

ART. XXXVII.—*Stratigraphy and Correlation of the Devonian of Western Tennessee*<sup>1</sup>; by CARL O. DUNBAR.

## INTRODUCTION.

For more than half a century the Devonian of western Tennessee has offered one of the most inviting fields to the stratigrapher and paleontologist, yet the list of publications relating to it comprises little more than a score of pages. It remains to-day the last important area of Lower Devonian in America to be adequately described. These strata are not only replete with finely preserved fossils, but they form the most complete and complex Lower Devonian sequence in the Mississippi Valley province, and the previously unsuspected occurrence here of the typical upper Oriskany gives to the Tennessee area the highest interest.

*Previous studies.*—The presence of the Helderbergian rocks in Tennessee was first noted by Safford in 1855, and in 1869 he more fully described these beds, to which in 1876 he and Killebrew applied the name Linden. In 1899 a second Devonian formation, the Camden chert, was made known by Safford and Schuchert, who assigned it to the lower Oriskany. Foerste in 1901 defined the Pegram limestone, and in his valuable paper on "The Silurian and Devonian Limestones of Western Tennessee" (1903) he more fully described the Camden and the Linden formations and subdivided the latter into two members, the Ross and Pyburn limestones respectively.

*Scope of the present paper.*—This paper is an abstract of a report on the Devonian of Tennessee which will be published at a later date as a bulletin of the Tennessee State Geological Survey. In the complete report the stratigraphic relations and faunal characteristics of each of the Devonian formations will be described in full, and detailed geologic sections of the important exposures will be given. The limits of the present paper will permit only a brief description of these formations and a presentation of the essential conclusions reached. The new species appearing in the faunas will be described elsewhere at an early date, and the manuscript names are therefore used in this article.

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*Acknowledgments.*—The present study was begun in 1916, when the writer spent two months in the field, making a large collection of fossils and gathering data which formed the basis of a monograph presented in 1917 as a dissertation for the degree of doctor of philosophy at Yale University. The problem proved so fruitful of results that, thanks to the interest of the late Doctor A. H. Purdue of the Tennessee State Geological Survey, the writer was enabled to spend two additional months in the field during the summer of 1917, and to elaborate the original study into a completed report.

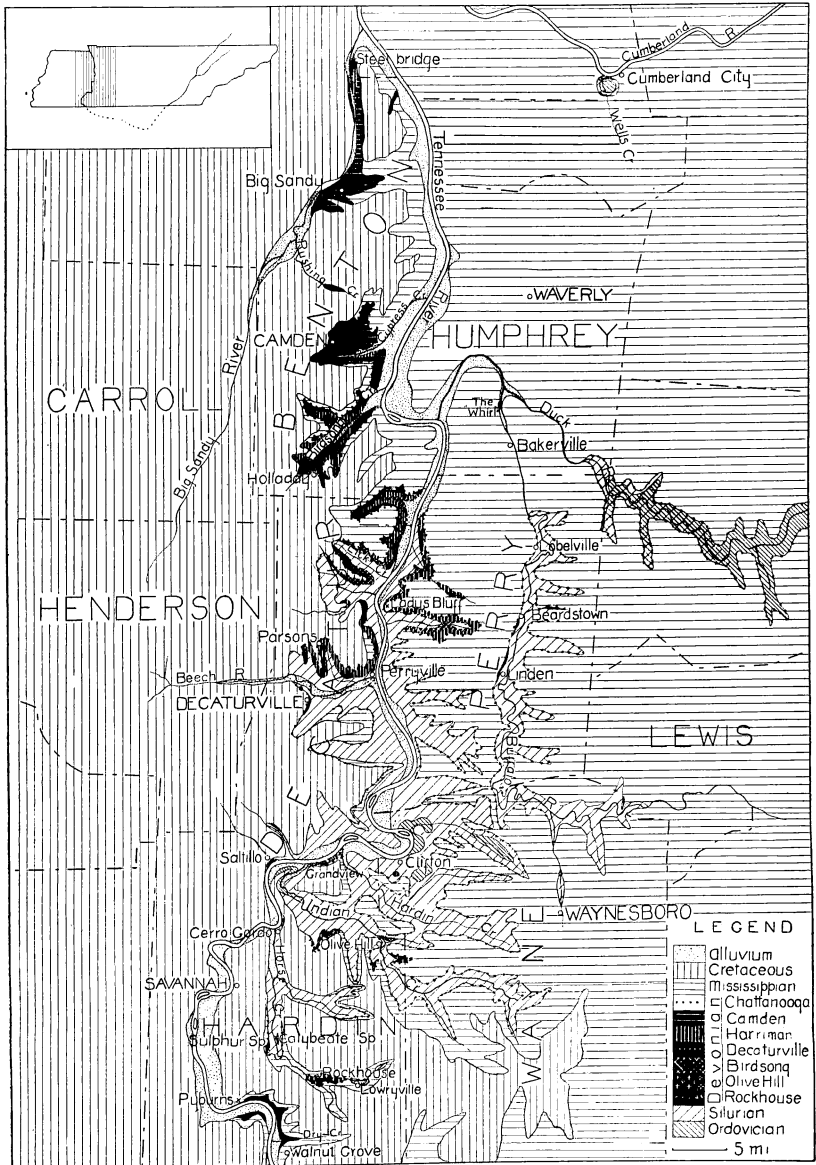
The original investigation was made possible by the kindness of Professor Charles Schuchert of Yale University, and the preparation of the manuscript has been done in the laboratories of the Peabody Museum under his constant supervision. It is a pleasant duty to acknowledge the writer's indebtedness to Professor Schuchert for many helpful suggestions and criticisms. Thanks are also due Doctor Bruce Wade for valuable information given in the field, and for several collections of fossils.

*Location.*—The Devonian rocks of Tennessee are exposed in numerous small irregular areas in a narrow belt along the western valley of the Tennessee River. They are best developed in Benton, Decatur, Perry, and Hardin counties. With very minor exceptions, this narrow belt across the state embraces all the Devonian strata save the widespread Chattanooga shale. (See map, fig. 1.)

#### STRATIGRAPHY AND CORRELATION

*Introduction.*—The Devonian rocks in Tennessee succeed those of the Middle Silurian, the contact being a disconformable one, usually with little physical evidence to direct attention to the long interval which separates these two series. In most of the exposed sections the Lower Devonian rests on the massive Decatur limestone, but in the more eastern occurrences it overlaps younger Silurian formations. Safford long ago recognized that these Lower Devonian strata form a westward-thickening wedge separating the Silurian limestones from the succeeding but much younger Mississippian shales and chert, and that they pinch out and disappear within a few miles east of the Tennessee River.

FIG. 1.



The total thickness of the Devonian strata in Tennessee is not over 500 feet and the longest single exposed sequence is less than 200 feet thick. Nevertheless the strata may be divided into nine formations, each separated by longer or shorter intervals of erosion when

Generalized Devonian Section of Western Tennessee

Series	Group	Formation	Thick-ness	Character	
Neodevonian	Chautauquan	Chattanooga shale	20'±	Black fissile carbonaceous shale Thin basal sandstone	
		Hardin sandstone member			
Mesodevonian	Senecan	Break			
		Erian			
	Ulsterian	Pedram limestone	10'±	Heavy-bedded white limestone	
Break					
Camden chert		0 - 200'±	Thin-bedded buff colored novaculite		
Break					
Paleodevonian	Oriskanian	Harrison chert	20 - 55'	Heavier bedded white and buff novaculite	
		Break			
		Quall limestone	10'±	Heavy-bedded cherty gray limestone	
	Break				
	Helderbergian or Linden	Olive Hill form.	Decaturville chert	6'±	Porous gray chert
			Break		
			Birdsong shale	35 - 65'	Bluish shaly limestone and shale
			Break		
			Flat Gap	0-58'	Massive pure limestone
			Bear Branch-Pyburn	0-45'	Massive limestone and oolitic hematite in north - impure cherty limestone in south
Ross			0-60'±	Impure thin-bedded cherty limestone	
Break					
		Rockhouse shale	0-28'	Bluish green calcareous shale	

some of them were reduced to remnants before the deposition of the succeeding formation. In consequence, the thicknesses of the several formations, and even the sequence, vary from section to section. In spite of this fact, the Devonian strata, like those of the Silurian beneath, are so generally horizontal in western Ten-

nessee that disconformities are the rule and unconformities the exception, even where the break in sequence is known to be a long one.

#### LOWER DEVONIAN SERIES

##### *Linden or Helderbergian Group*

*Rockhouse shale.*—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. But in southern Hardin County a still lower undescribed formation of fossiliferous shale comes in like a wedge between the Ross and the Decatur (Silurian) limestone. This formation thickens to the southward, where it goes permanently below drainage. A maximum thickness of 26 feet may be seen at Rockhouse, a hunters' clubhouse on Horse Creek, 5 miles northwest of Lowryville, and because of this good exposure the formation will be named the Rockhouse shale. It is much thinner where it forms a glade near the sulphur spring on Horse Creek, 5 miles southeast of Savannah, and it does not appear in the sections farther north. It is a glade-forming, calcareous shale of greenish gray color, interbedded with occasional thin bands of light gray crystalline limestone which toward the base of the shale become thicker and closer set, so that the formation appears to grade into the underlying Decatur limestone.

The shale is replete with fossils, among which the bulbous crinoid root *Camarocrinus* is most conspicuous. The fauna consists of thirty-five species, of which one third are new. The assemblage is an extremely interesting one, with a mingling of holdovers from the Silurian, along with heralders of early Devonian time. It indicates for the formation a position very early in the Devonian and near the Siluro-Devonian boundary line. The interesting biota includes *Edriocrinus pocilliformis*, *E. adnascens* n. sp., *Camarocrinus*, *Scyphocrinus* sp., *Pleurodictyum trifoliatum* n. sp. (ancestral to *P. lenticulare* but mature at the three-celled stage), *Dalmanella macra* n. sp., *D. rockhousensis* n. sp., *Rhipidomella oblata*, *R. preoblata*, *R. saffordi*, *Bilobites* (small form like *bilobus*), *Leptænisca adnascens*, *Dictyonella subgibbosa* n. sp., *Eatonia fissicosta* n. sp., *Delthyris cyrtinoides* n. sp., (very near *perlamellosa*), *Nucleospira concentrica*, *Mer-*

*ista tennesseensis*, *Meristina roemeri*, *Phacops* sp., and six species of gastropods.

The presence here of *Dictyonella subgibbosa* n. sp., *Nucleospira concentrica*, and *Merista tennesseensis* at first inclined the writer to refer this formation to the Silurian. On the other hand, the preponderance of the fauna is distinctly Devonian and the general paleogeographic conditions likewise strongly support this reference. The Upper Silurian in America was a time of marked restriction of the seas, scarcely a normal marine fauna being known anywhere of Upper Silurian time. Furthermore, no deposits whatever of this age have yet been found anywhere in the whole Mississippi basin. The Rockhouse fauna, however, is a normal marine assemblage, and is present in both Tennessee and Oklahoma. It represents, therefore, a wide embayment in this region, which is known to have been an early Devonian basin. The preserval of so thin and soft a formation in both Tennessee and Oklahoma beneath Helderbergian strata further supports the belief that it was not subjected to long erosion before the deposition of the latter.

The Devonian age of the fauna is indicated by the deployment of the gastropods, which make up one fourth of its number, for while gastropods are commonly abundant in the Lower Devonian, the New Scotland having thirteen and the Oriskany over twenty species, on the other hand but two or three species are found together in any Silurian fauna. Likewise the abundance and variety of orthoid brachiopods is a Devonian characteristic. Neither *Pleurodictyum* nor *Edriocrinus* is known in the Silurian, and the two species of the latter both characterize the succeeding Linden formations. Large specimens of *Rhipidomella oblata*, like those of this formation, are never seen in the Silurian, and the *Delthyris* is closely related to *perlamellosa*, which is so typical of the Helderbergian, and is much larger and more coarsely lamellose than any Silurian species of this genus.

Although this is the first known occurrence of a *Dictyonella* in the Devonian in America, Barrande described a species long ago from the Middle Devonian (stage G) of Bohemia. The presence of the Silurian holdovers, *Bilobites bilobus*, *Nucleospira concentrica*, and *Merista tennesseensis*, however, as well as the primitive expres-

sion of the *Pleurodictyum*, which is mature in the three-celled stage, indicate for the formation a place very early in the Devonian. This inference is further supported by the thick development of overlying strata of Coeymans and New Scotland age. The Rockhouse shale is, therefore, believed to represent a part of the Keyser formation at the known base of the Lower Devonian, although it belongs to a different basin and hence shows but slight faunal relation to the Keyser.

*Olive Hill formation.*—The Olive Hill formation succeeds the Rockhouse shale and further northward overlies the Decatur limestone, but, like the preceding formation, it is confined to the southern part of the state. The present outcrops occur in Hardin County, Tennessee, and adjacent portions of Mississippi and Alabama. At about the northern edge of Hardin County, it has been rapidly bevelled off by interformation erosion, while to the southward it goes permanently below drainage, with unreduced thickness. Lithologically it is a complex formation. The best exposure and the one from which it takes its name is clearly shown in the bluff on Indian Creek at Olive Hill, where it is fully 150 feet thick and consists of three distinct lithologic units. These are, in descending order, the Flat Gap, the Bear Branch, and the Ross limestone members.

The Flat Gap member is a heavy-bedded, coarsely crystalline or granular limestone of white or pinkish color, and is very sparingly fossiliferous. Toward the top *Rhipidomella oblata* and *Spirifer cycloptera* are common, and *Delthyris perlamellosa* and *Dalmanites pleuroptyx* are quite rare. Colonies of massive bryozoa and large pieces of crinoid stems complete the fauna.

The Bear Branch member consists of more impure, coarse-grained limestone in which there is a considerable quantity of oolitic hematite. The latter varies greatly in richness, and may be disseminated through the limestone, giving the whole a deep reddish color, or may be concentrated into richer bands of ore separated by layers of limestone. The member takes its name from an exposure on Bear Branch about 2 miles southeast of Olive Hill, where it forms a low bluff showing a thickness of 20 feet of low-grade ore (protore), analyzing on an average from 20 to 25 per cent Fe and much resembling the Clinton iron-ore. So far as the writer is aware, this is the

largest deposit of an oolitic iron-ore to be found above the Clinton. These beds yielded the ore which was mined before the Civil War at a locality about 2 miles southwest of Clifton. The cross-bedding which characterizes this member bears evidence that the oolite was deposited in shallow water. Fossils occur throughout it and are especially common in a band of muddy, cherty limestone near the middle. The fauna, however, closely resembles that of the Ross member below, fifteen of its eighteen species being common to the latter. The chief differences to be noted are the presence here of *Eatonia eminens* and the absence of *Camarocrinus* and the *Scyphocrini* which characterize the lower member.

The Ross limestone member was first described by Foerste (1903). It is a dense, fine-grained, siliceous or cherty limestone of dark gray color, disposed in thin layers from 2 to 5 inches thick. Although very hard and compact when fresh, it weathers to a soft, porous, shaly sandstone of rusty brown color. Its most characteristic fossils are the *Camarocrini* and *Scyphocrinus pyburnensis* and *S. pratteni*. Because of the abundance of the crinoid bulbs Foerste called it the "Camarocrinus or Ross limestone." Other fossils occur in more or less abundance, the more important of which are listed beyond (page 741).

For a distance of 20 or 25 miles to the south and southwest of Olive Hill, only the lower or Ross limestone member has escaped later erosion, but at Pyburns Bluff on the Tennessee River, and at a bluff on Dry Creek near the southern line of the state, thick sections of the Olive Hill formation are again exposed. Here, however, the subdivisions seen at Olive Hill cannot be clearly recognized. In the section at Pyburns the formation is between 80 and 100 feet thick, and its base is below drainage. Here it consists of dense, fine-grained, impure and cherty limestone throughout. The lower portion is characterized by *Camarocrini*, but this fossil is absent in the upper portion. On this faunal basis Foerste subdivided the section into the Ross limestone below and the Pyburn limestone above. The Ross here agrees in faunal and physical characters with that at Olive Hill and with the intervening sections as well. The Pyburn holds, more or less, the stratigraphic position of the Bear Branch member at Olive Hill, though its lithologic characters are

entirely different. Faunally, however, it seems to agree with the latter, especially in the absence of the *Camarcini*. It therefore seems highly probable that the Pyburn limestone is the equivalent of more or less of the Bear Branch; and that the latter is a local shallow-water phase is shown by its cross-bedding and the development of oolite. The author therefore holds that if the Bear Branch member could be traced southward it would be seen to grade into the impure gray limestone of the Pyburn. In this section the Pyburn member is unconformably succeeded by Mississippian shales, but in the next section to the south, on Dry Creek, the top of the Pyburn member becomes more sandy and somewhat irregularly bedded, and here it is separated by a slight erosional unconformity from a massive, coarsely crystalline, white limestone which seems to represent the Flat Gap member.

The Ross member only is exposed along Horse Creek on the Ross farm 5 miles southeast of Savannah and again for 2 or 3 miles above Rockhouse. This same member is exposed in the bluffs along the Tennessee River below Cerro Gordo, more extensively at Grandview, and also outcrops along tributaries of Indian Creek 3 or 4 miles east of Cerro Gordo.

At Olive Hill, where the three members are present, the total thickness is over 150 feet; the Ross and a part of the Bear Branch members are present near Clifton, but only a part of the Ross at Grandview; in the vicinity of Saltillo the whole formation is missing, the younger and southwardly overlapping Birdsong formation with its *Eospirifer macropleura* fauna here resting directly on the Decatur limestone. The progressive thinning of the Olive Hill formation toward the north and west, by the disappearance of the higher members first, strongly indicates a considerable interval of erosion following the deposition of this formation and preceding the Birdsong shale. So thick a series of limestones, with the upper 50 feet, especially, pure and heavy-bedded, must in all probability have extended farther north than the 12 or 15 miles which separates Olive Hill from Grandview and Saltillo.

The fauna of the Olive Hill formation is chiefly developed in the Ross member, from which fifteen species pass upward into the Bear Branch and four continue into the

terminal Flat Gap member. The more important forms of the Ross limestone are: *Pleurodictyum lenticulare*, *Favosites conicus*, *Edriocrinus pocilliformis*, *Scyphocrinus pratteni*, *S. pyburnensis*, and *S. mutabilis* (with their corresponding Camarocrini), *Rhipidomella oblata*, *Lep-tostrophia beckii*, *Stropheodonta planulata*, *Anastrophia verneuili*, *Rensselaerina medioplicata*, *Delthyris perlamellosa*, *D. octocostata* mut. *tennesseensis*, *Meristella atoka*, *M. laevis*, *Phacops logani* and *Dalmanites pleuroptyx*. The Bear Branch member contains, in addition, *Eatonia eminens*, but it and the Flat Gap member lack many species which occur in the Ross, especially the Scyphocrini and *Camarocrinus*.

Of this fauna of fifty-eight species, fifteen are indigenous to Tennessee, while twenty elsewhere occur in both the Coeymans and New Scotland, twenty-one being elsewhere confined to the New Scotland and one to the Coeymans. Its relations are therefore with the higher Coeymans and lower New Scotland, but it has more decidedly the impress of the latter. It does not, however, contain a number of significant species such as *Dalmanella perelegans*, *D. eminens*, *Orthostrophia strophomenoides*, *Camarotæchia bialveata*, and especially *Eospirifer macropleura*, which are very distinctive of the New Scotland, and which do occur in the succeeding Birdsong shale. 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, the Olive Hill must be referred to very early New Scotland time, if, in fact, it does not represent a part of the higher Coeymans.

The close relation of this fauna to that of the Birdsong shale will be noted below in the discussion of the latter.

*Birdsong formation.*—This shaly member of the Linden is the best known of the early Devonian formations of western Tennessee, because of its finely preserved fossils. It is the one exposed at Linden and is much better developed west of the Tennessee River and from Perryville northward to the mouth of Big Sandy River. It was provisionally correlated by Foerste (1903) with the Pyburn limestone which he defined in the section at Pyburns Bluff near the southern edge of the state. If this correlation could be substantiated, the name Pyburn

would be a most unfortunate one to apply to the formation, since the limestone at Pyburns is an isolated occurrence about 40 miles south of the nearest good section of the formation under discussion. Moreover, it is neither faunally nor lithologically typical or representative of the latter. It is the conclusion of the present study, however, that the Birdsong formation is distinct from and younger than the Pyburn limestone, and it is therefore given this new name because of its typical development along the valley of Birdsong Creek.

At the base of the formation is 8 to 10 feet of rather thick-bedded, coarsely crystalline, gray limestone, followed by a transition zone of thinner bedded crystalline limestone, interbedded with bluish calcareous shale, passing into bluish shaly limestone or limy shale which forms the upper half or two thirds of its thickness. It weathers into bluish clay and a rubble of small lumps of limestone, and frequently forms barren hillsides or "glades."

The formation attains a thickness of about 45 feet along Birdsong Creek, and continues with but little change, either lithologically or faunally, through northern Decatur County and Benton County, though it is generally below drainage in central and northern Benton County. About 5 miles above the mouth of Big Sandy River, where it comes to the surface again, it reveals an additional 20 feet of higher shaly layers not to be seen further south. To the south and east of Perryville it has been beveled off by interformational erosion, but a small outlier still persists in the vicinity of Saltillo. A thickness of only 8 feet of these strata is exposed at the boat landing at this locality. The association here of *Anastrophia verneuili*, *Dalmanella eminens*, and *Eospirifer macropleura* (very common) leaves no doubt of their reference to the Birdsong formation, and they apparently do not represent even the lowest layers, so that the formation appears to overlap to the south.

In all of the sections west of the Tennessee River this formation rests with a disconformable contact upon the Decatur limestone of the Silurian, the boundary line between them being usually difficult to locate. Farther northeastward, at Beardstown on Buffalo River and near Cumberland City in the Wells Creek basin, it overlaps younger Silurian strata.

Excepting the limestone at its base, the Birdsong for-

mation is extremely fossiliferous, and the perfect preservation of its fossils is scarcely to be duplicated in the whole of the Lower Devonian. Brachiopods greatly predominate, except in a narrow zone at the top of the formation in Benton and Decatur counties which is extremely crowded with bryozoa. Some of the more important fossils are: *Pleurodictyum lenticulare*, *Favosites conicus*, *F. foerstei* n. sp., *Edriocrinus pocilliformis*, *Orthostrophia strophomenoides*, *Dalmanella subcarinata*, *D. perelegans*, *D. eminens*, *Rhipidomella oblata*, *R. emarginata*, *Bilobites varicus*, *Leptostrophia beckii*, *Leptænisca adnascens*, *L. concava*, *Anastrophia verneuili*, *Gypidula multicostata* n. sp., *Eatonia tennesseensis* n. sp., *Camarotoechia bialveata*, *Rensselærina medioplicata*, *Eospirifer macropleura*, *Delthyris perlamellosa*, *Spirifer cycloptera*, *Trematospira simplex*, *T. costata*, *Meristella arcuata*, *M. atoka*, *M. lævis*, *Phacops logani*, *P. hudsonica*, *Dalmanites pleuroptyx*, and *D. retusus* n. sp.

The very striking resemblance of this fauna to that of the New Scotland of New York has long been recognized. Of the ninety-nine species identified from this formation, sixty also occur in the New Scotland, and among these are almost all the diagnostic species of the latter, especially noteworthy being *Eospirifer macropleura*. Considering the great distance which separates Tennessee, and even Maryland, from New York, the correspondence in these faunas is unusual and clearly indicates not only an equivalence in age, but the establishment of a rather direct communicating seaway. On the other hand, there are certain elements in the Birdsong fauna which do not recur at this time in the Appalachian trough and which appear to have reached Tennessee through the previously established southern embayment. Such, for example, are the various species of *Scyphocrinus* with their associated Camarocrini, the genus *Rensselærina*, characteristic new species of *Eatonia* and *Gypidula*, and *Meristella atoka*. The Scyphocrini were sequestered somewhere in the southern waters, their bulbs appearing in great abundance in both Oklahoma and Tennessee, and ranging from the Decatur limestone of the Middle Silurian to the top of the Birdsong shale, whereas they only temporarily invaded the Appalachian trough, appearing in a zone near the middle of the Keyser in Maryland and in the Manlius? of New York.

The intimate relationship of this fauna to that of the Ross member of the Olive Hill formation is shown in the fact that fifty-one out of fifty-eight species from the latter pass into the Birdsong shale. On the contrary, there is great deployment of *Camarocrinus* in the Ross, as in the Rockhouse shale, whereas these fossils are generally not common in the Birdsong formation, and neither the distinctive *Scyphocrinus pratteni* nor its huge bulb has been seen in the latter formation. At the same time, thirty-five species appear in the Birdsong that have not been found in the Ross. The most importance is attached to *Eospirifer macropleura*, which is always to be found in the Birdsong and never in the Olive Hill. Equally characteristic species of the former formation, such as *Eatonia tennesseensis*, *Camarotæchia bialveata*, *Dalmanella perelegans*, and *Dalmanites retusus*, are also lacking in the Olive Hill. The absence of these species from the Ross and Pyburn limestones may not be attributed to the control of the sediments, since they are known to occur elsewhere in impure cherty limestones. To this fauna evidence for the distinctness of the Birdsong shale from the Olive Hill formation should be added that of the general field relations. To correlate the Birdsong shale with the Ross limestone would demand a very abrupt faunal and lithologic change between Perryville and Grandview, though each formation maintains its own characters with uniformity for many miles from these localities. But the existence of any such transition is negated by the outlier of the Birdsong formation at Saltillo, which is as far south as Grandview. This being true, the erosion of the Ross limestone from the vicinity of Saltillo must have preceded the deposition of the Birdsong shale, and this fact, as well as the faunal evidence, precluded the correlation of the latter with either of the members of the Olive Hill formation.

*Decaturville chert.*—This thin formation is the highest member of the Linden group and unconformably overlies all of the preceding formations. It is well developed in the vicinity of Decaturville, from which place it takes its name. The most distinctive and widespread part of the formation is a very porous and extremely fossiliferous gray or slate-colored chert, which on the surface is stained with iron rust, and which forms a heavy layer from a few inches to over a foot thick. Beneath this is

thinner bedded sandy chert which weathers more readily and is not well exposed. This lower portion seems to vary in thickness from place to place, but was not seen to exceed 5 feet. Although so thin, this formation, with both its distinctive lithology and fauna, extends over half-way across the state. It was not seen north of Camden, but in various exposures along Birdsong Creek and further south on Lick Creek it disconformably succeeds typical sections of the Birdsong shale. Where best developed about the town of Decaturville, it rests on the basal layers of the Birdsong formation, though a full section of the latter is preserved at Perryville only 6 miles to the northeast. In the vicinity of Saltillo it rests in places on remnants of this formation, and elsewhere on the Decatur limestone, while 5 or 6 miles to the east at Grandview it succeeds the Ross limestone and near Walnut Grove at the south edge of the state it overlies the Olive Hill formation. Thus far it has not been identified east of the Tennessee River except in Hardin County.

The chert is replete with fossils which are preserved both as natural molds and casts and as replacements of the shell in white silica. The most striking feature of the fauna is the large size of many species, which exceeds their norm by 25 to 50 per cent. Some of the important fossils are as follows: *Favosites conicus*, *Pleurodictyum lenticulare*, *Dalmanella planoconvexa*, *Rhipidomella oblata*, *Leptostrophia beckii*, *Leptænisca concava*, *Schuchertella woolworthana*, *Chonostrophia jervensis*, *Eatonia singularis*, *E. medialis*, *Delthyris perlamellosa*, *Meristella* cf. *lævis*, *Anoplotheca concava*, *Homalonotus* sp. (large), and *Phacops hudsonica*.

This fauna is closely allied to those of the Birdsong and New Scotland formations and there are affinities which equally relate it to the Becraft. Of its nineteen species, twelve occur in both the New Scotland and Becraft, and two others have closely related species in both. Of the remaining forms, *Leptænisca concava* and *Phacops hudsonica* are elsewhere confined to the New Scotland, while *Chonostrophia jervensis* is limited to the Becraft. The chief distinction separating this fauna from that of the Birdsong or New Scotland is the absence here of many characteristic species of these formations, such as *Eospirifer macropleura*, *Bilobites varicus*, and *Anastrophia verneuili*. On the other hand, it lacks some

of the most distinctive forms of the Becraft, such as *Aspidocrinus scutelliformis*, *Rhipidomella assimilis*, and *Spirifer concinnus*. The faunal evidence is, therefore, not very conclusive, but it is not out of harmony with the assignment of this formation to early Becraft time. This reference of the formation, however, is based rather on its stratigraphic position. The distinct unconformity with which the formation overlaps the Birdsong shale indicates a considerable time break between it and the New Scotland equivalent, and since a thick section of the latter is already represented in the Birdsong formation, the distinctly younger Decaturville chert seems to be best referred to the earliest Becraft. The Becraft sea probably entered the Mississippi basin by the same route as that of the New Scotland, since it is present in southern Illinois, where Savage (1908) has reported such characteristic Becraft fossils in the upper part of the Bailey limestone as *Aspidocrinus scutelliformis* and *Spirifer concinnus*, associated with *Oriskania condoni* (?) and *O. sinuata* n. var.

#### Oriskany Group

The upper Oriskany, with its characteristic fauna of large species, is typically developed in the Appalachian trough extending from Gaspé to southern Virginia, but previous to 1913 it was believed that this sea had never attained the Mississippi basin. In that year, however, Weller (1914) discovered a very small occurrence of white limestone in eastern Missouri carrying this distinctive fauna. It is one of the chief contributions of the present study to record an extensive development of the typical upper Oriskany along the Tennessee valley, where it attains a thickness of over 50 feet and is exposed in numerous places for a distance of more than 75 miles. It unconformably overlies the Linden group and is in turn separated by local unconformities from the succeeding Camden chert. The Oriskany equivalents are here divided into the lower Quall and the higher Harri-man formations. The former name is applied to the basal siliceous limestone, and the latter to the much thicker and more extensively distributed superimposed novaculite.

*Quall limestone.*—This thin limestone formation is confined to the southern part of the state, having a

maximum thickness of only about 10 feet where exposed along Dry Creek, a small tributary which enters the Tennessee River near Walnut Grove. It thins out to the northward, being locally present in the bluff at Grandview, where its greatest thickness is scarcely 4 feet. The only other observed outcrop is at the town spring at Linden, where it is about 3 feet thick and rests disconformably on the lower part of the Birdsong formation. In these three exposures it rests in turn on the Flat Gap limestone, the Decaturville chert, and the basal part of the Birdsong shale, showing an unconformable relation indicative of a considerable break in the sequence, which is in harmony with the faunal evidence.

Where freshly exposed, the limestone is light gray in color and rather fine-grained. It is disposed in layers from 18 to 20 inches thick and appears to be magnesian and highly siliceous. Upon deep weathering, it forms a very porous, rotten, white and buff chert with yellow clay, in which fossils abound as free pseudomorphs or replacements in silica. The occurrence at Linden is more impure and darker in color.

The small fauna which has been secured includes *Edriocrinus* sp., *Striatopora* sp. (large), *Plethorhyncha* cf. *barrandei*, *Beachia suessana*, *Spirifer arenosus*, *S. murchisoni*, *S. purduei*, and *Platyceras gebhardi*. This fauna is clearly related to those of the upper Oriskany of the Appalachian trough and to the succeeding Harriman novaculite, having no species in common with the Linden or Helderbergian. The writer was first inclined to consider the Quall as only a member of the Harriman, but because of the stratigraphic relations described below under the latter formation, and because of certain faunal differences—though largely negative—it seems best to regard it as a distinct formation.

*Harriman novaculite*.—This formation is named for Harriman Creek, in Decatur County. It consists of so called chert or novaculite that is nearly white on fresh exposure but weathers to shades of yellow and buff. It is disposed in layers ranging from a few inches to over a foot in thickness, and is very hard and brittle, being thoroughly fractured, where weathered, into small angular fragments; in this condition it so closely resembles the Camden "chert" that only the fossils may be relied upon to distinguish these two formations. Where freshly

exposed, it is generally whiter and more heavily bedded than the latter.

The formation extends nearly across the state, attaining a thickness of 55 feet near the mouth of Big Sandy River in the north, and showing an almost equal thickness at Cerro Gordo and Grandview in northern Hardin County. It is well developed in the vicinity of Perryville and Parsons, where it forms "chert" hills and has been largely quarried for road metal.

In successive outcrops the Harriman novaculite rests upon the mid-Silurian and various members of the Linden group, giving the clearest evidence that it is separated from the latter by a considerable break and interval of erosion. Near the mouth of Big Sandy River it lies above the highest layers of the Birdsong shale, while on Sycamore Creek near Holladay it succeeds a zone 20 feet lower, and within 2 miles to the east on Wolf Creek it rests on the Decatur, all of the Linden being locally absent through erosion. Further south at Perryville, it rests again on the Birdsong shale, but 6 miles further to the southwest at Decaturville, the two formations are separated by the Decaturville chert. At Grandview it locally succeeds the Quall limestone, though the latter is absent at Cerro Gordo, and here it rests on the Ross member of the Olive Hill formation. Further southward, where the Quall limestone is better developed, the Harriman formation is absent.

This novaculite is generally fossiliferous, but unevenly so. Near the mouth of Big Sandy River, fossils could be found only near the top, but the portion exposed on Cypress Creek near Camden is rich in organisms, and here was secured the largest fauna. At Perryville the middle portion is abundantly fossiliferous, but the upper and lower part only sparingly so, while the section at Grandview is moderately fossiliferous. The fossils are preserved as natural molds and casts similar to those in the Camden "chert." The fauna of twenty-five species includes *Leptana ingens* n. sp. (very large), *Leptostrophia magniventra*, *Anoplia nucleata*, *Chonostrophia complanata*, *Plethorhyncha* cf. *barrandei*, *Rensseleria ovoides*, *Oriskania saffordi* n. sp., *Spirifer purchisoni*, *S. arenosus*, *S. paucicostatus*, *Metaplasia pyxidata*, *Meristella lata*, *M. rostellata*, *Anoplothea dichotoma*, *Leptocœlia flabellites*, *Platyceras gebhardi*, etc.

The relation of this fauna to that of the upper Oriskany in the Appalachian trough is very striking, especially in consideration of the great distance of over 600 miles which separates these regions. Nineteen of the twenty-five species found in Tennessee occur elsewhere in the upper Oriskany, thirteen of them being common to both Maryland and New York, and these include almost all the distinctive Oriskany forms. The distinctness of this fauna from that of the Linden group below is shown by the fact that only one species, the long-ranging *Eatonia peculiaris*, has been found in both.

The fauna of the Little Saline limestone of Missouri, discovered by Weller (1914), has not yet been described, and Weller's report is awaited with great interest. Nevertheless a preliminary comparison made by the writer with a collection sent to Yale by Professor Weller indicates that the Missouri fauna is less closely related to that of the Harriman novaculite than either of these is to that of the Appalachian trough.

#### *Middle Devonian Series*

##### Ulsterian Group

The earlier Middle Devonian or Ulsterian is represented in Tennessee by two formations, the Camden chert and the Pegram limestone. The former is well developed in the northern half of the valley, where it attains a measured thickness of 164 feet, while the latter is a very thin formation of which only remnants are now exposed at three widely separated localities.

*Camden chert.*—This formation was named by Safford and Schuchert (1899) for the village of Camden, Tennessee, where it is typically developed and well exposed. Although previous workers have regarded it as an Oriskany formation, it is one of the chief conclusions of the present study that it forms an early part of the Middle Devonian. When first described, it was referred to the lower Oriskany, and attention was especially directed to the absence here of the large brachiopods which characterize the upper Oriskany. When in 1907 Savage restudied the equivalent of these beds in Illinois, where they are known as the Clear Creek chert, he showed that they pass apparently by continuous deposition into the Grand Tower (Onondaga) formation, there being an

interbedding of the upper layers of the Clear Creek chert with the basal layers of the Grand Tower. He also clearly showed the intimate relation of the faunas of these two formations, and therefore assigned the Clear Creek to the highest Oriskany, assuming that deposition was continuous in southern Illinois from the Lower into the Middle Devonian. At that time, however, the typical upper Oriskany was entirely unknown in the Mississippi basin and the Camden chert seemed best to occupy this interval, the uniqueness of its fauna being ascribed to the fact that it belonged to a different basin from that of the Appalachian trough. The finding by Weller of typical Oriskany in Missouri and especially the discovery of its good development in western Tennessee, where it is unconformably succeeded by the Camden chert, give a new vista to the problem of correlation.

The Camden chert is a white to yellow brittle novaculite disposed in thin hard layers, usually from 1 to 3 inches thick—rarely as much as 8 or 10 inches—which are commonly separated by gritty clay along the bedding planes where weathering has begun. Locally there are irregular, more or less vertical pockets of white silica, apparently the result of leaching along ground-water passages. The rock breaks with an irregular fracture into angular, sharp-edged fragments, and it is always so thoroughly fractured that even the fresh quarry faces quickly break down into a talus slope, while natural outcrops appear only as a loose rubble of angular pieces of buff "chert" or novaculite, mostly smaller than one's fist. So characteristic is this broken-up condition of the rock that the quarries where it is extensively worked for ballast or road metal are generally known as "gravel pits." It has proved to be one of the finest of road metals, as it is very slightly soluble and has the important quality of "bonding" well so as to form a hard surface under traffic. The formation displays these physical characters in all the known exposures except the one at the "whirl" in Buffalo River, 4 miles north of Bakerville. Only the upper layers are here exposed and these are directly followed by the Pegram limestone. They consist of an alternation of layers of yellowish chert, 2 to 9 inches thick, and layers of dense bluish gray limestone. The fauna of these layers indicates that they are stratigraphically higher than those elsewhere exposed where the

formation is unconformably overlain by the much younger Chattanooga shale.

The Camden chert attains a total exposed thickness of 164 feet along Cypress Creek southeast of Camden, and if the layers exposed at the "whirl" on the Buffalo River be added, it has a total of about 200 feet. The log of the city well at Camden shows a thickness of 275 feet, which is to be divided between this and the Harriman chert. It is well developed from Big Sandy northward along the course of the Big Sandy River, and it also extends south of Camden along the valley of Birdsong Creek, but it seems not to extend as far south as Perryville and Parsons, the chert there exposed being referable entirely to the Harriman formation. While thicker in the more western sections, it appears to thin out by overlap eastward, only the succeeding Pegram limestone reaching as far eastward as Nashville, and in most sections its thickness is greatly reduced by later erosion. The formation doubtless continues under cover into southern Illinois, where it has a maximum thickness of 237 feet and is known as the Clear Creek chert.

The magnitude of the unconformity which separates the Camden chert from the Harriman chert below is shown by the circumstance that the latter has a thickness of 55 feet on the lower course of Big Sandy River, but is entirely absent by erosion on Rushing Creek about 7 miles south of Big Sandy, where the Camden chert rests directly on the Birdsong shale. Just south of Camden, the Harriman chert is again well developed beneath the Camden, but here its thickness can not be determined. The sharpness of the faunal break still further emphasizes the importance of the hiatus between these formations.

The fossils of the Camden chert are preserved as sharp natural molds and casts of both the exterior and interior, showing details of sculpture and internal characters in unusual perfection. As a whole the formation is abundantly fossiliferous, but some layers are relatively barren while others are replete with fossils. Among the more characteristic species of this formation are: *Stropheodonta* cf. *hemispherica*, *Schuchertella pandora*, *Eodevonia arcuata*, *Chonetes hudsonicus* mut. *camdenensis* n. mut., *Anoplia nucleata*, *Chonostrophia reversa*, *Centronella glansfagea*, *Amphigenia curta*, *Oriskania con-*

*doni*, *Atrypa reticularis* (var. with very large growth lamellæ), *Spirifer duodenarius*, *S. acuminatus*, *S. hemicyclus*, *S. worthenanus*, *Reticularia fimbriata*, *Metaplasia pyxidata*, *Pentagonia unisulcata*, *Leptocœlia flabellites*, *Phacops cristata*, and *Dalmanites myrmecophorus*. In the higher layers exposed on Buffalo River were found in addition *Rhipidomella* cf. *penelope* and *Spirifer macrothyris*.

The relation of this fauna to that of the Clear Creek chert of Illinois is very close. Of the forty-two species identified from Tennessee, twenty-four occur in Illinois and five more have close affinities which will probably prove to be identities. Even these numbers, 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.

In seeking to compare the fauna with those of the Oriskany and the Onondaga, about one-fourth of the species must be eliminated, because they are indigenous and peculiar to this southwestern embayment, so that their stratigraphic importance is not known. Seven additional species range through both Oriskany and Onondaga and may therefore be eliminated from consideration. Of the remaining nineteen, four are elsewhere confined to the Oriskany and twelve to the Onondaga. The assemblage here of such characteristic Onondagan species as *Chonostrophia reversa*, *Centronella glansfagea*, *Spirifer duodenarius*, *S. acuminatus*, *Pentagonia unisulcata*, *Phacops cristatus*, and *Dalmanites myrmecophorus*, is of the highest significance, and since this is corroborated by the facts that the Camden is separated by an interval of erosion from a normal development of typical upper Oriskany, which it overlies, and that it passes without a break into a recognized Onondaga formation (the Grand Tower of Illinois), the conclusion becomes inevitable that it belongs with the Onondaga in the Middle Devonian.

The distribution of this formation in Tennessee and Illinois, and possibly Arkansas (the Arkansas novaculite), the absence of the formation from the Appalachian trough, and finally its faunal affinities with the Middle Devonian of South America, already pointed out by Schuchert (1906), all indicate that it represents a southern or Gulf embayment. The species which show a close rela-

tion to the Maecuru fauna of South America are *Stropheodonta* cf. *blainvillei*, *Anoplia nucleata*, *Chonetes hudsonicus* mut. *camdenensis*, *Amphigenia curta*, *Spirifer duodenarius*, *Leptocœlia flabellites*, and *Actinopteria communis*.

Succeeding the Clear Creek in Illinois, the Grand Tower (Onondaga) formation is about 150 feet thick. The characteristic and widespread 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 seemingly came. Both the corals and cephalopods, he believes, are present in New York in lower strata equivalent to the lower half of the Grand Tower formation. If this be true, the inclusion of the Clear Creek (and Camden) chert in the Ulsterian series makes a thickness of over 300 feet of strata in this southern embayment before the advent here 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 equivalent of the Esopus and Schoharie grits of New York.

*Pegram limestone*.—This thin formation of heavy-bedded white limestone was named by Foerste (1901) for the village of Pegram, Tennessee. It attains a maximum thickness of 12 feet at this locality, but thins out eastward to 3 feet near Newsom. Only three widely separated remnants of the formation are known, the first being the small area about Pegram where several outcrops occur, the second fully 50 miles west at the "whirl" on Buffalo River 4 miles north of Bakerville, and the third in Wayne County near Fortyeight P. O.

The exposure 3 miles west of Newsom has yielded the diagnostic Onondagan blastoid, *Nucleocrinus vernevili* and in addition *Stropheodonta demissa*, *S. perplana*, *Rhipidomella penelope*, and *Nucleospira concinna*. The formation at the locality on Buffalo River 4 miles north of Bakerville is replete with Onondaga corals, among which are *Cyathophyllum rugosum*, species of *Heliophyllum*, *Blothrophyllum*, *Cystiphyllum*, *Cyathophyllum*, etc.

The fauna clearly indicates an equivalence with the Jeffersonville limestone of Indiana and Kentucky, of

which the Pegram limestone is supposed to be a southward extension.

The writer has not seen the exposure on Mills Creek near Fortyeight P. O. in Wayne County, but it is described by Drake (1914) as "nearly 6 feet of pebbly, coarsely crystalline, gray limestone." Here it rests on the Brownsport group of the Silurian, while farther east at Newsom it succeeds the still younger Lego limestone, but on Buffalo River it succeeds the Camden chert. At this locality only 45 feet of the highest part of the Camden formation is exposed, but within a few miles west at Camden it is known to be at least 164 feet thick. The overlap of the Pegram limestone eastward and south-eastward over the Silurian indicates that the Camden chert thins out rapidly in this direction by overlap, since it was closely followed by the Pegram.

The formation is probably separated by a short interval from the Camden chert, since the coral fauna which characterizes it does not appear until about the middle of the Grand Tower formation in southeastern Illinois, the lower part of the latter being unrepresented in Tennessee.

#### ? UPPER DEVONIAN SERIES

##### ? *Chautauquan Group*

*Chattanooga shale.*—The Chattanooga shale is a widespread formation, extending from the western valley to the mountains of eastern Tennessee, and from Alabama into Kentucky, overlapping many formations ranging in age from Ordovician to Middle Devonian. In central Tennessee it attains a considerable thickness, but in the western valley it is uniformly thin and is locally absent at many places, due apparently to later erosion. Here it generally ranges between 2 and 10 feet, and rarely exceeds 20 feet.

The shale proper is a black, fissile, carbonaceous shale of fine and even grain, and smells strongly of petroleum when struck with a hammer. Crystals and concretions of pyrite occur commonly and thin concretionary layers of gypsum may be found near the base.

Beneath the black shale there is usually present a thin basal sandstone called the Hardin sandstone member. It generally forms a single massive layer of fine-grained muddy gray sandstone from a few inches to 3 or 4 feet

thick, but it is absent at many localities and at Olive Hill has the exceptional thickness of 15 or 16 feet. Locally the base of the sandstone is conglomeratic.

Fossils in the Chattanooga shale are very meagre and of slight significance in correlation, being limited to supposed spore cases (*Sporangites*), microscopic annelid and conodont teeth, and a small species of *Lingula*. These fossils are abundant in the base of the shale in the well known quarry 3 miles west of Newsom, and they have been found at various other localities in western Tennessee. The *Lingula* has often been identified as *L. spatulata*, but the specimens collected by the writer are certainly distinct from that species, agreeing much more closely with *L. melie* of the Sunbury shale of Ohio.

The age of the Chattanooga shale is a mooted question. Most workers have regarded it as Upper Devonian, and both the Tennessee State Geological Survey and the United States Geological Survey continue to do so, while on the other hand Ulrich (1912) refers it to the base of the Mississippian. The known fauna being of little value, the problem will probably be solved only by a broad study of the stratigraphic relations of this widespread formation. No conclusive evidence could be found by the writer in western Tennessee, and he does not wish to take a decisive stand, but it has seemed advisable to conform to the established usage of the state and national surveys in referring the Chattanooga shale to the Upper Devonian.

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Yale University.