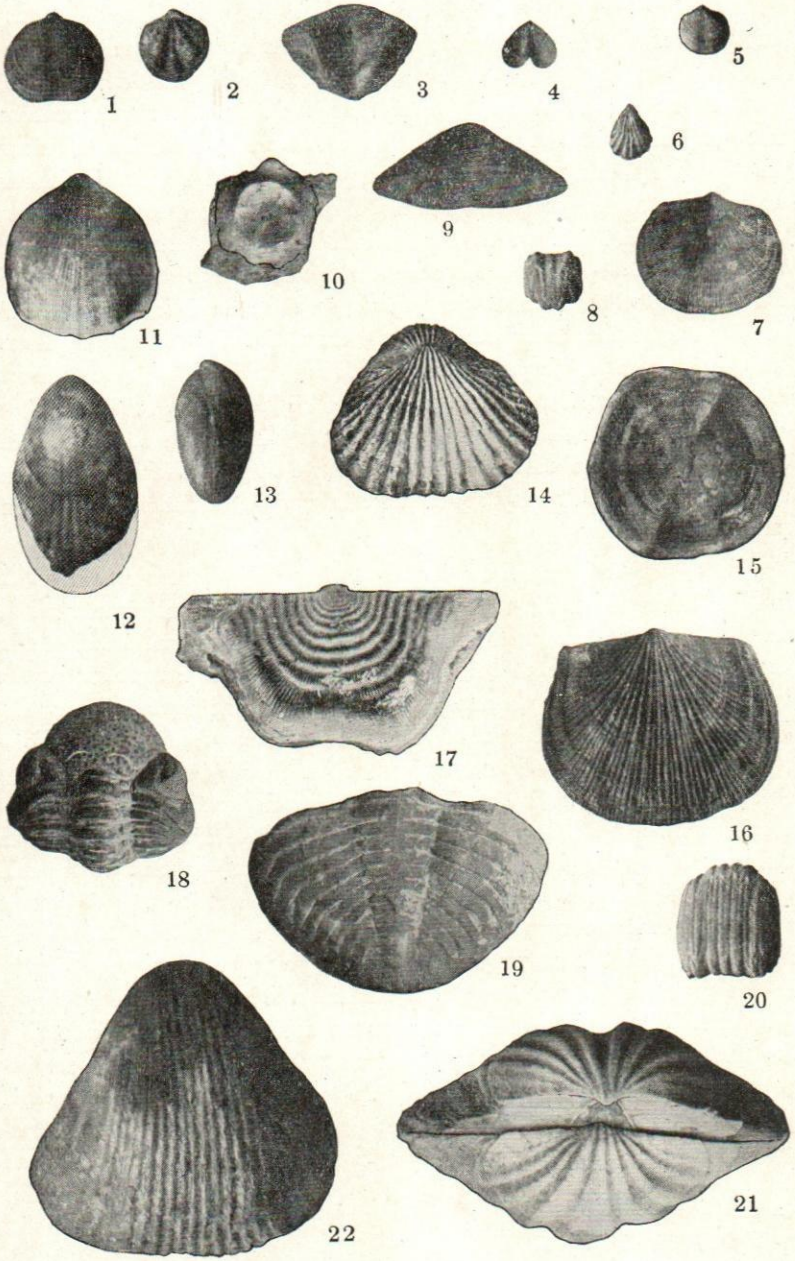
The bryozoa zone, although so thin, holds its character persistently for a distance of 50 miles from Perryville to Big Sandy, across which region it is the highest zone of the formation present. The shale at this horizon is usually interbedded with little lentils of limestone, mostly less than a foot across and an inch thick, which are covered with bryozoa or largely composed of massive or incrusting species.

At the steel bridge and at the old Swayne's mill site on the lower course of the Big Sandy River, the bryozoa zone seems to be absent. Here the brachiopod zone is succeeded by 22 feet of similar limy blue shale, containing numerous brachiopods, which do not occur below, and are especially characterized by trilobites. *Dalmanites* is abundant throughout these layers, while in the upper two-thirds *Phacops* is so common that numerous whole specimens can easily be secured. The lower 5 feet of this trilobite zone is harder and less fossiliferous, and is dominated by *Atrypa reticularis.* The succeeding 3½ feet of shale is crowded with *Anastrophia verneuili* almost to the exclusion of other species. *Phacops* begins to appear here. The softer shale which succeeds contains *Phacops* in abundance and many brachiopods, especially orthids. Among the latter are *Orthostrophia strophomenoides* and *Dalmanella eminens,* which do not occur lower in the formation. The rare crinoid, *Edriocrinus pyramidatus,* Springer MS., is confined to the upper half of this zone. The complete faunal list is given on pages 51-54, where it is compared with that of the Ross limestone, etc. Several of the characteristic species are illustrated in Plate 2.

PLATE 2.

Characteristic Linden Fossils.

1. *Rhipidomella emarginata* (Hall). Birdsong shale.
2. *Atrypina imbricata* (Hall). Common in the Birdsong.
3. *Meristella atoka* Girty. Small form typical of the upper portion of the Birdsong.
4. *Bilobites varicus* (Conrad).
5. *Dalmanella pugmœa* Dunbar. Confined to the Birdsong. Abundant in the higher portion at the Swayne's mill locality.
6. *Camarotœchia bialveata* Hall. A New Scotland "guide" fossil confined to the Birdsong member of the Linden.
7. *Dalmanella subcarinata* (Hall).
8. *Wilsonia wadei* Dunbar.
9. *Dalmanella perelegans* (Hall).
10. *Edriocrinus adnascens* Dunbar. Specimen from the Rockhouse shale. Species common only in the Birdsong shale.
11. *Eatonia tennesseensis* Dunbar. A characteristic species confined to the Birdsong shale.
12. *Rensselœrina medioplicata* Dunbar. Ventral view.
13. Young specimen of the same. Lateral view.
14. *Anastrophia verneuili* (Hall). A characteristic New Scotland fossil, very common in the Birdsong shale.
15. *Edriocrinus pyramidatus* (Springer M.S.). The base of an unusual crinoid calyx, confined to the upper portion of the Birdsong shale on the lower course of the Big Sandy.
16. *Orthostrophia strophomenoides* (Hall). A New Scotland "guide" fossil confined to the upper portion of the Birdsong. Common at the steel bridge and the Swayne's mill locality on Big Sandy River.
17. *Leptœna rhomboidalis* Wilckens. A characteristic shape for this common fossil in the Linden.
18. *Phacops logani* Hall. Abundant in the higher part of the Birdsong shale at the steel bridge on the lower course of Big Sandy River, and also common near the middle of the Bear Branch formation at Olive Hill. Elsewhere occurs sparingly in the Linden.
19. *Dalmanites retusus* Dunbar. Confined to the Birdsong.
20. *Uncinulus lindenensis* Dunbar.
21. *Eospirifer macropleura* (Conrad). The most diagnostic New Scotland fossil, confined in Tennessee to the Birdsong formation, where it is abundant.
22. *Gypidula multicostata* Dunbar. Typical of the Linden.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Correlation.—The very striking resemblance of this fauna to that of the New Scotland formation of New York has long been recognized. As early as 1859 Hall wrote[1] that "the collection of fossils [from Tennessee] are so like those from the Helderbergian mountains, near Albany, that but for their color and here and there a difference in the development of certain forms, there would be little to distinguish the two localities." Of the ninety-nine species listed above, sixty occur also in the New Scotland of New York. Among these are almost all of the diagnostic species, as *Orthostrophia strophomenoides, Dalmanella subcarinata, D. perelegans, Bilobites varicus, Leptostrophia beckii, Leptænisca adnascens, L. concava, Scenidium insigne, Anastrophia verneuili, Camarotœchia bialveata, Eospirifer macropleura, Delthyris perlamellosa, Spirifer cycloptera, Cyrtina dalmani, Phacops logani,* etc. Considering the distance which separates Tennessee and New York, the correspondence in these forms is remarkable, and clearly indicates not only equivalence in age but a rather direct communicating seaway.

On the other hand, there are a number of trilobites and crinoids in New York which did not get into the Mississippi embayment, while certain important elements in the Birdsong fauna do not recur at this time in the Appalachian trough. Such conspicuous examples are the various species of *Scyphocrinus* and the associated *Camarocrinus, Edriocrinus adnascens, E. pyramidatus, Rensselœrina medioplicata, Eatonia tennesseensis, Gypidula multicostata,* and *Meristella atoka.* These forms are believed to be of Gulf of Mexico derivation. The Scyphocrini with *Camarocrinus* in particular, were sequestered somewhere in the south from late Middle Silurian time (Decatur) almost to the end of the Helderbergian, appearing in great abundance in both Tennessee and Oklahoma, whereas they only succeeded in reaching the Appalachian trough for a very brief period, being known very rarely in the Manlius (?) of New York and in a zone near the middle of the Keyser of Maryland. This circumstance is believed to indicate that the Helderbergian seas of Oklahoma and Tennessee represent an embayment from the south, especially since *Camarocrinus* in Europe is limited to the southern or Bohemian province. Nevertheless, a communicating seaway most probably existed during New Scotland time between this Gulf embayment and the Appalachian trough (see Fig. 2).

[1]Hall, James. Pal N. Y., vol. 3, 1859, p. 38.

Its most likely position seems to have been across medial Kentucky and West Virginia, since this was the location, during much of Paleozoic time, of a sag or trough in the Cincinnati axis, and since in the Appalachian trough the Helderbergian formations thin out farther southward.

The Haragan shale of Oklahoma represents a western arm of this same epiric sea. Its fauna contains thirty-six species in common with that of the Birdsong shale, and the intimate relation of the faunas is further shown by the presence in both of species indigenous to this southern embayment, such as *Rensselaerina medioplicata* and *Meristella atoka*, and by the great abundance of *Camarocrinus*. The fauna of the Haragan shale, however, is characterized by the absence of *Eospirifer macropleura* and *Leptostrophia beckii* and by a greater abundance of *Phacops logani*, *Meristella atoka*, and *Orthostrophia strophomenoids*. In these respects it most nearly agrees with the upper or trilobite zone of the Birdsong. In the sections on the lower course of Big Sandy River, only a single specimen of *Eospirifer macropleura* was found, near the base of the trilobite zone, and *Leptostrophia beckii* seems to be absent. On the other hand, *Phacops* becomes very common, *Orthostrophia* appears in abundance, and *Meristella atoka* and *Rhipidomella emarginata* are very common. The Haragan shale, therefore, appears to be equivalent rather to the highest portion of the Birdsong.

The relation of the Birdsong fauna to that of the Ross limestone is very intimate, fifty-one species of the ninety-nine identified from the former being common to both. There are, however, certain important faunal differences to be noted. The striking crinoid, *Scyphocrinus pratteni*, which occurs at various localities in the lower portion of the Ross limestone, has never been found in the shale formation. On the other hand, the Ross lacks many of the Birdsong species, including some of the most significant ones, such as *Eospirifer macropleura*, *Eatonia tennesseensis*, *Camarotœchia bialveata*, *Leptœnisca concava*, *Dalmanella perelegans*, and *Dalmanites retusus*. In addition, many species which are common in one formation occur but rarely in the other. The *Camarocrini*, for example, are prolific in the Ross but rather rare in the Birdsong, while *Anastrophia verneuili*, *Gypidula multicostata*, *Rensselœrina medioplicata* and other brachiopods are common only in the latter.

Because of the circumstances that this formation is practically confined to the northern half of the valley, and the Olive Hill formation to the southern portion, and as the two have so many species in common, the writer has carefully considered the possibility that they are but lateral and contemporaneous phases of the same formation. Such an hypothesis, however, was found to be untenable. In spite of many Helderbergian species which they have in common, the entire absence from the Olive Hill limestones of *Eospirifer macropleura* and of certain other typical New Scotland species, as *Orthostrophia strophomenoides* and *Dalmanella perelegans*, is of great significance. *Eospirifer macropleura* is widespread in its distribution and is the most diagnostic New Scotland "guide" fossil. It occurs in abundance in the Birdsong formation, both in the shaly layers and in the purer limestone at its base, while in Maryland and New York it is at home in impure and cherty strata. Hence it was clearly not subject to a delicate control by the nature of the sediment. Moreover, the distinctness of the faunas of these formations is shown by the fact that in a number of cases a species in one fauna is represented by a related but different one in the other. For example, *Dalmanites retusus* is confined to the Birdsong, and *D. purduei* to the Ross, while *D. pleuroptyx* is common to both.

To make the Birdsong equivalent to the Ross limestone would require an abrupt change in the lithology within the distance of ten or twelve miles from Perryville to Grandview, although each formation is known to maintain its distinctive lithology for many miles and to show no evidence of transition on approaching these localities. In addition, the occurrence at Saltillo of an outlier of the Birdsong formation with its *Eospirifer macropleura* fauna precludes the possibility of such a transition. While this outlier here rests on the Decatur, it is only six miles east of Grandview, where 40 feet of the Ross limestone comes in above the Decatur, or an equal distance to the south where the same formation is present near Cerro Gordo. The Ross limestone must have been removed at Saltillo before the incursion of the *Eospirifer macropleura* fauna of the Birdsong. The outlier of the latter here preserved, though weathered and partly replaced by chert, is thin-bedded and shaly, and therefore seems not to be referable to the basal part of this formation, which consists of heavy-bedded limestone without shale. This implies that the Birdsong is a southwardly overlapping formation. If it is not, therefore, equivalent to the Ross limestone, but distinctly younger and separated from that lime-

stone by a period of erosion, it cannot for the same reason be equivalent to the succeeding members of the Olive Hill formation, which followed the Ross, and are also abruptly beveled off by interformational erosion toward the north and northwest.

DECATURVILLE CHERT

(See Sections 9, 13B, 18, 21B, 22, 23.)

Definition.—The name Decaturville is applied to a thin but widespread formation of yellowish to gray or slate-colored chert which is well developed in the vicinity of Decaturville. It is exposed in the heads of gullies tributary to Rushing Creek in the south and east edges of this village and forms a heavy "float" down the beds of these streams. The distinctive fauna of this chert is here typically developed.

The upper and most distinctive part of the formation is a layer from 6 inches to over a foot thick, composed of very porous and extremely fossiliferous gray or slate-colored chert, stained at the surface by iron rust. This layer is underlain by a variable thickness of lighter colored, thinner-bedded chert, which weathers more readily and is not well exposed. On Birdsong Creek, Section 9, this portion of the formation seems to be about 5 feet thick, but it is generally less.

Distribution and Stratigraphic Relations.—Where best developed, the formation is not very clearly exposed, but the maximum measured thickness is only 5 or 6 feet. Although it is so thin, it extends more than halfway across the State from north to south. It seems to be absent north of Camden, but is locally present along the valley of Birdsong Creek, where it succeeds the bryozoa zone of the Birdsong shale (section 9). The same relations obtain along Big Lick Creek north and east of Jeannette. While a thickness of 37 feet of the Birdsong formation is present at Perryville, the chert is absent, yet only six miles to the southwest, in the vicinity of Decaturville, the chert is well developed, resting on the basal limestone member of the Birdsong formation, of which the upper 20 feet or more is absent by interformational erosion. About four miles a little east of north from Saltillo, the formation is well developed, forming heavy "float" where the road crosses a branch of Stumans Creek about two miles east of Thurman. At this locality it holds a horizon just above the Decatur limestone. At the boat landing at Saltillo the chert is separated from the Decatur by a few feet of deeply weathered clayey and cherty strata which are referred to the upper portion of the Birdsong shale.

At Grandview, 40 feet of the Ross limestone separates the chert from the Decatur. Moreover, from the evidence of the crinoids especially, it is only the lower portion of the Ross limestone which is present here. The chert is succeeded by the Oriskany at this locality. Only thirteen miles farther southeast approximately the same layers of the Ross limestone are succeeded by 100 feet of Linden limestone, unconformably overlain by the "black" shale, and here the Decaturville chert is absent. South of here the horizon at which the chert should occur has generally been eroded away, but the chert is present on Dry Creek near Walnut Grove (section 30), where it succeeds fully 100 feet of the Linden. Thus far it has not been identified east of Perryville.

Fauna.—The chert is extremely fossiliferous. The fossils are preserved as natural molds and casts and also as pseudomorphs of white silica. The most striking feature of the fauna is the unusual size of many of its species, which exceed their size in the other Linden formation by 25 to 50 per cent. While brachiopods predominate, bryozoa are very abundant in places and two trilobites, *Phacops* and *Homalonotus*, are common. The following species have been identified:

Faunal Table.

a =related species c =common cc=very common r =rare rr=very rare, known only by 1 or 2 specimens	Decaturville	Birdsong	New Scotland	Becraft	Oriskany
Favosites conicus Hall	c	cc	x	x	x
Pleurodictyum lenticulare (Hall)	r	c	x		x
Pholidops cf. *ovata* Hall	c		a		
Dalmanella planoconvexa (Hall)	cc	rr	x	x	x
Rhipidomella oblata (Hall)	cc	cc	x	x	x
Leptæna rhomboidalis Wilckens	rr	cc	x	x	x
Strophonella punctulifera (Conrad)	c	c	x	x	
Leptostrophia planulata (Hall)	c		x	x	
Leptostrophia beckii (Hall)	cc	c	x	x	
Leptænisca concava (Hall)	rr	rr	x		
Schuchertella woolworthana (Hall)	cc	c	x	x	
Chonostrophia jervensis Schuchert	cc			x	x
Eatonia singularis (Vanuxem)	c		x	x	
Eatonia medialis (Vanuxem)	c		x	x	
Delthyris perlamellosa (Hall)	rr	cc	x	x	
Meristella cf. *lævis* (Hall)	cc	a	a	a	a
Anoplotheca concava (Hall)	cc	cc	x	x	
Actinopteria communis (Hall)	rr		x		x
Homalonotus sp.	r		a	a	a
Phacops hudsonica Hall	cc	r	x		

Correlation.—The fauna of the Decaturville chert is closely allied to that of the Birdsong and the New Scotland, but there are affinities that relate it also to the Becraft. The Linden formations already described form an unusually long Helderbergian section, and a considerable time break and erosional interval must have separated this chert from these older formations which it overlaps with marked unconformity. The stratigraphic relations, therefore, indicate an age younger than the New Scotland. The faunal evidence is not out of harmony with the assignment of the formation to early Becraft time. It is true that the diagnostic fossils of the Becraft of the Appalachian trough, namely, *Aspidocrinus scutelliformis, Rhipidomella assimilis, Spirifer coninnus,* and *Leptocœlia flabellites,* are absent from this chert, but so likewise are the chief New Scotland guides such as *Eospirifer macropleura, Bilobites varicus, Anastrophia verneuili,* etc. While many of the species in this fauna also occur in the underlying Linden formations, the converse is not true, for less than 14 per cent of the Linden fauna passes up into the chert, many of the most characteristic Linden species being absent. Twelve of the nineteen species listed above are common to both the New Scotland and Becraft, although of these *Dalmanella planoconvexa* and *Leptostrophia planulata* are more at home in the Becraft than lower, while *Delthyris perlamellosa,* which is uniformly abundant in the New Scotland, is rare in this formation and in the Becraft. Of the remaining seven species, *Pleurodictyum lenticulare* and *Actinopteria communis* are not reported from the Becraft but occur in both the New Scotland and Oriskany. *Meristella* cf. *lævis* and *Homalonotus* sp. each have affinities in both New Scotland and Becraft, but the large size of the trilobite argues strongly for its later age. *Phacops huadsonica* and *Leptænisca concava* are elsewhere confined to the New Scotland, while *Chonostrophia jervensis,* an abundant species in the chert, does not occur below the Becraft. Finally, the unusually large size of most of the species argues for the later age of the fauna. This conclusion is made on the principle that species as a rule begin smaller than their norm and tend to culminate with their maximum size later in their life history. While this is a generalization of undoubted importance in paleontology, the robust character of this particular fauna must have been further aided by some especially favorable ecologic condition.

On the whole the balance of evidence favors the Becraft age of the formation, although its faunal resemblance to the New Scotland and the

lack of a decisive Becraft facies doubtless mean that it represents only a very early portion of this division of Helderbergian time. It is not surprising to find the Becraft represented in Tennessee, since it is undoubtedly present in the upper portion of the Bailey limestone of southern Illinois, which was a part of the same basin of deposition. The fauna listed by Savage from this formation includes *Aspidocrinus scutelliformis, Oriskania sinuata* var., and *Spirifer concinnus*. The Becraft sea, therefore, probably entered the Mississippi basin by the same route as that of New Scotland time.

Oriskanian Group

The upper Oriskany is typically developed in the Appalachian trough, where from Gaspe to southern Virginia it is characterized by brachiopods of unusually large size. Previous to 1913 this fauna had not been seen in the entire Mississippi basin, and it was generally believed that the Appalachian embayment of Oriskany time had not reached west of eastern Ontario. The discovery by Weller[1] of a typical New York Oriskany fauna in Ste. Genevieve County, Missouri, was, therefore, of the highest interest, since it extended the area of the embayment some 500 miles to the westward.

One of the chief contributions of the present study has been the discovery of an extensive development of typical upper Oriskany along the Western Valley of Tennessee, recording a further expanse of the Oriskany sea some 200 miles south of the Missouri locality. These strata are divided into the Quall and Harriman formations. The former name is applied to the basal siliceous limestone; the latter, to the superimposed novaculite, which is much the thicker and more extensive in distribution. They are separated from one another by an erosional unconformity.

The Camden chert of Tennessee and the Clear Creek chert of southern Illinois have previously been regarded[2] as equivalent in age to the upper Oriskany of the Appalachian trough, notwithstanding the fact that their fauna lacks all the large brachiopods which characterize the latter. The correlation, however, was based on the supposed absence from this region of the typical Oriskany and the faunal differences were attributed to the fact that the Camden sea was a southern

[1]Announced at the meeting of the Geological Society of America at Princeton, December 31, 1913.

[2]Schuchert, C., Bull. Geol. Soc. America, vol. 20, 1910, p. 544. Savage, T. E., Amer. Jour. Sci., vol. 25, 1908, pp. 436-438.

invasion and consequently belonged to a different faunal realm from that of the Appalachian trough. Evidence will be presented further on to show that the Camden and Clear Creek cherts belong with the Onondaga in the Middle Devonian and are not a part of the Oriskany.

QUALL FORMATIONS

(See Sections 19A, 21, 30.)

Definition.—The name Quall limestone is proposed for a thin formation which is best exposed on the farm of Mr. Jim Quall in the valley of Dry Creek, a small tributary entering the Tennessee near Walnut Grove. The total thickness does not seem to exceed 10 feet. Where freshly exposed, the limestone is light gray in color, rather fine-grained, and disposed in layers from 18 to 24 inches thick. It appears slightly magnesian, and highly siliceous. Upon deep weathering it breaks down into a very porous rotten white and yellow chert and yellow clay, in which fossils abound as free pseudomorphs in silica.

Distribution.—The best exposure of this formation may be seen at the roadside between the house and the barnyard on Mr. Jim Quall's place, half a mile east of Paulk's store, at Walnut Grove. A thickness of 10 feet of the limestone is exposed and its base is below drainage. The total thickness, however, is probably only a little greater. About 200 yards east of this section there is another exposure at the roadside, but at the ford, half a mile farther east, the formation is absent by erosion. A little over half a mile north of Mr. Quall's house, a low bluff exposes this limestone where it succeeds the Linden, and is overlain by Mississippian (Ridgetop) shale. The formation seems to be absent, due to interformational erosion, from the rest of the Western Valley, except for small remnants at two localities, Grandview and Linden. At the former place, which is eight miles west of Clifton, it is only 4 feet at a maximum and seems to be absent part of the way along the bluff. It is highly fossiliferous but deeply weathered to porous chert and yellow clay. Here it overlies the Ross member of the Linden and is succeeded by 40 feet of the Harriman novaculite.

Between the Hardin sandstone and Birdsong member of the Linden, at the town spring on the northeast edge of Linden, occurs a massive layer of muddy and cherty gray limestone, 30 inches thick, which Saf-

ford did not distinguish from the Linden. Foerste, finding it to contain *Spirifer murchisoni*, recognized its Oriskany age and correlated it with the Camden, believing the latter also to be Oriskany. However, it is certainly distinct from that formation. The writer has collected two very diagnostic Oriskany Spirifers, *S. arenosus* and *S. murchisoni*, and a large *Striatopora* which is very common in the Quall formation. While it may belong to the Harriman formation, it seems more probable that it is a remnant of the Quall limestone. Its muddy condition may indicate a proximity to the shore-line.

Contacts.—Because of the very localized distribution and exposures of this formation it is impossible as yet to demonstrate the nature of its contact with the Linden formation below. It is evident, however, from the age of its fauna, that a considerable interval must have intervened which in the Appalachian trough is represented by some hundreds of feet of strata of Becraft and lower Oriskany age.

The fact that it is thickest some twenty miles south of the known extent of the Harriman formation and is only locally present beneath it, with a maximum thickness of 4 feet, suggests a period of erosion separating it from this succeeding but closely related formation.

Fauna.—Fossils are abundant in the Quall limestone and may be easily secured as free pseudomorphs in the clay wherever the formation is weathering away. The fauna embraces only a few species, of which the following have been identified:

Edriocrinus cf. *becraftensis* Clarke
Striatopora sp.
Streptelasma sp.
Leptostrophia magnifica (Hall)
Plethorhyncha cf. *barrandei* (Hall)
Beachia suessana (Hall)
Spirifer arenosus (Conrad)
Spirifer murchisoni Castelnau
Spirifer perdewi Schuchert
Platyceras gebhardi Conrad

Correlation.—This fauna is clearly related to that of the upper Oriskany of the Appalachian trough and to that of the succeeding Harriman formation. The writer was at first much inclined to deal with this limestone as only a member of the latter. However, the stratigraphic relations seem to indicate that it is separated by an hiatus from the succeeding novaculite. The fauna, moreover, lacks many of the very characteristic species of the Harriman chert, and on the

other hand is distinguished by others, notably *Edriocrinus* cf. *becraftensis* (which is especially abundant) that do not appear in the higher formation. It has seemed necessary, therefore, to regard the limestone as a separate formation representing a brief and slightly earlier incursion of the Oriskany sea, followed after a short land interval by the greater spread of the Harriman formation.

HARRIMAN NOVACULITE

(See Sections 1, 5, 10, 12, 15, 17, 18, 21, 23.)

Definition.—This formation is named for Harriman Creek, a small tributary which joins Beech River about two and one-half miles west of Perryville. The stream arises in the "chert hills" east of Parsons, and bluffs of the formation border its valley on either side. The formation consists of white or buff colored novaculite, and carries a fauna of upper Oriskany age. It overlies the Quall limestone and is succeeded by the very similar Camden chert. The formation is most widely exposed in the vicinity of Perryville and Parsons, where it forms a belt of chert hills and has been extensively quarried for road metal.

Novaculite, a name referring to its use as hones or whetstones, is an extremely finely crystalline rock formed of quartz with more or less impurity of clay. Its composition is, therefore, identical with flint or chert, from which it differs only in being entirely crystalline, while they are partially, at least, non-crystalline or amorphous. In common parlance this type of rock usually receives the less exact but more familiar name chert, and thus one speaks of the Camden chert, the Clear Creek chert, etc., though both are really novaculite.

The Harriman chert or novaculite is nearly white on fresh exposure, but weathers to shades of yellow and buff. It is disposed in layers varying from a few inches to over a foot in thickness, and is very hard and brittle. Where exposed to weathering, it is thoroughly fractured into small angular fragments and in this condition so very closely resembles the Camden chert that only the fossils can be relied on to distinguish the two formations. Where freshly exposed, it seems to be whiter and more heavily bedded than the Camden chert.

Distribution.—The Harriman chert extends for a distance of over 75 miles along the Western Valley, ranging in thickness from 30 to 50 feet. A thickness of 55 feet is exposed near the north edge of the State (section 2). In the vicinity of Big Sandy, it is covered by the Camden chert, if present at all. Six miles north of Camden (sec-

PLATE 3.

CHARACTERISTIC ORISKANY SPECIES OF THE HARRIMAN CHERT FAUNA.

1, 5. *Spirifer murchisoni* Castelnau. Anterior and ventral views of this characteristic upper Oriskany shell.

2. *Oriskania saffordi* Dunbar. A species closely related to *Megalanteris ovalis* Hall, of the Oriskany.

3. *Chonostrophia complanata* (Hall). Ventral interior.

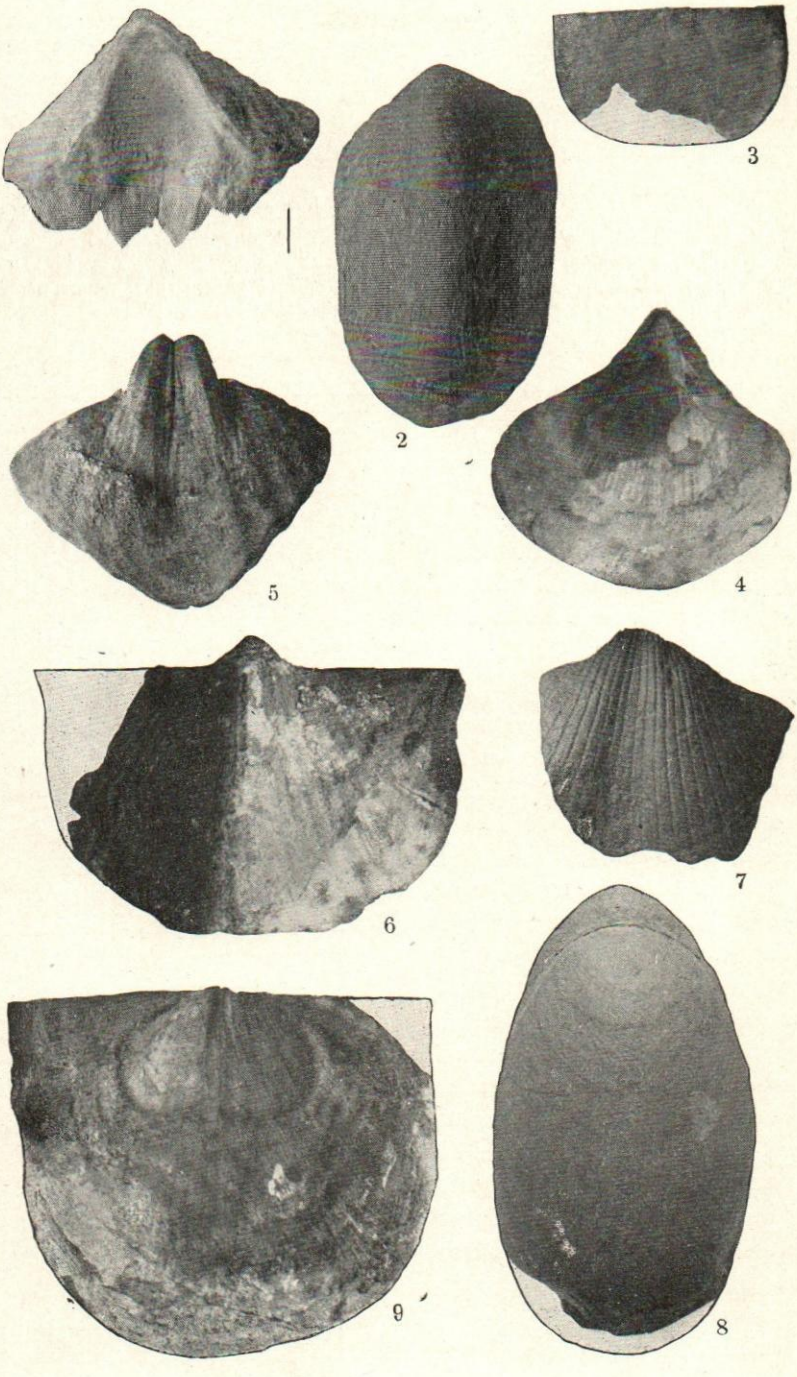
4. *Meristella lata* (Hall). Interior mold of the ventral valve. Note the vascular markings and the striation of the muscle pit.

6. *Spirifer arenosus* (Conrad). Interior mold of the dorsal valve of this very characteristic Oriskany species.

7. Cast made from the external mold of the ventral valve of the same specimen.

8. *Ren selæria ovoides* (Eaton). Cast made from an external mold of this typical upper Oriskany shell.

9 *Leptæna ingens* Dunbar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tion 3) it is locally absent, but south of this village it appears again on Cypress Creek (section 5). Numerous exposures occur farther south into central Decatur County, where it forms extensive chert hills. At Perryville, the formation measures 33 feet thick. While absent by erosion from the southern portion of Decatur County, sections at Grandview and Cerro Gordo, where it is over 40 feet thick, indicate that it once extended considerably farther to the south.

The buff colored novaculite exposed in the Wells Creek basin is provisionally referred to the Harriman formation on the basis of a single valve of *Spirifer murchisoni* (?), the only fossil yet found at this locality. It is exposed in the south bank of the Cumberland River about 1 mile southwest of Cumberland City, where it overlies the Linden. Its thickness at this locality cannot be accurately determined, but it is probably as much as 20 feet. The rock is extremely fractured in this region of sharp disturbance, and consequently deeply weathered at the surface. In this condition the lithology does not help to distinguish it as either Harriman or Camden chert, but the rarity of fossils is a character more often exhibited by the former formation.

Unconformity between the Harriman and the Linden.—In successive outcrops the Harriman novaculite rests upon the mid-Silurian and various members of the Linden. In sections 4½ miles north (section 9), 7 miles northeast (section 7), and 8 miles southeast (section 13) of Holladay, the Linden exceeds 45 feet in thickness, while it is entirely absent at another locality on Wolf Creek about 1½ miles east of this village, and here the Harriman chert directly succeeds a fossiliferous mid-Silurian limestone. The Linden appears again, however, within half a mile upstream from this last locality, and is more extensively exposed on Sycamore Creek about 1 mile west of Wolf Creek. At Perryville the novaculite rests on the bryozoa zone of the Birdsong member of the Linden, and at Decaturville, 7 miles to the southwest, it follows the Decaturville chert member. At Grandview (section 21A) it is separated from the Ross member of the Linden by remnants of both the Decaturville chert and Quall formations. Within 10 miles to the southeast (section 25) 100 feet of additional Helderbergian limestone succeeds the Ross limestone which is absent at both Grandview and Cerro Gordo beneath the Harriman. This stratigraphic evidence of a lost interval between the Linden and Harriman formations is corroborated by the difference in age of their faunas.

During the intervals of Becraft and lower Oriskany time some 200 feet of limestones and chert were deposited in the Appalachian trough which are not represented in Tennessee.

Fauna.—The Harriman formation is unevenly fossiliferous. Near the mouth of Big Sandy River where the formation is 55 feet thick it seems to be barren of fossils except at the top. The portion exposed at Cypress Creek is very fossiliferous, and here was secured the largest and most typical fauna; that exposed at Holladay is sparingly so; at Perryville it is slightly fossiliferous in the upper and lower portions, while the middle third contains an abundance of fossils. It is only moderately fossiliferous in the section at Grandview. In general, it is more apt to be barren of fossils than the very similar Camden "chert." The fossils are preserved as natural molds and casts which often show details of surface sculpture or interior structure in a perfection scarcely to be excelled. The fauna is listed and the range of the various species indicated in the table below. The relative abundance of each in the fauna is given in the first column. The last column, showing a correlation with the Little Saline limestone of Missouri, is based on a small collection at the Peabody Museum, Yale University, made by Professor Weller's son. Some of the characteristic fossils of the Harriman chert are illustrated in Plate 3.

Faunal Table.

a =related species c =common cc=very common e =Upper Devonian elsewhere r =rare rr=very rare	Harriman	Camden Chert	Upper Oriskany		Lower Oriskany		Little Saline ls.
			N. Y.	Md.	N. Y.	Md.	
Zaphrentis sp.	rr						
Zaphrentis parsonsensis Dunbar	rr						
Pleurodictyum lenticulare (Hall)	rr						
Leptæna ingens Dunbar	cc		a	a			a
Leptostrophia magniventra (Hall)	rr		x	x			a
Leptostrophia oriskania Clarke	r		x				x
Anoplia nucleata (Hall)	rr	cc	x	x	x		
Chonetes hudsonicus mut. *camdenensis* Dunbar	r	cc					
Chonostrophia complanata (Hall)	c		x	x	x	x	x
Eatonia peculiaris (Conrad)	r	r	x	x	x		x
Plethorhyncha cf. *barrandei* (Hall)	rr			x			a
Rensselæria ovoides (Eaton)	cc		x	a			a
Oriskania saffordi Dunbar	cc		a	a			a
Spirifer murchisoni Castelnau	cc		x	x	x	x	x

Faunal Table—Continued

a=related species c =common cc=very common e =Upper Devonian elsewhere r =rare rr=very rare	Harriman	Camden Chert	Upper Oriskany		Lower Oriskany		Little Saline ls.
			N. Y.	Md.	N. Y.	Md.	
a =related species	r		x	x	x		x
Spirifer paucicostatus Schuchert	cc						
Spirifer (?) nearpassi Weller	c	r			e		
Metaplasia pyxidata (Hall)	c	rr	x	x	x		
Cyrtina rostrata (Hall)	c	r	x	x	x		
Meristella lata (Hall)	cc		x	x	x		x
Meristella rostellata Schuchert	cc			x			
Anoplotheca dichotoma (Hall)	cc		x	x	x		
Leptocœlia flabellites (Conrad)	r	cc	x	x	x	x	
Diaphorostoma ventricosum (Conrad)	cc		x	x	x		
Platyceras gebhardi Conrad	c		x	x			
Plectonotus derbyi (?) Clarke	rr		e				

Correlation.—The preceding table shows the Harriman fauna to be very distinct from that of the succeeding Camden chert. Seventy-five per cent of the fauna (including all the large and really characteristic Oriskany species) is lacking in the Camden and, vice versa, 86 per cent of the latter fauna does not appear in the Harriman. Of the six species which are common to both, *Anoplia nucleata, Eatonia peculiaris, Cyrtina rostrata* and *Leptocoelia flabellites* range both through the Oriskany and Onondaga in other regions.

On the other hand, the faunal relations of these strata in Tennessee with the upper Oriskany of New York and Maryland are very close, especially when the great distance of 600 to 900 miles which separates these regions is considered. Nineteen of the twenty-five species in the Tennessee fauna occur elsewhere in the upper Oriskany, thirteen of them being common to both Maryland and New York. With the lower Oriskany of Maryland there is little in common. It must be noted that two very characteristic species of the upper Oriskany of the Appalachian trough, namely, *Rhipidomella musculosa* and *Hipparionyx proximus*, have not been found in Tennessee. Nevertheless, the association of so many very characteristic species as *Leptostrophia magniventra, Chenostrophia complanata, Plethorhyncha* cf. *barrandei, Rensselaeria ovoides, Spirifer murchisoni, S. arenosus, Meristella lata, Anaplotheca dichotoma*, and *Platyceras gebhardi* is strong-

ly indicative of equivalence with the upper Oriskany and direct communication with the Appalachian trough.

The Little Saline limestone of Ste. Genevieve County, Missouri, is a pure, white, crystalline limestone. Its fauna has not yet been described and Weller's publication is awaited with great interest. The writer made a brief visit to this locality, however, and secured a small collection of fossils, which, with others sent to Yale University by Professor Weller's son, enabled some preliminary comparison to be made, and, though it may appear surprising, the two faunas seem to show less resemblance to each other than either does to that of the Appalachian trough. Of eleven species identified by the writer from the Little Saline, only six occur in Tennessee. Some of the most common and characteristic of the Tennessee species, such as *Meristella rostellata, Anoplotheca dichotoma, Spirifer paucicostatus,* and *Diaphorostoma ventricosum* appear to be absent in Missouri, and on the other hand, several of the common species of the Little Saline do not occur in Tennessee. Although the number of identities in these faunas will doubtless be increased when the Little Saline fauna is fully known, nevertheless the lack of agreement is emphasized by the substitution of certain related but not identical species such as the large *Renssalaeria ovoides* in Tennessee for the small slender *R marylandica* (?) in Missouri, *Plethorhyncha* cf. *barrandei* for *P. speciosa* (?), and *Leptaena ingens* for *L. ponderosa.*

MIDDLE DEVONIAN SERIES

Ulsterian Group

The Ulsterian group in western Tennessee consists of two formations, the Camden chert and the Pegram limestone—the former an earlier invasion from the southwest, the latter representing a brief incursion of the Onondagan coral fauna which apparently spread southward into Tennessee from the Kentucky-Ohio basin where it was so well developed at the Falls of the Ohio.

The Camden chert has been previously considered an Oriskany formation, but it is one of the chief conclusions of this study that it forms an early part of the Middle Devonian. As early as 1856[1] this yellow "chert" or novaculite was described in southwestern Illinois by Worthen, who named it the Clear Creek chert and correlated it

[1]Worthen. Geol. Survey Illinois, vol. 1, pp. 126-129.

with the Oriskany sandstone of New York. In Tennessee it was still considered a part of the succeeding Mississippian chert (Fort Payne) until 1899, when Safford and Schuchert[1] described it as the Camden chert. These authors noted the absence from this fauna of the large brachiopods which are so characteristic of the upper Oriskany as it is developed in New York and Maryland, and therefore referred it to a somewhat lower horizon of the Oriskany.

When in 1907 Savage[2] restudied the Clear Creek in southern Illinois, he found it to pass apparently by continuous deposition into the Onondaga. The evidence for this transition is an interfingering of the upper layers of the former and the basal layers of the latter. He also clearly showed the intimate relation of the fauna of the Clear Creek to that of the succeeding Onondaga. Since, however, the typical Oriskany was believed to be absent from the southern Mississippi Valley, and the Clear Creek fauna was recognized to be a southern invasion and consequently from a different faunal realm, he considered the latter late Oriskany, practically equivalent in age to that of New York. He, therefore, believed deposition to have been continuous in southern Illinois from Lower into Middle Devonian time.

Since then Weller has shown that the typical Oriskany of the Appalachian trough did invade this region, though the relation of his Little Saline limestone to the Clear Creek chert could not be shown. It has been one of the main points of interest in the present study to show that in the Harriman formation of western Tennessee the typical upper Oriskany was more widely developed in the Mississippi Valley and that it underlies the Camden chert. A critical study of larger collections of fossils from the latter shows that the faunal affinities of the Camden chert are decidedly more Onondagan than Oriskanian. As the evidence has accumulated there seems to be no reason for retaining this formation in the Oriskany. It may be considered the earliest invasion of the southern Onondagan seas, probably equivalent, at least in part, to the Schoharie and Esopus grits which are developed in eastern New York.

[1]Safford and Schuchert. Amer. Jour. Sci., vol. 7, pp. 429-432.
[2]Savage. Bull. 8, Geol. Survey Illinois, pp. 107-116.

CAMDEN CHERT

(See Sections 2-6.)

Character.—The Camden chert was named by Safford[1] for the town of Camden, Tennessee, where it is typically developed and widely exposed. It is a white to buff-yellow, brittle novaculite. Athough flinty hard and very resistant to decomposition, the ultimate effect of weathering is to reduce the rock to finely powdered silica mixed with more or less clay, the latter being an insoluble impurity in the novaculite. The character of the formation is best shown in numerous quarry faces where it is disposed in thin hard layers, usually from 1 to 3 inches thick, rarely as much as 8 or 10 inches. These layers

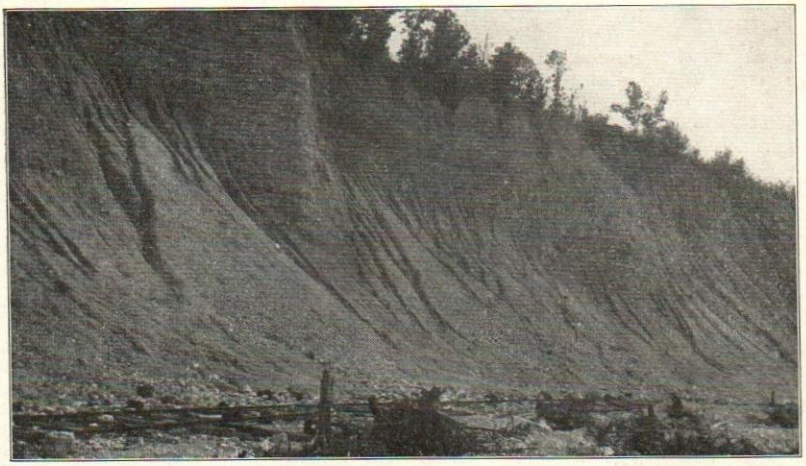


FIGURE 10.—A typical exposure of the Camden novaculite in the quarry of the Memphis Stone and Gravel Co., which is located in a bluff on Cypress Creek about two miles southeast of Camden, Tennessee.

are commonly separated by softer gritty clay along the bedding planes. Locally there are irregular and more or less vertical pockets of pure white powdered silica, apparently the result of leaching along groundwater channels. The novaculite breaks with an irregular fracture into angular, sharp-edged fragments. It is always extremely fractured so that under the influence of weathering even a fresh quarry face quickly breaks down into a talus slope (Fig. 10), while natural outcrops ap-

[1]Safford and Schuchert, op. cit., p. 429.

pear only as a loose rubble of rough angular pieces of chert, mostly smaller than one's fist. So characteristic is this finely broken-up condition of the rock that the quarries where it is extensively worked for ballast or road metal are commonly called "gravel pits."

The brecciated condition of the formation is to be ascribed to the warping and compressive stresses to which western Tennessee has been subjected in the geologic past while mountains were being formed to the east in Appalachia or to the southwest in Oklahoma. The softer limestones and shales of the valley have yielded to these compressive forces by mashing; but this deformation, being distributed throughout the formation, is so slight at any point that it leaves almost no visible evidence of its effect. The extreme hardness and brittleness of the novaculite, however, caused it to yield only by crumpling and breaking. It is very notable that the bedding of the Camden chert is seldom quite horizontal for more than a few yards at a time even where the adjacent shales or limsetone show no disturbance. It is commonly thrown into low open folds with frequent sharp crumplings or small close folds only a few yards across but with dips ranging from 45 to 90 degrees. Thrust faults of a few inches throw are likewise not uncommon.

In the Camden chert, the Western Valley has one of the finest road metal deposits of the State. The thin-bedded and minutely fractured condition of the rock facilitates its quarrying and crushing to suitable fineness, while its hardness and very slight solubility make it durable. It also has the important quality of "bonding" well so as to form a hard surface under traffic and weather.

The typical character of the formation is uniformly maintained in every exposed section, except the one about to be described (section 6). At the "whirl" on Buffalo River a series of interbedded limestone and chert is exposed for a thickness of 45 feet above water-level, being directly succeeded by the Pegram limestone with its Onondagan coral fauna. The yellowish chert is disposed in layers from 2 to 9 inches thick, which alternate with similar thicknesses of the dense, bluish gray limestone. The presence of certain very diagnostic fossils, such as *Amphigenia curta*, strongly suggests the reference of these strata to the Camden chert formation, though both the fauna and lithology are so different from those of the rocks exposed at Camden that they can hardly be considered equivalent strata. They

are believed to be higher stratigraphically than any part of the formation elsewhere exposed. Except at this locality on Buffalo River, the Camden is always unconformably overlain by much later strata of late Devonian or even Cretaceous age, and it is highly probable that its top was more or less eroded away during later middle Devonian time when land conditions prevailed in western Tennessee. But since the Pegram limestone must have followed closely upon the deposition of the Camden chert, its presence at the "whirl" makes it equally probable that here the upper portion of the chert has been protected. The absence from the fauna of these layers on the Buffalo River of many elements of the Camden fauna, and the presence of certain Onondagan species such as *Spirifer macrothyris* also strongly support the belief that these strata are higher than those exposed at Camden. They are therefore to be regarded as the transition beds between the true Camden and the Pegram.

Distribution.—The Camden chert attains a maximum exposed thickness of 164 feet along Cypress Creek southeast of Camden (section 5), while the log of the city well on the courtyard at Camden reports a thickness of 275 feet of chert. This, however, undoubtedly includes the Harriman chert, of which the thickness here is not known. The Camden is present further south along Birdsong Creek and extending into northern Decatur County, but it does not seem to reach as far south as Parsons and Perryville, where only the Harriman has been identified. It forms extensive exposures along the lower course of Big Sandy River, finally disappearing beneath the Cretaceous sands near the north edge of the state. It appears at the surface again in southwestern Illinois, with a maximum thickness of 237 feet, where it is called the Clear Creek chert. In general, the formation is thickest in the more western exposures and thins out toward the east and southeast by overlap, being absent at Pegram and Newsom in Cheatham County and again on Mill Creek in Wayne County, where the directly succeeding Pegram limestone is preserved. It is also reduced in thickness toward the south by later erosion.

It is believed that the Camden chert represents an embayment of the seas from the southwest and, this being true, the formation probably once covered all of Tennessee west of the exposures described. Whether it was later eroded away or is still preserved beneath the heavy covering of later deposits is not known. On the other hand,

in the Ouachita Mountains of west central Arkansas there is a great development of novaculite, parts of which have been tentatively correlated with the Camden formation by Ashley,[1] Ulrich,[2] and Miser.[3] Miser describes three lithologic divisions of the Arkansas novaculite —"a lower one, made up almost entirely of massive white novaculite; a middle one consisting mainly of thin layers of dense dark colored novaculite interbedded with shale; and an upper one consisting chiefly of massive, highly calcareous novaculite. These divisions vary in thickness and character from place to place. . . . The only remains of animals thus far found in the formation consist of numerous conodonts in a pebbled novaculite conglomerate and of conodonts and small linguloids and sporangites in associated shales, which have been obtained from the middle division of the formation at Caddo Gap. Upon them E. O. Ulrich bases the opinion that the middle and upper divisions of the formation are to be correlated with the Woodford chert in the Arbuckle Mountains in southern Oklahoma and with the Chattanooga shale. He assigns these two formations to the Mississippian series of the Carboniferous and accordingly regards the middle and upper division of the Arkansas novaculite as belonging to that series, but the United States Geological Survey tentatively places these two divisons of the novaculite in the upper Devonian. The lower division is separated from the middle one by an unconformity of at least local extent and, by its lithologic character and stratigraphic relations, is correlated with the Camden chert of western Tennessee." This type of rock occurs at so many horizons, however, in the southern part of the United States that the correlation of the Camden chert with the Arkansas novaculite can only be tentative until fossils are found in the latter.

Unconformity below the Camden.—The magnitude of the time interval or break between the Camden and the Linden has not been appreciated by previous workers. When Foerste's studies of these strata were made, the Camden chert was regarded as lower Oriskany in age and he concluded that: "The writer has not seen any locality where it is possible to draw any sharp line between these formations.

[1]Ashley, G. H. The Camden chert—an ideal road material. Resources of Tenn., vol. 1, No. 2. 1911, p. 43.

[2]Ulrich, E. O. Discussion at the Albany meeting of the Geological Society of America, Dec. 29, 1916.

[3]Miser, H. D. Manganese deposits of the Caddo Gap and De Queen quadrangles, Arkansas. Bull. 660, U. S. Geol. Survey, 1917, p. 68-71.

Lithologically, the formations are alike, and paleontologically, the change from the Linden bed fauna to the Camden chert fauna appears to be gradual rather than abrupt."[1]

To be sure, the highest member of the Linden is a yellowish to gray chert, but chert, like soil, is a general term embracing widely dissimilar products of different processes and of different sources, and the porous gray chert of the Linden differs so widely from the dense novaculite of the Camden that no significance whatever can be attached to the lithologic resemblance. Moreover, the present writer shows that the faunas of these formations differ widely. In the Linden fauna of over one hundred species and the Camden fauna of forty-three, there are but three species in common, namely, *Eatonia peculiaris*, *Leptæna rhomboidalis*, and *Atrypa reticularis*. Each of these has a long range, and consequently no significance.

On Rushing Creek, 6 miles north of Camden (section 3), the Camden chert rests directly on the bryozoa zone of the Linden, certainly with no appearance of either a faunal or lithologic transition, although the beds appear conformable. Easily seen unconformities, however, are the exception in the Paleozoic strata of western Tennesee, though many clearly determinable breaks occur in the sequence. The validity of the faunal evidence of an hiatus between these formations is clearly established by the presence, in other sections, of the Harriman chert, which has been shown to succeed the Linden with distinct erosional unconformity and to underlie the Camden chert.

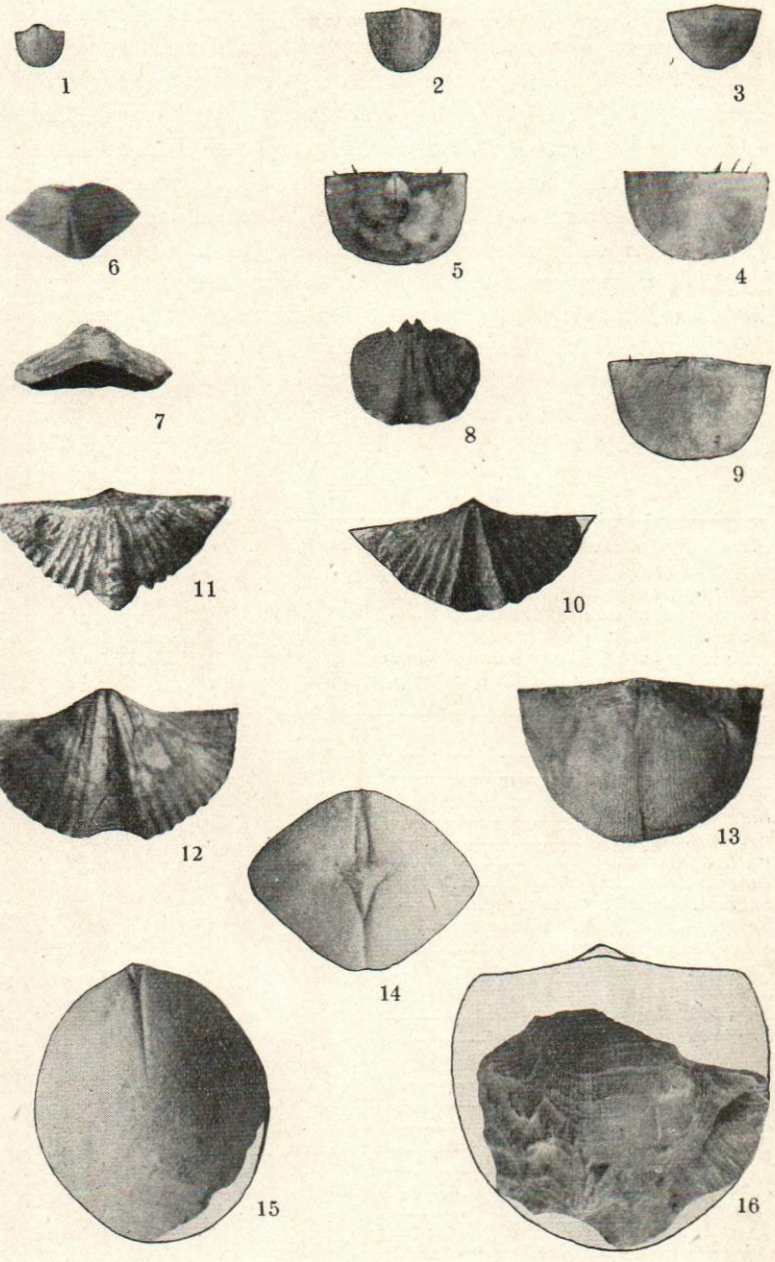
The actual contact of the Camden on the Harriman formation has not been seen by the writer. Contacts in cherts are inherently difficult to locate and especially so when the rock is thoroughly fractured. While numerous quarries in either formation were studied, only one, that on Cypress Creek, exposes both of them, and unfortunately the contact here is already obscured by talus from the Camden chert. To see the contact in natural exposures is well-nigh hopeless, since the novaculite appears only as a loose rubble and the bedding is then obscure or even obliterated. A comparison of different sections, however, shows the unconformable relations of the two novaculites. On the lower course of Big Sandy River (section 1) the Harriman formation is at least 55 feet thick. At the section on Rushing Creek (section 3), it is entirely absent and the Camden chert lies directly on

[1]Op. cit., 1903, p. 686.

PLATE 4.

CHARACTERISTIC FOSSILS OF THE CAMDEN CHERT.

1. *Anoplia nucleata* (Hall). A small specimen, such as is common in the Camden.
2. Large specimen of the same. Ventral valve.
3. Dorsal valve of the same.
4-5. *Chonostrophia reversa* (Whitfield). Characteristic of the Onondaga and very common in the Camden.
6-7. Posterior and anterior views of *Pentagonia unisulcata* (Conrad).
8. *Leptocœlia flabellites* (Conrad).
9. *Chonetes hudsonicus* mut. *camdenensis* Dunbar.
10-11. *Spirifer hemicyclus* Meek and Worthen. Ventral and dorsal views, respectively, of interior molds.
12. *Spirifer worthenanus* Schuchert. The lateral slopes are more arched and the sinus shallower and broader than in the preceding species.
13. *Eodevonaria arcuata* (Hall). Typical of the Onondaga.
14-15. *Amphigenia curta* (Meek and Worthen).
16. A squeeze from a cast of a large specimen of *Atrypa reticularis* (Linnæus), having wide growth frills.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the Linden. A short distance farther south, however, it is present again near Camden, where only the upper portion is exposed (section 4), and it has a thickness of over 30 feet in the vicinity of Perryville and Parsons. The sharpness of the faunal break, already emphasized, also argues for an hiatus between the Harriman and Camden formations.

Fauna.—The fossils of the Camden chert are preserved as sharp natural molds and casts, of both exterior and interior, in which details of sculpture, muscle scars, etc., are shown in unusual perfection. The formation as a whole is abundantly fossiliferous, but sparingly fossiliferous layers alternate with others which are replete with fossils. The fauna is a small one in which brachiopods overwhelmingly predominate. In the following table the geologic range of each species of the fauna is shown. Some of the characteristic fossils are illustrated in Plate 4.

Faunal Table.

a =Closely related species c =common cc=very common H =occurs in the Hamilton r =rare, less than 10 specimens rr=very rare, being represented in our collection by only 1 or 2 specimens. x —Denotes occurrence.	Camden	Clear Creek	Onondaga	Upper Oriskany	Lower Oriskany
Zaphrentis sp.	r	a			
Rhodocrinus sp.	rr				
Rhopalonaria robusta Ulrich & Bassler	rr				
Lingula cf. *ligea* Hall	rr		a		
Orbiculoidea sp.	rr				
Pholidops areolata Hall	r	x	x		
Rhipidomella alsa? (Hall)	rr		x		
Schizophoria cf. *propinqua* (Hall)	rr	x	a		
Leptæna rhomboidalis Wilckens	r	x	x	x	x
Stropheodonta inæquiradiata Hall	r		x		
Stropheodonta cf. *hemispherica* Hall	rr		a		
Stropheodonta cf. *blainvillei* (Billings)	r	a	a	a	
Schuchertella pandora (Billings)	cc	x	x		
Eodevonaria arcuata (Hall)	cc	x	x		
Chonetes hudsonicus mut. *camdenensis* Dunbar	cc	x			
Chonetes fornacula Dunbar	r				
Anoplia nucleata (Hall)	cc	x	x	x	
Chonostrophia reversa (Whitfield)	cc	x	x		
Eatonia peculiaris (Conrad)	r	x	x	x	x
Camarotœchia cf. *sappho* (Hall)	rr	x			
Centronella glansfagea (Hall)	r	x	x		
Amphigenia curta (Meek & Worthen)	cc	x	x		
Oriskania condoni (McChesney)	c	x			

Faunal Table—Continued

a =closely related species c =common cc=very common H =occurs in the Hamilton r =rare, less than 10 specimens rr=very rare, being represented in our collection by only 1 or 2 specimens. x —Denotes occurrence.	Camden	Clear Creek	Onondaga	Upper Oriskany	Lower Oriskany
Atrypa reticularis (Linnaeus)	r	x	x	x	x
Spirifer (?) nearpassi Weller	r	x		x	
Spirifer duodenarius (Hall)	c	x	x		
Spirifer acuminatus (Conrad)	rr		x		
Spirifer unicus Hall	rr		x	a	
Spirifer hemicyclus Meek & Worthen	cc	x			
Spirifer worthenanus Schuchert	cc	x			
Reticularia fimbriata (Conrad)	r		x	x	x
Metaplasia pyxidata (Hall)	rr	x		x	
Cyrtina rostrata (Hall)	r	a	x	x	x
Meristella lentiformis Clarke	r	x		x	
Pentagonia unisulcata (Conrad)	r		x		
Leptocœlia flabellites (Conrad)	cc	x	x	x	x
Phacops cristata Hall	c	x	x		
Dalmanites myrmecophorus (Green)	rr		x		
Orthonychia cf. *tortuosa* (Hall)	r	x	a	a	
Strophostulus (?) cancellatus Meek & Worthen	cc	x	a		
Cypricardinia cf. *distincta* Billings	rr	a	a		
Actinopteria communis (Hall)	r	a		x	

This list includes only the fauna of the typical novaculite. The higher layers of alternating chert and limestone, exposed at the "whirl" on Buffalo River, have yielded the following species: *Rhipidomella* cf. *penelope* (Hall), *Leptæna rhomboidalis, Stropheodonta* cf. *blainvillei*, S. cf. *hemispherica, Schuchertella pandora, Chonostrophia reversa, Eatonia peculiaris, Oriskania condoni, Amphigenia curta, Leptocœlia flabellites, Spirifer macrothyris* Hall, S. *hemiculus* (?), and *Meristella lentiformis.*

Correlation.—That the clear Creek chert of southwestern Illinois is a northward extension of the same strata, which in Tennessee are called the Camden chert, cannot be doubted. The lithology is identical and the faunas very similar. Of the forty-two species identified from Tennessee, twenty-four have been identified in Illinois and five more have close affinities which probably would prove to be identities on comparison. Even these figures, however, fail to express the close resemblance of the faunas, for the twenty-nine species just noted embrace practically all those of frequent occurrence in either fauna. Of

the remaining thirteen species, nine are extremely rare, and four others very rare. The most notable difference is the common occurrence in Illinois of *Charionella scitula* and *Oriskania navicella* n. var., which have not been found in the Camden chert. Nevertheless, considering the fact that the faunas were collected over 100 miles apart, the resemblance is very close.

Oriskany vs. Onondaga.—One-fourth of the Camden fauna is peculiar to this southwestern embayment and is not known in either standard Oriskany or Onondaga formations. Most of these species have little or no stratigraphic importance: such are: *Zaphrentis* sp., *Rhodocrinus* sp., *Rhopalonaria robusta, Lingula* cf. *ligea, Orbiculoidea* sp., *Chonetes camdenensis, C. fornacula, Camarotoechia* cf. *sappho, Spirifer hemicyclus, S. worthenanus, Orthonychia* cf. *tortuosa.* While Spirifers in general are important in correlation, the writer is unable to make any significant comparisons with the two species mentioned. The rest of the list is comprised of genera which are of little service in correlation or of species which could not be certainly identified.

Of the remaining indigenous species, *Oriskania condoni* would favor the Oriskany, since the genus is elsewhere confined to that formation. But in contrast *Schizophoria* cf. *propinqua, Stropheodonta* cf. *hemispherica, S.* cf. *blainvillei, Cypricardinia* cf. *distincta* are closely related if not identical with Onondaga species, so that the balance falls in favor of the latter.

Seven species range through both Oriskany and Onondaga and may therefore be eliminated from consideration. Of the remaining nineteen species, four are elsewhere confined to the Oriskany. It is surprising to find in this fauna *Spirifer nearpassi* of the lower Oriskany of New Jersey, but from the literature it is impossible to distinguish our specimens from that species. *Metaplasia pyxidata* is a characteristic fossil of the upper Oriskany and may be considered of considerable importance. *Meristella lentiformis* loses most of whatever value it might have, since Savage reports *M.* cf. *lentiformis* from the Grand Tower (lower Onondaga) formation of southern Illinois. *Actinopteria* of this collection has no particular value because of its fragmentary condition, and may be disregarded.

The sum of the evidence in favor of the Oriskany age of the Camden chert is, therefore, one characteristic and widely known species, a second but little known, two others of minor significance, and a representative of the Oriskany genus *Oriskania.* It scarcely needs say-

ing, however, that only the broadest correlation can be based on generic identifications.

Several of the Onondaga species also have but little value, such, for example, as *Pholidops areolata, Rhipidomella alsa* (*?*) and *Schuchertella pandora.* But on the other hand the assemblage of such characteristic Onondaga forms as *Chonostrophia reversa, Centronella glansfagea, Spirifer duodenarius, S. acuminatus, Pentagonia unisulcata, Phacops cristata, and Dalmanites myrmecophorus* is of the highest significance.

When such faunal evidence is corroborated by the facts that the formation is separated by an erosional interval from the typical upper Oriskany which it overlies, and that it passes without a break in deposition into a recognized Onondaga formation (the Grand Tower of Illinois), the conclusion that the Camden chert belongs with the Onondaga in the Middle Devonian becomes inevitable.

Succeeding the Clear Creek chert in southern Illinois, the Grand Tower formation is about 150 feet thick. The characteristic and widespread Onondaga coral fauna does not appear here until about the middle of the formation. Savage's studies have led to the conclusion that its appearance marks the first confluence of this southern embayment with the northeastern one whence the corals came. He believes both the corals and cephalopods are present in New York in lower strata equivalent to the lower half of the Grand Tower. The inclusion of the Clear Creek in the Ulsterian series makes a thickness of over 300 feet of strata in this southern embayment before the advent of the coral fauna. The incursion of this embayment must therefore have taken place very early in the Middle Devonian, and the Camden (and Clear Creek) chert may be partially at least the time equivalent of the Esopus and Schoharie grits of New York.

The geographic distribution of the Camden and Clear Creek formations, the absence of equivalent strata over a wide region separating them from the Appalachian trough, and the large percentage of indigenous species in their fauna, all suggest that the Camden embayment did not come from the north or east. The only alternative is a southern invasion, and the belief that the fauna came from the south is confirmed by faunal affinities[1] with the Middle Devonian Maecurú

[1]Schuchert, C. Geology of the Lower Amazon region. Jour. Geology, vol. 14, p. 737.

sandstone of the province of Para, Brazil. The following close affinities and identities may be noted:

Camden chert	Maecurú sandstone
Stropheodonta cf. *blainvillei*	*S. perplana*
Anoplia nucleata	*A. nucleata*
Chonetes camdenensis	*C. comstocki*
Amphigenia curta	*A. elongata*
Spirifer duodenarius	*S. duodenarius*
Leptocœlia flabellites	*L. flabellites*
Actinopteria communis	*A. eschwegii*

Anoplia nucleata was identified in the Maecurú fauna by Clarke, who regards its presence as very significant of northward connections. This species, *Amphigenia curta*, and *Leptocoelia flabellites*, are three of the most common forms in the Camden chert.

PEGRAM LIMESTONE

(See Section 6.)

Character and Distribution.—The Pegram limestone was named by Foerste[1] for its outcrop near Pegram, Tennessee. It is a rather pure, heavily bedded, light gray limestone, reaching a maximum thickness of 12 feet at Pegram but thinning to only 3 feet at Newsom, where another small outcrop occurs. At this locality it overlies the mid-Silurian Lego limestone. Here it has yielded the very diagnostic Onondaga blastid, *Nucleocrinus verneuili*, and in addition, *Stropheodonta demissa*, *S. perplana*, *Rhipidomella penelope*, and *Nucleospira concinna*.

The next exposure of the limestone is over 50 miles to the west, at the "whirl" on Buffalo River, where it is only 3 feet thick and directly succeeds the Camden chert formation. While the lithology is similar to that at Pegram, the limestone is here characterized by many Onondaga corals. The fauna includes species of *Heliophyllum*, *Blothrophyllum*, *Cystiphyllum*, *Cyathophyllum*, *Cladopora*, and bryozoa. *Cyathophyllum rugosum* was identified, but it was impossible to recognize more than a few of the many corals present because of the massive character of the rock and the very limited exposure.

One other occurrence of the Pegram limestone is known on Mills Creek near Fortyeight P. O. in Wayne County. Drake, who identified the formation at this locality, describes it as "nearly 6 feet of pebbly,

[1]Foerste, A. F. Bull. Geol. Soc. America, vol. 12, 1901, pp. 425-426.

coarsely crystalline gray limestone."[1] The writer has not seen this section.

The four small and widely separated exposures noted above constitute the known present occurrence of the formation, but it is evident from their distribution that the Pegram limestone was once far more extensive, probably covering much of western Tennessee.

Correlation.—The formation is correlated with the Jeffersonville limestone of Indiana because of the presence of the corals, and especially of *Nucleocrinus verneuili.* It is probably separated by a short break in deposition from the Camden chert below, though no evidence of a break was seen in the small exposure where it succeeds the latter. In southern Illinois, however, the Clear Creek chert (a more or less exact equivalent of the Camden chert) passes without a break into the Grand Tower (Onondaga) limestone. The Jeffersonville coral fauna first appears about the middle of the latter, *i. e.*, about 75 feet above the top of the Clear Creek, so that if the corals in the Pegram hold an equivalent horizon in Tennessee, the lower half of the Grand Tower is not here represented. It then gives a measure of the break in deposition in Tennessee. However, the land must have remained very low to allow the subsequent wide pulsation of the waters free of muds but crowded with corals.

UPPER DEVONIAN SERIES

CHAUTAUQUAN GROUP

CHATTANOOGA SHALE

(See Sections 6, 15, 19A and C, 21A, 25, 29, 30.)

Character.—The Chattanooga shale formation consists of two members, a basal sandstone and the "black" shale proper. The basal Hardin sandstone is generally a rather fine-grained, muddy, gray sandstone composing a single massive layer. Exceptionally its base is conglomeratic. Crystals and concretions of pyrite are common and on weathering they give rise to rusty specks and blotches. The sandstone is locally absent at many localities and generally ranges from a few inches to 3 or 4 feet thick, though an exceptional thickness of 15 or 16 feet occurs at Olive Hill.

The shale proper is a highly carbonaceous, black, fissile shale of fine and even grain, which splits like slate into very thin flat sheets.

[1]Drake, N. F. Resources of Tenn., vol. 4, No. 3, 1914, p. 105.

It gives a petroliferous odor when struck with a hammer, and upon heating smells distinctly of petroleum. Crystals and concretions of pyrite are abundant and gypsiferous layers have been found near its base.

Distribution and Stratigraphic Relations.—The Chattanooga shale is a widespread formation, extending from the Western Valley to the mountains of East Tennessee and from Alabama into Kentucky, overlapping many other formations ranging in age from Ordovician to Middle Devonian. In central Tennessee, it attains a considerable thickness, but in the Western Valley is uniformly thin and locally absent at many places, apparently due to later erosion. While in general ranging between 2 and 10 feet thick, a maximum of 22 feet is reported from Wayne County.

The shale overlies the Harriman chert in the Wells Creek basin near Cumberland City, while in the vicinity of Camden it is separated from that formation by over 160 feet of Camden chert. At the "whirl" in Buffalo River the Hardin sandstone is not developed and the shale rests on the Pegram limestone. At Perryville and at Linden the formation is well exposed, the sandstone being about 3 feet thick and the shale fully 10 feet. At the former locality it rests on the Harriman chert, and at the latter overlaps a remnant of this formation on to the Linden, while 1½ miles south of the village it rests on the Decatur (Middle Silurian) limestone, over 60 feet of strata which was preserved at Perryville, 13 miles to the west, having been eroded away before its deposition. At Grandview, the Hardin sandstone is about 3 feet thick where it succeeds 40 feet of the Harriman chert, but at Olive Hill it reaches a thickness of 16 feet and the "black" shale of 10 feet or more. Here it overlies the Helderbergian limestone with distinct angular unconformity, the Harriman being absent. Within a distance of 5 miles up Indian Creek it rests on Middle Silurian limestone, the Linden, which was over 150 feet thick at Olive Hill, having pinched out by erosion.

At two localities near the Tennessee River at the south edge of the State, the "black" shale is absent, but a sandstone having the character of the Hardin underlies the Ridgetop shale. It may, however, be a basal member of the latter. One of these exposures may be seen at Dry Creek schoolhouse near Walnut Grove, and the other on Yellow Creek near the center of section 27, Tishomingo County, Mississippi. The sandstone shows the same interesting character at both localities. It is about 3 feet in thickness, forming a single dense mas-

sive layer with about 6 inches of conglomerate at its base. The pebbles of the conglomerate are chiefly composed of gray and black chert and range in size up to 3 inches across. The majority are flattish and oblong and many are angular or subangular. A single well rounded oblong pebble of coarse-grained red quartzite was found associated with the chert pebbles. This conglomerate is a veritable bone bed; many flat pieces of fish bone 2 or 3 inches across, apparently broken pieces, are associated with other whole bones, the largest of which measures 5¾ inches long and 3 inches broad across the wide end. Unfortunately none of these remains is complete enough to identify.

Fauna.—The fauna of the Chattanooga is very meagre and of slight significance in correlation. In most of the sections studied in the Western Valley, the shale is quite barren except for supposed spore cases (*Sporangites*). A thin layer at the base of the shale 3 miles west of Newsom is crowded with microscopic annelid and conodont teeth, and a small species of *Lingula* which is very close if not identical with *L. melie.* The same *Lingula* and teeth have been found in the shale at many other localities in the state, and the *Lingula* is locally abundant in the Hardin sandstone. Professor Lull and Doctor Hussakof kindly examined the bones collected by the writer from the sandstone (probably Hardin) on Yellow Creek in Tishomingo County, Mississippi, and both pronounced them too incomplete to identify. Doctor Hussakof states that they are fish bones and apparently had been considerably water worn before burial.

Correlation.—The age of the Chattanooga shale is a mooted question. Most workers have placed it in the Upper Devonian, and both the Tennessee State Geological Survey[1] and the United States Geological Survey continue to follow this reference. Ulrich, on the other hand, in 1911 and again in 1912 presented arguments for its early Mississippian age. Since the known fauna is of little significance in correlation, the problem will probably be solved only by a comprehensive study of the stratigraphic relations of this widespread formation. In the limited area of western Tennessee the writer was unable to find any decisive evidence and he does not feel warranted in taking a stand on the age of the formation. It has seemed best, however, in this report to conform to the established usage of the state and national geological surveys.

[1]Since the above manuscript was written the Tennessee State Geological Survey has taken the stand that the upper part of the Chattanooga shale as it occurs in Sumner and Cheatham counties is of early Mississippian age.

CHAPTER III

Detailed Geologic Sections

The following sections are presented in the order of their geographic occurrence, beginning on the lower course of Big Sandy River near the north edge of the State and proceeding southward. Since the area of outcrops is so narrow, the accompanying figure of the more significant sections represents practically a north-south line across the State, a distance of about 100 miles (see Fig. 11). These sections are superposed on a map of the region so that both the geologic and geographic relations of the various outcrops are shown at once. The map is drawn in perspective as though viewed from an angle above, the geologic sections arising vertically from its surface. The exposures of Devonian rocks are indicated on the map by solid black, and the numbers show the location of the corresponding sections which are described in this chapter. Since the reader is looking a little north of west toward the Tennessee River valley, the northern sections are at the right and the southern at the left.

(1) Sections Near the Mouth of Big Sandy River

On the lower course of Big Sandy River there may be seen two good exposures of the highest layers of the Birdsong shale. These sections are of special interest because the horizon of the shale they reveal is absent in all exposures farther south. They will be designated Section A and Section B.

SECTION A.

At the steel bridge about 4 miles above the mouth of Big Sandy River and about 1 mile west of Lashlee's store (formerly Pace post office), the river is impinging against a low bluff. Beneath the bridge and for a distance of 160 yards below it the following section is clearly exposed (see Fig. 9):

Big Sandy, Steel Bridge Section

(Cretaceous) sand to the grass roots
Unconformity
(Devonian)
Linden group
Birdsong shale
Trilobite zone

	Feet
Bluish gray shale, poorly exposed	2
Impure gray limestone in courses up to 4 inches thick, in places banded with chert	2

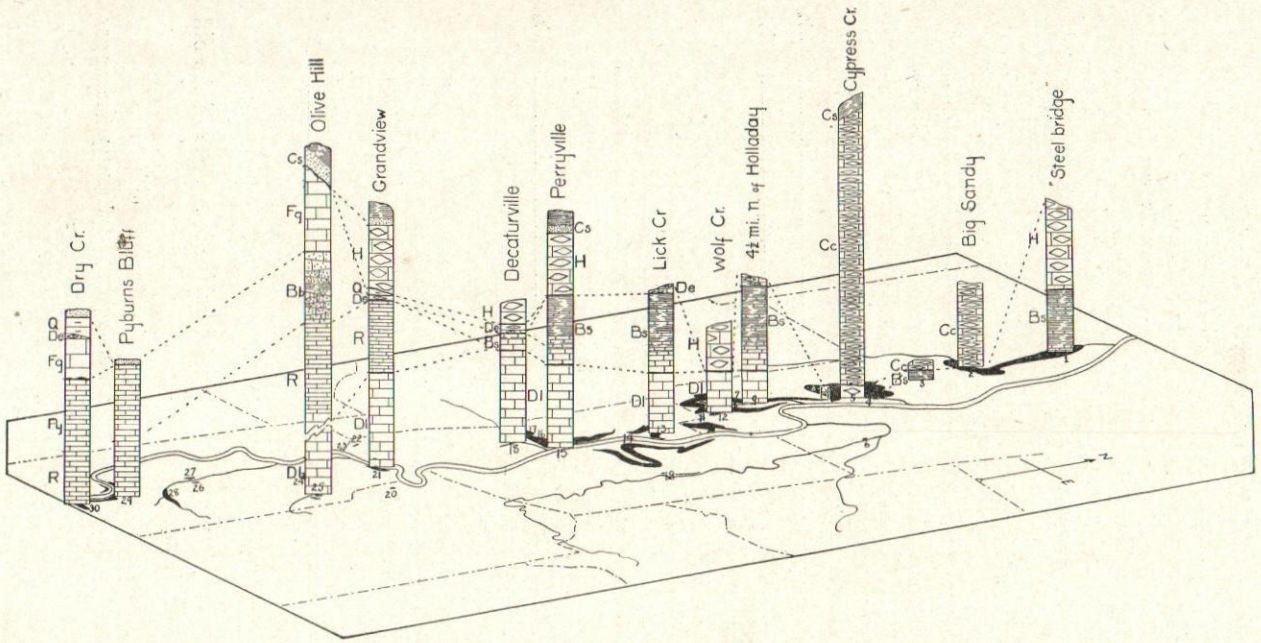

FIGURE 11. Geologic sections along the Western Valley of the Tennessee River. The sections are erected upon a map of the region projected to appear as though viewed from an angle to the side and above the southeast corner. Areas of Devonian outcrop are shown in black. The numbers show the position of the corresponding sections described in Chapter III. Symbols for the several formations are: Bb, Bear Branch limestone; Bs, Birdsong shale; Cc, Camden chert; Cs, Chattanooga shale; Dc, Decaturville chert; Dl, Decatur limestone; Fg, Flatgap limestone; H, Harriman novaculite; Py, Pyburn limestone; Q, Quall limestone; R, Ross limestone.

Big Sandy, Steel Bridge Section.—Continued

Soft, bluish, calcareous clay shale. Very fossiliferous. *Edriocrinus pyramidatus* confined to this zone. *Phacops logani* very abundant. Other species: *Enterolasma strictum, Dalmanella pygmæa, D. subcarinata, Rhipidomella oblata, R. emarginata, Bilobites varicus, Leptæna rhomboidalis, Orthostrophia strophomenoides, Strophonella lineolata, Brachyprion purduei, Leptænisca concava, Eatonia tennesseensis, Uncinulus vellicatus? Rhynchospira formosa, Delthyris perlamellosa, Meristella atoka, Atrypina imbricata, Anoplotheca concava, Platyceras tenuiliratum, Orthoceras rude, Dalmanites retusus* 5

Highly fossiliferous, bluish shale like that above. Orthids very abundant. *Dalmanella eminens, Uncinulus swaynensis? Phimocrinus* n. sp. apparently confined to this zone. *Favosites conicus* and all the brachiopods listed in the zone above also occur here. *Phacops logani* common 2½

Muddier shale, only sparingly fossiliferous..... 2½

Bluish, highly calcareous shale, slightly harder than that above, capped by a two-inch band of limestone. The shale is replete with *Anastrophia verneuili. Phacops logani* and *Orthostrophia strophomenoides* are rare. Other species occurring here: *Favosites conicus. Enterolasma strictum, Dalmanella subcarinata, Rhipidomella oblata, R. emarginata, Bilobites varicus, Strophonella lineolata, Brachyprion purduei, Eatonia tennesseensis, Delthyris perlamellosa, Dalmanites retusus*..... 3½

More indurated limy shale and shaly limestone in which *Atrypa reticularis* predominates. A single specimen of *Eospirifer macropleura* was found. Other fossils: *Enterolasma strictum, Leptæna rhomboidalis, Dalmanella subcarinata, Rhipidomella oblata, Orthostrophia strophomenoides, Anastrophia verneuili, Gypidula multicostata, Delthyris perlamellosa, Scenidium insigne, Meristella atoka, Orthoceras pauciseptatum, Phacops logani, Dalmanites retusus.* To the water's edge..... 5

SECTION B.

About one mile upstream from the steel bridge is the site of the old Swayne's mill. The bluff which extends for about 400 yards above the mill site is partly composed of the same strata which form section A, but the base of the bluff exposes lower layers, apparently the upper portion of the "brachiopod zone." The upper portion is less clearly exposed than in the previous section.

Swayne Mill Section

(Devonian)
Linden group
Birdsong shale
Trilobite zone

Feet

Bluish, calcareous clay shale, softer above and gradually becoming more limy and indurated at the base. The equivalent of that portion of section A above the *Anastrophia* zone. The following fauna was secured, but collecting here was less complete than in the previous section: *Favosites conicus, Enterolasma strictum, Dalmanella pygmæa, D. subcarinata, D. perelegans, Rhipidomella oblata, R. emarginata, Bilobites varicus, Orthostrophia strophomenoides, Leptæna rhomboidalis, Leptænisca concava, Strophonella lineolata, Eatonia tennessseensis, Uncinulus swaynensis, Rhynochotreta insinuata, Anastrophia verneuili, Rhynchospira formosa, Delthyris perlamellosa, Atrypina imbricata, Meristella arcuata, M. atoka, Platyceras multisinuatum, P. tenuiliratum, Phacops logani, Dalmanites retusus.* To the grass roots..... 12

Harder, bluish, limy shale, replete with *Anastrophia verneuili*..... 3

Harder, limy shale and shaly limestone like that above. *Anastrophia* rare. *Atrypa reticularis* predominates..... 5

Brachiopod zone

Softer, bluish, calcareous clay shale. Highly fossiliferous. Fauna includes: *Favosites conicus, F. foerstei, Enterolasma strictum, Edriocrinus adnascens, Dalmanella subcarinata, D. perelegans, D. pygmæa, Rhipidomella oblata, R. emarginata, Bilobites varicus, Leptæna rhomboidalis, Leptænisca concava, Brachyprion purduei, Strophonella lineolata, Schuchertella woolworthana, Eatonia tennesseensis, Camarotœchia transversa, C. bialveata, Gypidula multicostata, Anastrophia verneuili, Scenidium insigne, Rhynchospira formosa, Atrypa reticularis, Eospirifer macropleura, Delthyris perlamellosa, Spirifer cycloptera, Cyrtina dalmani, Anoplotheca concava, Atrypina imbricata, Meristella atoka, Nucleospira ventricosa, Platyceras tenuiliratum, Dalmanites retusus, Phacops logani.* To the water's edge..... 15

Although not exposed in either of these sections, the Harriman and Camden cherts are both present in this vicinity. At the home of Mr. Mose Evins, about 1½ miles south of section B, the top of the Birdsong shale, poorly exposed, is succeeded by 55 feet of the Harriman chert. The latter seems to be barren of fossils except at its top, where a few characteristic species such as *Spirifer murchisoni, Oriskania saffordi,* and *Plethorhyncha* cf. *barrandei* were found. About 3 miles south of this locality the Camden chert is well exposed in the road on a hillside.

(2) Sections About Big Sandy

About the village of Big Sandy there are numerous small exposures of the Camden chert, though neither its top nor bottom is to been seen. The Linden formations are entirely below surface. The bluff, along the southeast side of Big Sandy River a mile or so above the town, is gentle enough to be soil-covered, but loose chunks of chert in the soil indicate a thickness of not less than 50 feet for the Camden formation.

About 1¼ miles north of the station the railroad runs near a low bluff, giving a poor exposure from which were secured *Stropheodonta blainvillei, Schuchertella pandora, Chonetes hudsonicus* mut. *camdenensis, Anoplia nucleata, Eodevonaria arcuata, Chonostrophia reversa, Spirifer hemicyclus,* and *S. worthenanus.*

Within a half-mile north of the depot and about 200 yards west of the railroad track there is a sharp bend in the river where it transects a small anticline, giving a good section of 12 feet of the same formation. Some of the chert is stained bright red and the layers are separated by partings of white clay. Here were obtained *Eodevonaria arcuata, Amphigenia curta,* and *Spirifer hemicyclus.*

The hill rises rapidly from the river at the western edge of the village and the road up the hillside exposes chert all the way, but the dip corresponds so nearly to the slope of the road that only 12 feet of strata are shown. This locality yielded *Leptaena rhomboidalis, Schuchertella pandora, Amphigenia curta, Centronella glansfagea, Eatonia peculiaris, Spirifer hemicyclus, S. worthenanus,* and *Cypricardinia* cf. *distincta.*

(3) Section on Rushing Creek

One mile east of Herrin's store, which is 6½ miles north of Camden, the road crosses Rushing Creek where the latter transects a low anticline, displaying the contact of the Birdsong shale and the Camden chert. The Harriman chert is absent.

Rushing Creek Section

	Feet
(Devonian)	
Camden chert	
Light, buff-colored novaculite, thoroughly fractured, to the grass roots	2
Disconformity	
Linden group	
Birdsong shale	
Rusty brown shale with laminae of limonite. Bedding obscured. Apparently a "fossil" regolith	3

Rushing Creek Section.—Continued

Bryozoa zone

Blue calcareous shale, interbedded with small lentils of limestone, the latter mostly formed by massive and incrusting bryozoa. The whole zone replete with ramose bryozoa. Many of the Linden brachiopods also occur, but we may note the absence of *Leptostrophia beckii* and *Spirifer macropleura*. To the creek bed..... 4½

For a distance of 2 miles below here the stream bed lies in the Camden chert of which a thickness of 30 feet may be seen in an anticline about one-fourth mile northeast of Herrin's store. About 1 mile below this point, another low anticline brings up the top of the Birdsong shale, duplicating the section given above. This is in Mr. Lawrence Ryan's barnyard.

(4) Sections About Camden

The town of Camden is surrounded by outcrops of the Camden chert, a fact which gave the formation its name. The base of the novaculite is not to be seen and no great thickness is exposed at any one place. Excellent collecting is afforded by a gully in a pasture just back of the houses in the northeast corner of the town, where the following species were secured: *Leptaena rhomboidalis, Schuchertella pandora, Anoplia nucleata, Chonostrophia reversa, Eodevonaria arcuata, Amphigenia curta, Oriskania condoni, Spirifer duodenarius, S. worthenanus, S. hemicyclus, Meristella lentiformis, Leptocœlia flabbellites,* etc.

A small quarry east of the town shows 50 feet of the Camden chert, and other exposures occur in all the gulches both north and south of the village. A well on the courtyard went through a thickness of 265 feet of chert before reaching the Linden. Extensive new exposures were made by the Nashville, Chattanooga & St. Louis Railway during the summer of 1916 about the present site of the depot at Camden. The material excavated has been used to make a fill across the valley and it affords a limitless wealth of material from which to collect Camden chert fossils.

Just east of the first trestle, several car loads of Harriman chert have been dumped, showing that the excavations have crossed the Harriman-Camden contact. The following fossils were collected: *Pleurodictyum lenticulare, Leptæna insegns, Chonostrophia complanata, Oriskania saffordi, Rensselæria ovoides, Spirifer murchisoni, S. paucicos-*

tatus, Cyrtina rostrata, Meristella lata, Metaplasia pyxidata, and *Anoplotheca dichotoma.*

At the time the writer visited the excavation, however, none of the Harriman chert could be seen in place because of the heavy talus of Camden chert which invariably covers the lower portion of the exposure.

(5) Section on Cypress Creek

The thickest section of the Camden chert known in Tennessee is to be seen in the enormous "gravel" quarries operated near the Nashville, Chattanooga & St. Louis Railway in the bluff along Cypress Creek, about 2 miles southeast of Camden. The two quarries are separated by a ravine and an unexposed interval about 75 yards across. In the northern quarry, which is the older, the thin-bedded chert has crumbled down so as to largely obscure the bedding, but a thickness of 50 feet can be safely ascribed to it. In the south quarry 100 feet of strata are clearly shown and in the bluff above it an additional 20 feet is indicated. Judging from the dip on both sides of the ravine the strata in the northern quarry go below that in the southern quarry, so that the thickness of the chert is at least 170 feet. All but the lowest portion, exposed in the extreme north end of the quarry, may be referred to the Camden formation. The section is as follows:

Cypress Creek Section

(Devonian)
Ulsterian group
Camden chert — Feet

Buff-yellow novaculite, usually disposed in layers from one to five inches thick but occasionally thicker. Very brittle and thoroughly fractured, forming steep, heavy, talus slopes. The lithologic character remains the same throughout its whole thickness, and collections from the lower and upper portions reveal no essential faunal change. Characterized by: *Chonetes hudsonicus* mut. *camdenensis, Eodevonaria arcuata, Anoplia nucleata, Chonostrophia reversa, Amphigenia curta, Oriskania condoni, Spirifer hemicyclus, S. worthenanus, S. duodenarius, Pentagonia unisulcata, Leptocœlia flabellites, Phacops cristata* ..... 164+

Contact hidden by talus
Oriskanian group
Harriman chert

More heavily bedded white novaculite in courses from six to twelve inches thick. Distinguished by large molds and casts of big Oriskany fossils, including: *Leptæna ingens, Leptostrophia magniventra, Chonetes hudsonicus* mut. *camdenensis, Chonos-*

Cypress Creek Section.—Continued

trophia complanata, Oriskania saffordi, Rensselaeria ovoides, Spirifer murchisoni, S. paucicostatus, S. (?) nearpassi, Meristella lata, M. rostellata. To the quarry floor ..... 6+

(6) Section at the "Whirl" on Buffalo River

At the "whirl" four miles north of Bakerville, the Buffalo River is bordered by a steep bluff which affords a unique section. It is the only locality in the Western Valley where the typical Onondaga coral horizon appears. The Camden chert presents an unusual aspect, consisting of alternate layers of yellow chert and compact gray limestone. These appear to be higher strata of the formation than those elsewhere exposed in the valley. The section is as follows:

Buffalo River Section

(Devonian)
Chautauquan group
Chattanooga shale
Disconformity
Ulsterian group
Pegram limestone — Feet

Light gray, finely crystalline limestone. Practically composed of corals, both simple and composite. *Cyathophyllum rugosum, Blothrophyllum, Heliophyllum,* etc. ..... ¾

Unexposed interval 1½

Camden chert

Massive layer of very hard, compact, bluish-gray limestone with thin bands of chert. *Leptæna rhomboidalis, Chonostrophia reversa, Schuchertella pandora, Oriskania condoni, Amphigenia curta, Spirifer macrothyris, S. hemicyclus (?), Meristella lentiformis* 1½

Bands of limestone like that above, interbedded with yellow chert bands of equal thickness. *Rhipidomella* cf. *penelope, Leptæna rhomboidalis, Strophеodonta* cf. *blainvillei, S.* cf. *hemispherica, Schuchertella pandora, Eatonia peculiaris, Oriskania condoni, Amphigenia curta, Leptocœlia flabellites, Meristella lentiformis*.... 8

Unexposed interval 2

Alternating layers of bluish-gray, compact limestone and yellowish chert from five to nine inches thick. Near its base is a nine-inch band of chert crowded with molds of crinoidal material 5

Poorly exposed interval consisting of gray limestone alternating with layers of yellow chert which make up from one-third to one-half the whole 21

Vertical exposure at the river bank consisting of the same alternation of limestone and chert. The only fossils seen are Spirifers which may be found on the weathered surface of the chert bands. To the water's edge 8

(7) Section at Allen's Mill

The bluff of the Birdsong at Allen's mill, 7 miles north of Holladay, affords the most northern exposure of the base of the Birdsong shale. The lower portion of the bluff is composed of very massive layers of coarsely crystalline pinkish Silurian limestone. The partially soil-covered slope above this limestone shows the grosser characters of the Birdsong shale, though the details are obscured because the exposure is old and much weathered.

Allen Mill, Section A

(Devonian)
Linden group
Birdsong shale

Bryozoa zone	Feet
Gray, calcareous clay shale, partially weathered to soil. Surface profusely strewn with ramose bryozoa	10±
Brachiopod zone	
Gentle slope covered with fragments of shaly limestone and soil from which may be secured the common Linden brachiopods	30±
Bluish gray crystalline limestone in courses five or six inches thick at the base, becoming thinner bedded and interbedded with shale above, grading into the next zone. Linden brachiopods occur	15
Disconformity	
(Silurian)	
Niagaran group	
Decatur limestone (?)	
Very massive, coarsely crystalline, pink to reddish limestone. Almost barren of fossils. To the base of the bluff	20

(8) Section 1½ Miles South of Allen's Mill

Most of the brachiopod zone of the Birdsong shale is exposed by a small glade where the road crosses a tributary of Birdsong Creek about 1½ miles south of Allen's mill.

Allen Mill, Section B

(Devonian)
Linden group
Birdsong shale

Brachiopod zone	Feet
Very fossiliferous, highly calcareous, bluish shale. Fauna a duplicate of that of the same zone in section 9, except that the smaller species of brachiopods seem to predominate. Near the middle of this zone was found the rare blastoid, *Codaster lorœ*. To the grass roots	14

Allen Mill, Section B.—Continued

Bluish shale like that above, replete with *Atrypa reticularis*..... 5
Impure, coarsely crystalline limestone in layers eight to ten inches thick. *Eospirifer macropleura, Schuchertella woolworthana, Rhipidomella oblata,* etc. To the water's edge..... 2

(9) Section 4½ Miles North of Holladay

About 4½ miles north of Holladay, near the home of Mr. Will Love, the Holladay-Gis Mundy road crosses a small tributary of the Birdsong just before it emerges into the valley of the latter. At this point the road crosses large glade exposures which reveal a typical development of the Birdsong shale and afford a wealth of beautifully preserved fossils. Another glade about one-half mile south of this one exposes the upper portion of the shale and a part of the overlying Decaturville chert. It is incorporated in the following section:

Will Love Section

(Devonian)
Linden group
Decaturville chert — Feet
Gray to yellowish porous chert and yellow clay, weathered and thoroughly fractured at the surface. Characterized by an abundance of *Anoplotheca concava,* by very large specimens of *Rhipidomella oblata, Leptostrophia beckii, Schuchertella woolworthana,* and *Meristella* cf. *laevis* and by the presence of *Phacops hudsonica* 5
Disconformity
Birdsong shale
Bryozoa zone
Highly calcareous bluish clay shale, replete with ramose bryozoa which may be swept up by handfuls from the surface..... 5±
Brachiopod zone
Highly calcareous bluish clay shale with occasional bands of shaly limestone. This is the zone of the typical Linden brachiopod fauna The more characteristic or common elements of the fauna are as follows: *Edriocrinus adnascens, Favosites conicus, F. foerstei, Pleurodictyum lenticulare, Enterolasma strictum, Dalmanella subcarinata, D. perelegans, Rhipidomella oblata, R. emarginata Bilobites varicus, Leptæna rhomboidalis, Strophonella punctulifera, Leptostrophia beckii, Schuchertella woolworthana, Leptænisca adnascens, Scenidium insigne, Anastrophia verneuili, Gypidula multicostata, Eatonia tennesseensis, Carmarotœchia tran versa, C. bialveata, Rensselœrina medioplicata, Atrypa reticularis, Atrypina imbricata, Eospirifer macropleura, Delthyris perlamellosa, D. octocostata* mut. *tennesseensis, Spirifer cycloptera, Cyrtina dalmani, Rhynchospira formosa, Nucleospira ven-*

Will Love Section.—Continued

tricosa, Meristella arcuata, M. atoka, Anoplotheca concava. Camarocrinus and fragments of *Scyphocrinus* are scattered throughout the lower third of this zone. *Rensselœrina* seems to be confined to the upper two-thirds and *Eatonia tennesseensis* to the upper third. *Anastrophia* is much more common toward the top 30

Thin layers of impure crystalline limestone, alternating with bands of bluish shale, characterized by the abundance of *Leptostrophia beckii. Eospirifer* and other Linden brachiopods are also present 5

Impure, coarsely crystalline, grayish limestone in layers up to four inches thick. *Camarocrini* are associated with *Delthyris perlamellosa, Rhipidomella oblata, Bilobites varicus, Leptœna rhomboidalis, Atrypa reticularis,* etc. To the stream bed..... 5

(10) Section 1¼ Miles North of Holladay

The following section is revealed in a ditch at the roadside about 1¼ miles north of Holladay. It has the appearance of a sort of lithologic transition from the Birdsong shale into the Oriskany chert. That it is not a real transition is known because of the absence of the higher trilobite zone of the Birdsong and of the Decaturville. Moreover, there is no faunal transition.

Holladay Section

(Devonian)

Oriskanian group

Harriman chert (?) — Feet

Buff-colored, thin-bedded, thoroughly fractured novaculite. No fossils found 10

Linden group

Birdsong shale

Greenish-white clay with thin bands of impure chert of the same color, impregnated with granules of bright green glauconite. *Leptœnisca concava, Eospirifer macropleura, Delthyris perlamellosa, Spirifer cycloptera, Meristella arcuata.* Many crinoids in the upper half 2½

Greenish-white, impure chert, weathering to clay like that above. Fenestelloid and ramose bryozoa abundant. *Rhipidomella oblata, Leptostrophia beckii, Schuchertella woolworthana, Meristella arcuata, Anoplotheca concava,* etc. ..... ½

Greenish-yellow phosphatic clay interlaminated with thin crusts of limonite. Fossils indistinct 2

Concretionary impure limonite ..... ½

Impure limonite layers, one or two inches thick, interbedded with impure greenish-white clay marked with rusty specks..... 3

Holladay Section.—Continued

Concretionary impure limonite 4
Greenish clay like that above, poorly exposed..... 2

Bryozoa zone
Highly calcareous, greenish blue clay shale crowded with ramose bryozoa. To the bottom of the exposure..... 4

(11) Section on Sycamore Creek

A few yards above the ford on Sycamore Creek, one-half mile east of Holladay, the preceding section is duplicated in detail. Within a mile upstream there are numerous small exposures of the upper part of the Birdsong shale. The last exposure just below Mr. Johnson's house is a larger one where for 100 yards or so the creek is cutting against a low bluff.

Sycamore Creek Section

(Devonian)
Linden group
Birdsong shale
Bryozoa zone

Feet

Soft, calcareous, blue shale, replete with bryozoa. Also yielding many of the brachiopods of the zone below. To the grass roots.... 4

Brachiopod zone
Highly calcareous, bluish shale, gradually becoming more indurated toward the base, where it is a shaly limestone. Extremely fossiliferous. *Edriocrinus adnascens, Stereocrinus* sp., *Pleurodictyum lenticulare, Favosites conicus, F. foerstei, Enterolasma strictum, Dalmanella perelegans, D. subcarinata, D. pygmæa, D. planoconvexa, Rhipidomella oblata, R. emarginata, Bilobites varicus, Leptæna rhomboidalis, Leptænisca adnascens, L. concava, Schuchertella woolworthana, Eatonia tennesseensis, Camarotœchia transversa, C. bialveata, Anastrophia verneuili, Gypidula multicostata, Scenidium insigne, Rensselœrina mediоplicata, Atrypina imbricata, Atrypa reticularis, Eospirifer macropleura, Delthyris perlamellosa, D. octocostata* mut. *tennesseensis, Spirifer cycloptera, Cyrtina dalmani, Rhynchospira formosa, Nucleospira ventricosa, Meristella arcuata, M. atoka, Anoplotheca concava.*
To the water's edge 19

(12) Section on Wolf Creek

The Holladay-Chaseville road crosses Wolf Creek about 1½ miles east of Holladay. Within a half mile above the ford there are several small exposures of the upper part of the Birdsong shale, but they are weathered and partially overgrown so that they add but little to our knowledge of these beds. About 100 yards below the ford, the

east bank of the creek exposes 25 feet of very massive, pure, white limestone, which is either of Decatur or older Silurian age. It is dense and fine-grained and the whole thickness shows no bedding planes. The lower portion is almost a solid mass of single species of diphyphylloid coral which seems to have grown up with its long slender corallites nearly parallel and thickly spaced. These have fallen over in masses and lie matted down in a more or less horizontal position. In fact, this limestone has all the appearance of a coral reef formation. Such masses of coral also form much of the upper part of the formation, where they are associated with isolated specimens of a large *Amplexus*, large colonies of *Favosites favosus*, masses of *Halysites catenularia*, incrusting bryozoa, rarely a small brachiopod, and very rarely a crinoid. These are all features of a coral reef limestone.

At this exposure the limestone extends from the creek bed to the grass roots. Only 100 yards south and on a level with its top, the Camden chert outcrops in the road where the writer secured *Anoplia nucleata*, *Schuchertella pandora*, *Leptocœlia flabellites* and *Chonetes hudsonicus* mut. *Camdenensis*. A few yards further upsream the Birdsong shale comes in beneath the chert, separating it from the white limestone. About one-fourth mile downstream from this locality, a small tributary enters the creek from the east, and here is exposed the top of the white limestone overlain by Harriman chert. The following section combines this and the previous exposure:

Wolf Creek Section

(Cretaceous) red sand

Disconformity

(Devonian)

Oriskanian group

Harriman chert — Feet

Buff-yellow novaculite, thoroughly fractured, only sparingly fossiliferous. *Rensselœria ovoides*, *Oriskania Saffordi*, *Spirifer murchi oni*, *Leptocœlia flabellites* 14

Disconformity. Late Silurian and Helderbergian time not represented.

The Birdsong formation comes in within one-half mile upstream

(Silurian)

Niagaran group

Decatur limestone (?)

Coarsely crystalline and crinoidal light gray limestone with *Diphyphyllum* and *Striatopora* as that below..... 2

Unexposed 10

Massive, compact, white coral reef limestone, largely composed of one species of diphyphylloid coral. Bedding planes lacking.

Wolf Creek Section.—Continued

Other mid-Silurian fossils such as *Favosites favosus, Halysites catenularia, Marsipocrinus tennesseensis* (*?*) and *Plectambonites transversalis*. Thickness at the upper exposure, to the creek bed.. 25

The Silurian age of this white limestone is evident but its detailed correlation is yet uncertain. While the Lobelville is the great mid-Silurian coral horizon, it displays a large fauna of many species of the tetracorals. This formation, on the contrary, has only two species, neither of which occurs in the Lobelville, and there seem to be no more grounds for a correlation with either the Beech River or Bob formations. The lithology and stratigraphic position both agree best with the Decatur, but the fauna of the latter is so meagre and so little known that there is little basis for a correlation. It seems probable, however, that the limestone on Wolf Creek is a local coral reef development in the Decatur.

The absence of the Birdsong formation at this locality is apparently due to local warping and interformational erosion.

(13) Sections on Big Lick Creek

Numerous "glade" exposures of the Birdsong shale occur along Big Lick Creek north and northeast of Jeannette. Of these, there are two on the Allen Conrad place 2½ miles northeast of that village which will be designated section A and section B.

SECTION A.

In front of Mr. Conrad's house the road descends a bare rock slope which affords a good exposure of the base of the Birdsong shale and its contact with the subjacent formation.

Big Lick Creek, Section A

(Devonian)
Linden group
Birdsong shale
Brachiopod zone — Feet
Only the basal portion. Coarsely crystalline and crinoidal gray limestone in layers up to six or eight inches thick, separated by shale partings. Camarocrini common. *Pleurodictyum lenticulare, Dalmanella subcarinata, Rhipidomella oblata, Delthyris perlamellosa*, etc. 10
Disconformity
(Silurian)
Niagaran group
Decatur limestone
Grayish crystalline limestone similar to that above but lacking the shale partings. Unfossiliferous 5

Big Lick Creek, Section A.—Continued

Finer grained, heavier bedded, light gray limestone, variegated with thin bands of reddish limestone which increase in thickness downward. Camarocrini common 5
Variegated red and light gray limestone, the former color dominant 5
Massive gray limestone with variable amount of thinner red bands. Unfossiliferous 15
Massive layer of dark red limestone 3
Massive layer of gray limestone 3

SECTION B.

A large section may be seen at a big glade in the timber a little over half a mile northwest of the Conrad house.

Big Lick Creek, Section B

(Devonian)
Linden group
Decaturville chert — Feet
Represented by loose chunks of porous chert of gray and buff color, in the soil. *Anoplotheca concava* abundant, large *Meristella* cf. *lævis*, *Rhipidomella oblata*, etc.....
Birdsong shale
Bryozoa zone
Soft, calcareous, blue shale, weathering greenish blue, forming a gentle slope strewn with ramose bryozoa 5
Brachiopod zone
Highly calcareous, bluish shale with bands of impure, shaly limestone, becoming more limy toward the base The lower 5 or 6 feet impure coarsely crystalline limestone, interbedded with shale partings. Harder bands of limestone also occur at 10 and 13 feet above the base, forming terraces along the glade. Richly fossiliferous, the fauna exactly duplicating that of the brachiopod zone in section 8..... 35
Coarsely crystalline gray limestone without shale partings. Camarocrini abundant 5
Disconformity
(Silurian)
Niagaran group
Decatur limestone
Heavy bedded, rather coarsely crystalline, light gray limestone. Camarocrini common. No other fossils seen..... 5
Gray limestone, finer grained than that above, variegated with red bands. Camarocrini present. To stream bed 15

(14) Section at Lady's Bluff

For a mile or more north of the mouth of Lick Creek (Perry County) the Tennessee River is bordered by a bold cliff known as Lady's Bluff. It gives an extensive exposure of the following section:

Lady Bluff Section

(Devonian)
Linden group
Birdsong shale — Feet
Only basal portion, consisting of coarsely crystalline gray limestone in thin layers. *Enterolasma strictum, Favosites foerstei, Rhipidomella oblata, R. emarginata, Leptostrophia beckii, Leptænisca adnascens, Atrypa reticularis, Eospirifer macropleura, Delthyris perlamellosa, D. octocostata* mut. *tennesseensis, Meristella arcuata,* etc. ..... 7+
Disconformity

(Silurian)
Niagaran group
Decatur limestone
Massive light gray limestone, forming an almost inaccessible vertical cliff. *Camarocrinus* seen at 20, 25 and 35 feet above its base. No other fossils seen 63
Disconformity. The coral zone of the Lobelville, which is absent here, comes in at this level at Mousetail, 1 mile south
Lobelville formation
Bryozoa zone
Variegated, reddish purple and light greenish gray, thin-bedded, shaly limestone 22
Bob formation
Very massive, hard, light gray limestone characterized by *Uncinulus stricklandi* 15
Beech River formation
Thin-bedded limestone and interbedded shale, abundantly fossiliferous. To the water's edge ..... 45+

(15) Section at Perryville

One-half mile north of the village of Perryville there is a large quarry in the bluff along the Tennessee River. It affords quite the clearest exposure of the base of the Linden and its contact with the Decatur which is to be seen in the valley.

Perryville Section

(Devonian)
Chautauquan group
Chattanooga shale — Feet
Black, fissile, carbonaceous shale, barren of fossils 10
Hardin sandstone
Impure, muddy, rusty gray sandstone 3
Unconformity. The sandstone is horizontal, the chert below locally folded and faulted

Perryville Section.—Continued

Oriskanian group

Harriman chert

White to yellowish novaculite in layers varying from 1 to 8 inches thick. Hard, brittle, and thoroughly fractured. Locally, sharply folded and broken by little faults. Fossils not common in the upper and lower thirds, but the middle portion characterized by *Leptæna ingens, Chonostrophia complanata, Oriskania saffordi, Spirifer murchisoni, S. paucicostatus, S. arenosus, Metaplasia pyxidata, Meristella lata, M. rostellata* 30

Disconformity. Sharp contrast in adjacent beds. Becraft and lower Oriskany time not represented

Linden group

Birdsong shale

Bryozoa zone

Soft, calcareous shale interbedded with little lentils of limestone. The upper half more or less decomposed and colored rusty brown; the lower half replete with ramose bryozoa with which also occur many of the brachiopods of the next zone below..... 5

Brachiopod zone

Highly calcareous, very fossiliferous, blue shale. The fauna duplicates that of the brachiopod zone in sections 7 and 12. The more common and characteristic species are: *Enterolasma strictum, Pleurodictyum lenticulare, Favosites conicus, F. foerstei, Dalmanella perelegans, Rhipidomella oblata, R. emarginata, Leptæna rhomboidalis, Leptænisca adnascens, Leptostrophia beckii, Gypidula multicostata, Anastrophia verneuili, Eatonia tennesseensis, Camarotœchia transversa, Rensselœrina mediplicata, Atrypina imbricata, Atrypa reticularis, Eospirifer macropleura, Delthyris perlamellosa, D. octocostata* mut. *tennesseensis, Spirifer cycloptera, Cyrtina dalmani, Rhynchospira formosa, Nucleospira ventricosa, Meristella arcuata, M. atoka, Anoplotheca concava* 15

Impure, bluish gray, crystalline limestone in courses 2 to 12 inches thick, separated by shale layers 1 to 4 inches thick. *Leptostrophia beckii* the most characteristic fossil. *Scyphocrinus pyburnensis* and *Camarocrinus* near the top. Other Linden forms as *Enterolasma strictum, Favosites conicus, F. foerstei, Dalmanella subcarinata, Rhipidomella oblata, R. emarginata, Leptæna rhomboidalis, Leptostrophia beckii, Leptænisca concava, Schuchertella woolworthana, Gypidula multicostata, Camarotœchia transversa, Atrypa reticularis, Delthyris perlamellosa, Meristella arcuata, M. atoka* 8

More heavily bedded, impure, coarsely crystalline, bluish gray limestone, without shale partings. Fossils not abundant. *Camarocrinus, Enterolasma strictum, Rhipidomella oblata, Rensselœrina mediplicata, Delthyris perlamellosa,* etc..... 7

Perryville Section.—Continued

Massive layer of buff-red, coarsely crystalline limestone. An irregular margin from 2 to 8 inches thick along both top and bottom is gray instead of reddish. Central portion marked by many small, irregular cavities. Fossils very rare. *Delthyris perlamellosa, Rhipidomella oblata* 2½

Disconformity. The contact is a sharp-cut bedding plane, but the beds appear perfectly conformable all along the quarry face. (See Fig. 5.)

(Silurian)

Niagaran group

Decatur formation

Heavy-bedded, light bluish gray limestone, very sparsely fossiliferous. *Atrypa reticularis, Leptæna rhomboidalis, Camarocrinus, Astræospongia meniscus.* From this zone Springer has secured a fauna of mid-Silurian crinoids including the genera *Clonocrinus, Desmidocrinus, Gazacrinus, Eucalyptocrinus, Marsipocrinus, Lecanocrinus,* and *Pisocrinus* 8

Massive layer of buff-red, coarsely crystalline limestone very similar to the base of the Linden. Only *Astræospongia meniscus* seen..... 2½

Heavy-bedded, compact, light bluish gray limestone, varying from fine to coarsely crystalline, extending to the quarry floor..... 14

Massive limestone similar to that above, exposed along the bluff below the quarry. *Camarocrinus* and other crinoidal material. Rarely a large *Orthoceras*..... 28

(16) Section 2½ Miles Northeast of Parsons

Near a small stream on a farm belonging to Mr. J. P. Rains, 2½ miles northeast of Parsons, there is another "glade" formed by the shaly brachiopod zone of the Birdsong shale. Finely preserved fossils cover the slope in great abundance, the fauna closely duplicating that of this same zone in sections 9 and 15. In addition, *Codaster lorœ* was found near the center of the exposures. Along the base of the glade *Rhipidomella oblata* and *Dalmanella subcarinata* are especially plentiful.

(17) Section 1 Mile East of Parsons

The hills east of Parsons are all composed of buff novaculite, similar to that at Perryville and carrying the same Harriman fauna. About a mile east of the town the railroad is operating ballast quarries which expose a face of 30 feet of this formation. It is rather sharply folded and disturbed and the bedding is obscured by its extremely fractured condition so that the thickness of strata cannot be accurately determined.

The spur from the railroad going up into the quarry cuts into the upper shaly portion of the Linden at a level of 25 feet below the quarry floor. Many Linden fossils and slabs of bryozoa can be seen in the debris along the spur, but there is no good exposure.

(18) Section at Decaturville

In the vicinity of Decaturville the Devonian strata are thin and the exposures of limited extent, yet they are of great importance because of the breaks in the section. In a gulch in the south edge of the town, the top of the Decatur may be seen, then a little further up the gully, following an unexposed interval of about 10 feet, the Decaturville chert is exposed, and is succeeded by about 15 feet of the Harriman chert.

A second gully south of the new school building in the southeast corner of the town duplicates the section of the former, and in addition there are large chunks of crystalline gray limestone in the ditch at the unexposed interval just above the Decatur. These clearly show the presence of the basal part of the Birdsong shale. From the several exposures the following section can be constructed:

Decaturville Section

(Cretaceous)

(Devonian)

Oriskanian group

Harriman chert — Feet

White and buff novaculite, brittle, and thoroughly fractured and disturbed by small sharp folds. *Rensselæria ovoides, Spirifer murchisoni, Meristella lata, M. rostellata,* etc. ..... 15+

Disconformity. Contact exposed at only a few points. Becraft and lower Oriskany time not represented

Linden group

Decaturville chert

Heavy layer of porous, bluish gray chert. Highly fossiliferous. *Pleurodictyum lenticulare, Favosites conicus, Pholidops* cf. *ovata, Dalmanella planoconvexa, Rhipidomella oblata, Leptostrophia beckii, L. planulata, Strophonella punctulifera, Schuchertella woolworthana, Chonostrophia jervensis, Eatonia singularis, E. medialis, Delthyris perlamellosa, Meristella* cf. *lævis, Anoplotheca concava, Phacops hudsonica, Homalonotus* sp. 1

Thinner bedded, yellowish chert and sandy clay with many bryozoa. Poorly exposed 3

Contact. Not observable. Upper 30 feet of the Birdsong absent.

Birdsong shale

Unexposed interval with chunks of coarsely crystalline gray limestone which are characterized by *Leptostrophia beckii,* and also

Decaturville Section.—Continued

contain *Dalmanella subcarinata, Rhipidomella oblata, Delthyris perlamellosa,* and *Spirifer cycloptera.* This clearly represents the basal part of the brachiopod zone ..... 10±

(Silurian)

Niagaran group

Decatur limestone

Massive, compact, light gray limestone, almost barren of fossils. Only the upper portion exposed at Decaturville, but the entire formation well exposed at the bridge over Beech River north of the town. Near the middle of the limestone at this section were secured *Rhipidomella hybrida, Stropheodonta* (*planulata* group), *Dictyonella gibbosa, Wilsonia saffordi, Atrypa reticularis, Cypricardinia* sp.

(19) Sections About Linden

Only the basal portion of the Birdsong formation is preserved in the three following sections about the village of Linden.

SECTION A.

At the town spring at the northeast edge of the village is the original type section for the Linden. As now exposed, it is as follows:

Linden, Section A

(Mississippian)

Kinderhookian group

Ridgetop shale — Feet

Bluish black, hard, carbonaceous shale .....

Disconformity

(Devonian)

Chautauquan group

Chattanooga shale

Black, fissile, carbonaceous shale..... 10

Hardin sandstone

Hard, fine-grained, gray sandstone forming a single massive layer.... 2½

Disconformity. Middle Devonian time not represented

Oriskanian group

Quall limestone (?)

Subcrystalline impure and cherty limestone of dark bluish gray color, forming a single massive layer. *Leptostrophia planulata, Spirifer arenosus, S. murchisoni, Striatopora* sp..... 2½

Unconformity. Upper portion of the Birdsong absent by erosion

Linden group

Birdsong formation

Coarsely crystalline, pinkish limestone 2½

More impure but massive and granular limestone 3

As much as 11 feet of the Linden used to be exposed at this locality in a low bluff east of the spring, and Linden fossils could be secured, but the exposure is now entirely concealed by soil. About one-fourth mile north of this locality, where the road strikes the next branch and turns west, the Linden limestone is directly overlain by the Hardin sandstone.

SECTION B.

A small exposure occurs at the spring at Mr. Ledbetter's home one mile north of Linden and is duplicated at a small quarry in the woods about one-fourth mile northeast of there, where the following section may be seen:

Linden, Section B

(Devonian)
Linden group
Birdsong formation — Feet
Coarsely crystalline light gray limestone with *Rhipidomella oblata, Leptæna rhomboidalis, Leptostrophia beckii,* and *Strophonella punctulifera* 5
Disconformity. Contact line not easily located.
(Silurian)
Niagaran group
Decatur limestone
Coarsely crystalline light gray limestone similar to that above. Beaks of *Gypidula* and *Atrypa reticularis* common 5
Limestone like that above, with thin bands of chert 5
Finer-grained, heavy-bedded and compact, light gray limestone. No fossils seen except crinoid stems 20

SECTION C.

At the north end of the bridge crossing Buffalo River east of Linden this section is exposed:

Linden, Section C

(Devonian)
Chautauquan group
Hardin sandstone — Feet
A single heavy layer of rather fine-grained, compact, gray sandstone 3
Disconformity. Upper portion of the Birdsong absent by erosion.
Linden group
Birdsong formation
Heavy-bedded, coarsely crystalline limestone at the base, becoming thinner bedded toward the top where clay shale partings occur replete with fossils. *Favosites foerstei, Rhipidomella oblata, Leptæna rhomboidalis, Atrypa reticularis, Delthyris perlamellosa, Spirifer cycloptera, Nucleospira ventricosa* 10
Disconformity

Linden, Section C.—Continued

(Silurian)
Niagaran group
Decatur limestone
Heavy-bedded, compact, light gray limestone with lentils of chert. No fossils could be seen. To the water's edge 12

(20) Section 2 Miles South of Clifton

The "old iron mine," 2 miles south of Clifton, is located in Devonian rocks which cap a rounded hill about one-fourth mile west of the toll gate. The hilltop is covered with small fragments of cherty rock and clay which form a regolith that is colored a deep red by the hematite iron ore. The old pits and talus heaps are so weathered down that the rock strata can not be seen in place. At a horizon along an old road on the southwest brow of the hill about 30 feet below its top, deeply weathered cherty strata outcrop, abounding in Linden brachiopods. The fossils are pseudomorphs in silica and are stained a brick-red color from the overlying iron-ore. The following fossils were secured from the surface of these layers: *Hindia sphæroidalis, Enterolasma strictum, Favosites*, n. sp., *F. helderbergiæ, Rhipidomella oblata, R. emarginata, Stropheodonta planulata* (?), *Camarotœchia transversa, Atrypa reticularis, Delthyris perlamellosa, Cyrtina dalmani, Rhynchospira formosa, nucleospira ventricosa, Meristella arcuata, M. atoka.*

The fauna is clearly that of the Ross limestone, and the succeeding iron ore beds undoubtedly belong to the Bear Branch formation, for the latter, rich in oolitic hematite, succeeds the Ross 10 miles to the south.

(21) Sections at Grandview

About 8 miles west of Clifton is the boat landing known as Grandview. Below the landing the rocks rise gently into a broad open anticline forming a bluff for over 2 miles down the south bank of the river. Silurian rocks rise almost to the top of the bluff near the apex of the anticline, but the Devonian is exposed on each flank. A section on the east and another on the west limb of the anticline will be designated Section A and Section B, respectively.

SECTION A.

About 2 miles below the landing a gully cuts down across the face of the bluff, and here the following section may be seen:

Grandview, Section A

(Devonian)
Chautauquan group
Chattanooga shale — Feet
Black, fissile, carbonaceous shale
Hardin sandstone
Impure, muddy, rusty, fine-grained sandstone 3
Disconformity. Contact not well exposed. Middle Devonian time not represented.
Oriskanian group
Harriman chert
Buff to white, brittle novaculite in courses 6 to 8 inches thick. *Spirifer arenosus* associated with *S. murchisoni, S. paucicostatus, Meristella lata, M. rostellata,* etc. Typical *S. arenosus* found within 5 feet of the top 40
Contact. Not clearly exposed.
Quall formation
Very porous, rotten, yellowish chert. Poorly exposed. Highly fossiliferous. *Leptostrophia magnifica* (?), *Plethorhyncha barrandei* (?), *Spirifer arenosus, S. murchisoni, Platyceras gebhardi, Edriocrinus* cf. *becraftensis* very common 4
Contact. An unexposed interval of less than 1 foot hides the contact. At this level along the slope occur chunks of the gray porous Decaturville chert, though it was not seen in place. Two breaks in the section, therefore, occur in this interval.
Linden group
Ross limestone
Thin-bedded limestone and shale, the former rather siliceous but more coarsely crystalline than that below. Bryozoa abundant.... 4
Thin-bedded, impure, siliceous, dark bluish-gray limestone..... 10
Harder, compact layer of siliceous limestone 1
Thin-bedded, impure, siliceous, dark bluish-gray limestone..... 15
Harder, compact, siliceous limestone 1
Thinner bedded siliceous limestone 2
Harder, impure, siliceous limestone 5
Thinner bedded, impure, siliceous limestone 10
Purer and moderately crystalline limestone. More fossiliferous..... 5
Disconformity
(Silurian)
Niagaran group
Decatur limestone (?)
Heavy-bedded crystalline limestone with *Camarocrinus*. To the water's edge ..... 40+

SECTION B.

The road ascending from the boat landing in front of Mr. De Berry's store adds some details not shown in the previous section.

Grandview, Section B

(Devonian)
Oriskanian group
Harriman chert
F.
To the grass roots 2
Disconformity
Quall chert
Porous, rotten, yellowish chert and clay with *Edriocrinus* 2
Linden group
Decaturville chert
Porous, gray, fossiliferous chert, characterized by *Phacops hudsonica*, large *Schuchertella woolworthana*, *Rhipidomella oblata*, etc. ½
Yellowish, thin-bedded, rotten chert and clay with *Anoplotheca concava* very abundant 2
Disconformity
Ross limestone
Impure, fine-grained, bluish gray limestone, with many bryozoa. Weathers to chert and clay 5
Thin-bedded, impure, siliceous limestone, weathering to rotten, porous, sandy chert and clay. Fossils collected from the weathered slope include: *Enterolasma strictum*, *Favosites conicus*, *F. foerstei*, *Pleurodictyum lenticulare*, *Leptostrophia beckii*, *Leptæna rhomboidalis*, *Rhipidomella oblata*, *R. emarginata*, *Dalmanella subcarinata*, *Schuchertella woolworthana*, *Anastrophia verneuili*, *Uncinulus lindenensis*, *Wilsonia wadei*, *Camarotœchia transversa*, *Gypidula coeymanensis*, *Rensselœrina medioplicata*, *Atrypa reticularis*, *Dlethyris octocostata* mut. *tennesseensis*, *D. perlamellosa*, *Spirifer cycloptera*, *Meristella atoka*, *M. arcuata*, *Rhynchospira formosa*, *Nucleospira ventricosa*, *Platyceras multisinuatum*, *P. tenuiliratum* 20

(22) Section on Stuman's Creek

The top of the Decatur limestone is exposed where the road crosses a branch of Stuman's Creek 1½ miles east of Thurman. It is a pinkish, massive, crystalline limestone containing *Camarocrinus*. On a low soil-covered slope just above the exposure are scattered large chunks of the Decaturville chert. This chert is gray in color, porous, and highly fossiliferous. The fauna is composed of the following species: *Pleurodictyum lenticulare*, *Favosites conicus*, *Pholidops* cf. *ovata*, *Dalmanella planoconvexa*, *Rhipidomella oblata*, *Leptostrophia beckii*, *L. Planulata*, *Strophonella punctulifera*, *Leptœisca concava*, *Schuchertella woolworthana*, *Chonostrophia jervensis*, *Eatonia singularis*, *E. medialis*, *Delthyris perlamellosa*, *Meristella lœvis*, *Anoplotheca concava*, *Phacops hudsonica*, *Homalonotus* sp.

(23) Section at Saltillo

The Devonian rocks at the boat landing at Saltillo reach a thickness of almost 50 feet, though the section is only partly exposed. Just south of the landing the massive Decatur limestone dips below water-level at an angle of about 25° to the north. Here it contains *Camarocrinus*, beaks of *Gypidula*, and *Atrypa reticularis*. Succeeding the Decatur is 4 feet of whitish clay with thin sandy and cherty layers grading into thin-bedded, impure, sandy chert with whitish clay partings. The whole is deeply weathered but highly fossiliferous. The succeeding layers at this point are covered by river alluvium. About 200 yards farther downstream, however, the Decatur comes above water again, dipping about 25 degrees to the south. The interval immediately succeeding is here covered by alluvium, but the Harriman chert is exposed from 35 to 45 feet above the top of the Decatur where it is overlain by red Cretaceous clays and gravel. A petrified log of wood was observed near the base of the latter. Chunks of the Decaturville chert were seen on the intermediate slope just south of the sawmill. The section may be given as follows:

Saltillo Section

(Cretaceous) red sand and gravel

Unconformity

(Devonian)

Oriskanian group

Harriman chert

	Feet
Hard, brittle, buff and yellow chert or novaculite. Sparingly fossiliferous and thoroughly fractured. *Chonetes hudsonicus* mut. *camdenensis, Metaplasia pyxidata, Spirifer paucicostatus, Meristella lata*	10
Unexposed interval. Covered by alluvium. Much of the interval is probably occupied by the Harriman chert, which is extensively exposed in a gulch to the west of the landing, where it is strongly folded and disturbed. The Decaturville chert also occurs in the unexposed interval.	27

Linden group

Birdsong formation

Whitish clay with thin cherty laminæ forming the lower half and grading upward into impure sandy yellowish chert with whitish clay partings (all deeply weathered). Very fossiliferous. Bryozoa common. Other fossils secured: *Favosites conicus, Dalmanella eminens, Leptæna rhomboidalis, Anastrophia verneuili Camarotœchia transversa, Atrypa reticularis, Eospirifer macropleura* (common), *Delthyris perlamellosa, Spirifer cycloptera, Meristella arcuata*	8

Saltillo Section.—Continued

Contact. Not clearly exposed. A long break in the section occurs here, however, representing late Silurian time.

(Silurian)

Niagaran group

Decatur limestone

Massive light gray limestone with a few specimens of *Camarocrinus*, the beaks of a *Gypidula*, and Atrypas.

(24) Section on Smith's Fork

Numerous exposures of the Ross limestone occur in the vicinity of the old government "still" on Smith's Fork, a tributary of Indian Creek, 4 miles east of Cerro Gordo. The roads fork about one-fourth of a mile east of the "still" and one branch goes up the hill to the south. Exposures along the road show that the base of the hill is formed of massive light gray limestone carrying *Camarocrinus*. It is referred to the Decatur. The Ross limestone which succeeds it for a thickness of 45 feet is deeply weathered so that it appears as a porous, soft, shaly sandstone of rusty yellow color. Fossils are plentiful, occurring as siliceous pseudomorphs. The following fauna was obtained: *Hindia sphæroidalis, Enterolasma strictum, Favosites conicus, F. fœrstei, Rhipidomella oblata, R. emarginata, Leptæna rhomboidalis, Gypidula coeymanensis, Rensselœrina medioplicata, Atrypa reticularis, Spirifer cycloptera, Meristella arcuata, Nucleospira ventricosa.*

These strata are exposed in a thoroughly weathered condition in a deeply gullied pasture between one-half and three-quarters of a mile to the northeast of the exposure just described. The lowest layers exposed in the gully below the well are characterized by *Scyphocrinus pratteni* and a great abundance of its ponderous Camarocrini.

(25) Section at Olive Hill

The longest Helderbergian section known in Tennessee is finely exposed in the bluff on Indian Creek facing Olive Hill. The exposure is a cross-section of the west limb of a large syncline to which the Devonian rocks owe their preservation. The bluff is 50 to 75 feet high and over a mile long, but it is divided into three sections by the valleys of Franklins Branch and a smaller unnamed tributary which enter Indian Creek about a quarter of a mile apart. In the western section, 38 feet of the massive Decatur limestone may be seen overlying the coral zone of the Lobelville and dipping to the east. The

Ross limestone is exposed in the middle bluff, followed by the Olive Hill limestone, and that in turn by the Hardin sandstone. In the east bluff the dip increases to the east, and the Flat Gap limestone comes in between the Olive Hill and the Hardin sandstone. The following section is clearly shown:

Olive Hill Section

(Devonian)
Chautauquan group
Chattanooga shale

	Feet
Black, carbonaceous, fissile shale	10

Hardin sandstone

Rather fine-grained, gray sandstone	16

Unconformity. In the east bluff the Hardin sandstone rests with angular unconformity on the Flat Gap limestone, and within ½ mile west it comes down on to the Olive Hill limestone.

Linden group
Olive Hill formation
Flat Gap limestone

Very massive, pure, coarsely crystalline limestone with a small fauna consisting of *Rhipidomella oblata, Delthyris perlamellosa, Spirifer cycloptera, Dalmanites pleuroptyx*, and *Platyceras* sp.	53

Contact. A sharp, distinct bedding plane separates these massive limestones. The line is slightly irregular, varying as much as 3 inches. Neither of the limestones above or below is very evenly bedded, however.

Bear Branch limestone

Heavily bedded, light gray, finely crystalline limestone with oolitic hematite scattered through it, bringing out a pattern of miniature cross-bedding. Abundantly fossiliferous but because of its massive nature only a small collection could be secured. Among the fossils are: *Favosites helderbergiæ, Rhipidomella oblata, Brachyprion purduei, Spirifer cycloptera, Meristella atoka*, and *Dalmanites pleuroptyx*	23
Finer grained, impure, thin-bedded, gray limestone with thin bands of chert. No oolitic ore occurs. The limestone is highly fossiliferous, the fauna including *Rhipidomella oblata, Brachyprion purdeui, Leptæna rhomboidali-, Schuchertella woolworthana, Chonetes wadei Anastrophia verneuili, Eatonia eminens, Delthyris perlamellosa, Meristella lævis, Platyceras gibo sum*, and *Phacops logani*	5
Coarsely crystalline limestone with a variable quantity of oolitic hematite. The color of the various layers varies from gray to deep red, depending on the quantity of iron present. The latter is chiefly concentrated into irregular bands up to 6 or 8 inches in thickness. Fossils are common, as: *Rhipidomella oblata, Leptæna*	

Olive Hill Section.—Continued

rhomboidalis, Schuchertella woolworthana, Rensselœrina mediopli-cata, Atrypa reticularis, Spirifer cycloptera, Delthyris perlamel-losa, and *Meristella arcuata* 15

Contact. The beds seem to be conformable and there is a lithologic transition, the dense siliceous Ross limestone passing into crystal-line limestone before the iron-ore begins to appear.

Ross limestone

Dark gray, compact, fine-grained, highly siliceous limestone in thin layers 1 to 4 inches thick. The following fossils were collected: *Favosites conicus, Enterolasma strictum, Rhipidomella oblata, Leptœna rhomboidalis, Strophonella lineolata, Schuchertella woolworthana, Uncinulus vellicatus, Camarotœchia transversa, Atrypa reticularis, Delthyris perlamellosa, Cyrtina dalmani, Nu-cleospira ventricosa, Meristella atoka, Phacops logani*..... 45

Unexposed interval 1

Coarsely crystalline, heavy-bedded, light gray limestone exposed at the west end of the middle bluff. Camarocrini common, and in the upper 10 feet the following brachiopods occur: *Leptœna rhomboidalis, Leptostrophia beckii, Schuchertella woolworthana, Chonostrophia lindenensis, Gypidula cœymanen.is, Uncinulus vellicatus* (?) *Atrypa reticularis, Delthyris perlamellosa, Meris-tella atoka. Camarocrinus* continues into the lower layers, while the other fossils drop out. It is possible that the lower portion belongs to the Decatur, but if so the contact was not located 32

(Silurian)

Niagaran group

Decatur limestone

(Exposed in the west bluff.) Heavy-bedded, pure, light gray to white limestone, almost barren of fossils except for *Atrypa reticularis*, the beaks of Gypidulas, and rarely a *Camarocrinus* 38+

Contact. Apparently conformable.

Lobelville formation

Coral zone. Yellowish shale, thin-bedded limestone, and inter-bedded chert. Corals abundant, including species of *Favosites, Heliolites*, and horn corals ..... 10+

(26) Section at Chalybeate Spring

There is an excellent exposure of the Ross limestone at the chaly-beate spring on Horse Creek, 5 miles southeast of Savannah. The spring issues from a joint in a sheer face of 60 feet of this formation. The section is located on a farm belonging to Mr. Ross and was, there-fore, by implication made the type section for the Ross limestone when Foerste selected this name. The formation consists of thin-bedded, dense and hard, dark gray limestone. It is impure and highly siliceous,

yet but little chert is seen in spite of the fact that the rock analyzes over 20 per cent SiO_2. At this fresh vertical exposure the formation appears to be very sparingly fossiliferous, but along the bluff a few yards upstream these same strata are crowded with Camarocrini.

About 200 yards downstream the base of the bluff for 8 feet is formed of heavily bedded, light gray, crinoidal limestone which is referred to the Decatur. Between it and the base of the Ross limestone above there are a few feet of greenish gray calcareous shale, very poorly exposed. Its fauna will be discussed in the next section, where it is better shown.

(27) Section at Sulphur Spring

An instructive section can be pieced together from several small exposures near the sulphur spring which is also on Mr. Ross' farm about a mile south of the previous section. The spring issues from reddish limestone which Foerste has identified as the Dixon. Above the red limestone comes heavy-bedded, light gray limestone which forms the low bank for some yards above the spring. About 100 yards southeast of the spring the Rockhouse shale forms a glade at the edge of the field, while 200 yards farther southeast and across the valley the Ross limestone is well exposed. No contacts may be seen and thicknesses can be only approximately determined, though the order of sequence seems to be perfectly safe.

Sulphur Spring Section

(Devonian)

Linden group

	Feet
Ross limestone	
Dark gray thin-bedded limestone where fresh, but appearing as rusty sandstone when more deeply weathered. Exposed along the road up the hill. *Camarocrinus* very abundant, but other fossils quite rare	24
Rockhouse shale	
Light greenish gray, highly fossiliferous, calcareous shale forming a glade 100 yards southeast of the spring. Small *Camarocrinus* bulbs very common. Fauna characterized by *Pleurodictyum trifoliatum, Edriocrinus adnascens, Dalmanella macra, D. rockhousensis, Rhipidomella oblata, R. preoblata, R. saffordi, Bilobites bilobus, Eatonia fissicosta, Atrypina imbricata, Delthyris cyrtinodes,* and *Anoplotheca concava.* Thickness uncertain	10+

Sulphur Spring Section.—Continued

(Silurian)
Niagaran group
Decatur limestone (?)
Heavy-bedded, light gray, crystalline limestone poorly exposed in the hill for 50 yards east of the spring. No fossils seen..... 20+
Dixon limestone
Heavy-bedded, reddish limestone ..... 6+

(28) Section at Rockhouse

On the bank of Horse Creek about 5 miles west of Lowryville is located the cabin of a hunting club which is known as Rockhouse. In the bluff above the clubhouse the Rockhouse shale is typically developed, being underlain by the Decatur (?) and succeeded by the Ross limestone. For the most part the upper portion of the shale is weathered into a gentle slope and the bedding and contact with the Ross limestone is obscured; but a fresh exposure of the entire section of the shale is made by a ditch just above the spring south of the clubhouse. Two fallen trees at 8 and 12 feet, respectively, above the base of the formation have upturned masses of shale with their roots, forming small but excellent exposures from which to collect fossils.

Rockhouse Section

(Devonian)
Linden group
Ross limestone
Feet
Thin-bedded, dark, siliceous limestone, identical with that seen at the chalybeate spring 55
Disconformity. Contact clearly exposed for only a very short distance above the spring south of the clubhouse. The beds appear conformable, but the contact is sharp and the lithologic contrast marked
Rockhouse shale
Greenish gray, calcareous shale with thin bands of limestone at intervals of 3 or 4 feet (best seen at the spring south of the clubhouse). At the base the bands of limestone increase in frequency and the change into the massive limestone below is a gradual one. *Camarocrinus* is quite common in the shale and a 2-inch band of limestone at 5 feet from the base of the formation is essentially made up of these bulbs, mostly collapsed and broken. Loose fossils collected from the upper portion of the weathered surface of the shale bed include: *Hindia sphæroidalis, Enterolasma waynense, Pleurodictyum trifoliatum, Favosites* sp., *Edriocrinus adnascens, Camarocrinus saffordi, Rhipidomella oblata, R. preoblata, Leptæna rhomboidalis, Eatonia fissicosta, Atrypina imbricata, Delthyris cyrtinoides, Meristina roemeri,* and *Phacops* sp.

Rockhouse Section.—Continued

The following species were collected *in situ* where two trees had been uprooted at 8 and 12 feet, *respectively*, above the base of the shale: *Enterolasma waynense, Favosites* sp., *Dalmanella rockhousensis, Rhipidomella preoblata, R. saffordi, Bilobites bilobus, Leptæna rhomboidalis, Leptænisca adnascens, Dictyonella subgibbosa, Camartœchia transversa, Delthyris cyrtinoides, Nucleospira concentrica, Meristina roemeri* (?), and *Merista tennesseensis* 26

Contact. Not distinct. The shale becomes more limy at the base, resembling the limestone beneath.

(Silurian)
Niagaran group
Decatur limestone

Heavy-bedded, light gray limestone overhanging the creek. No fossils seen. To the water's edge 12

(29) Section at Pyburns Bluff

Exposures of the Ross limestone line the north bank of the Tennessee River for some 2 miles above Pyburns landing. The thickest section, that given below, occurs just below the mouth of Bluff Creek. Here the strata are dipping westward at an angle of about 8 degrees, but the dip gradually dies out to the west and the strata are practically horizontal at the west end of this bluff, about half a mile below Bluff Creek. There is another bluff across the valley of Anderson and Johnson branches repeating the same section, with the strata dipping westward again. A fault with a throw of 25 to 50 feet is required to account for this repetition of the section.

Pyburns Bluff Section

(Mississippian)
Fort Payne chert
Ridgetop shale

Feet.

Limy and carbonaceous black shale which gives a fetid odor when struck with a hammer ..... 45+

Disconformity

(Devonian)
Chautauquan group
Chattanooga formation
Hardin sandstone member

Fine-grained, muddy, gray sandstone with *Spirophyton*-like markings 1½

Disconformity. Contact sharp. All of Middle Devonian time not represented.

Pyburns Bluff Section.—Continued

Linden group

Pyburn limestone

Impure, highly siliceous, heavy-bedded, compact limestone. Sparingly fossiliferous. *Leptostrophia beckii, Rhipidomella oblata, Leptæna rhomboidalis, Uncinulus, Spirifer cycloptera* 10

Limestone like that above only thinner bedded and more impure. Fossils few. 8

Blue chert replete with fossils 1-3

Impure, thin-bedded limestone like that above 5

Blue chert, replete with fossils ..... ½

Impure, thin-bedded limestone like that above 7

Purer, finely crystalline, light bluish gray limestone, sparingly fossiliferous 3

Bluish chert, replete with fossils. *Favosites conicus, Pleurodictyum lenticulare, Rhipidomella oblata, Leptostrophia beckii, Spirifer cycloptera, Delthyris perlamellosa, Meristella arcuata* 1

Finely crystalline limestone like that above 6

Ross limestone

More impure, siliceous, dark bluish gray, thin-bedded limestone with more or less chert. *Camarocrinus* common. Other fossils few 9

Purer, compact, light gray limestone. *Camarocrinus* common. Other fossils sparse 20

Compact, light gray, fine-grained limestone with black chert in thin layers and irregular bands. *Camarocrinus* common. In the black chert occur *Leptostrophia beckii, Rhipidomella oblata, Uncinulus vellicatus* (?) and *Dalmanites pleuroptyx* 9

(30) Section on Dry Creek

The Oriskany limestone outcrops at the roadside between the house and barn on Mr. Jim Quall's place, one-half mile east of Paulk's store at Walnut Grove. About one-half mile north of this place the Linden limestone forms a low bluff along Dry Creek where it is succeeded by the same Oriskany limestone. The same distance east of Mr. Quall's house is Dry Creek schoolhouse, and the ford crossing the stream. The schoolhouse is situated in the mouth of a deep, narrow, V-shaped tributary valley which intersects the bluff at this point. Linden limestone forms the lower portion of the bluff, dipping westward at an angle of 5 or 6 degrees. The Ridgetop (Mississippian) shale lies nearly horizontal, beveling across the Linden. As a result, the lower strata exposed in the east bluff dip below the surface west of the schoolhouse, while the heavy limestone of the west bluff is truncated and does not appear east of the schoolhouse. The information

afforded by these exposures is combined in the following section for the vicinity of the Dry Creek schoolhouse:

Dry Creek Section

(Mississipian)
Fort Payne chert
Ridgetop shale
Disconformity
(Devonian)
Chautauquan group
Chattanooga formation
Hardin sandstone member
Massive, compact layer of fine-grained gray sandstone with a 6-inch layer of conglomerate at the base. Pebbles mostly sub-angular, chiefly composed of black and gray chert. Associated with the pebbles are numerous pieces of flat fish bones 3
Unconformity. Angular discordance of 5 or 6 degrees.
Oriskanian group
Quall limestone
Heavy-bedded, dense, light gray, siliceous limestone, weathering to porous, rotten, yellow chert and yellow clay. Characterized by *Edriocrinus* cf. *becraftensis*, which is very common. Also *Spirifer murchisoni*, *S. perdewi*, *Beachia suessana*, etc. ..... 10+
Contact. Not observed. In the best exposure, one-half mile north of Mr. Quall's house, there is a small unexposed interval at this level. The beds seem to be accordant.
Linden group
Flat Gap limestone (?)
Rather pure, coarsely crystalline, heavy-bedded, light gray limestone. Only a few species such as *Rhipidomella oblata* and *Spirifer cycloptera* are moderately common ..... 25+
Unconformity. Contact sharp and irregular. Adjacent beds contrast sharply in lithology. Seen best in the bluff one-half mile north of Mr. Quall's house.
Pyburn limestone
Fine-grained, highly siliceous, bluish gray limestone. Weathered surface is brownish, appears sandy, and shows small cross-bedding, especially in the middle and upper portions. This last character is best shown one-half mile north of Mr. Quall's house 25
Ross limestone
Impure, fine-grained, dark gray limestone, grading into that above. A 6-inch band of bluish chert at 5 feet and another at 10 feet are replete with a single orthid, *Rhipidomella oblata*. *Camarocrinus* present 15
More impure, siliceous, dark, thin-bedded limestone, grading into that above. Irregular thin bands and concretions of dark chert. Very sparingly fossiliferous. *Camarocrinus* occurs 40

It is interesting to find the Decaturville chert present at this locality. Its next known exposure is at Grandview, 25 miles to the north. Pieces of the chert, crowded with fossils, were found loose on the slope near the top of the Linden and just below its contact with the Hardin sandstone east of the schoolhouse. At this point the upper massive crystalline member of the Linden is absent, so that the relation of the chert to the latter could not be positively determined. Where the massive limestone is present west of the schoolhouse, its contact on the lower Linden can be seen for some distance, and the chert is not present between them. The same conditions obtain in another section north of Mr. Quall's house. The chert, therefore, very probably succeeds the massive limestone whose upper contact is soil-covered in both sections.

END.