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WALTER F. POND, *State Geologist*

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THE STRATIGRAPHY

OF THE

Central Basin of Tennessee

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United States National Museum

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FOREWORD

WALTER F. POND, *State Geologist*

There is no question in the minds of the geologist and mining engineer of the value of a scientific report such as this. They are well acquainted with the need for it, and the wide-spread reputation of the author, Dr. R. S. Bassler, Head Curator of Geology in the United States National Museum, is sufficient evidence of its authority. This foreword is intended to explain to the citizens of the state who, through appropriations, have made it possible, the need and use of the work.

This report is of the broad basic research type and gives the fundamentals of the geology of all counties in the Central Basin with complete correlation of the different areas. Before a detailed study of the geology of a limited area, such as a county, can be made, it is necessary to make a fundamental study of a larger area to determine the broad general characteristics and relationships of the different rock formations or groups of strata. Some formations are very similar to each other in appearance and it is only by examining the fossils or shells contained in them and determining which shells are characteristic of the different layers of rocks that the separate formations may be distinguished. This requires the work of an expert who has a thorough knowledge of fossils, their appearance and relationships and their relative age, that is, whether they are found in lower or higher ledges, for it has been found that, in rocks all over the world, which have been formed about the same time the fossils contained in them have many characteristics in common and therefor indicate the same age.

When the characteristics of the rocks and their fossils have once been determined there is a basis for the division of rock layers into formations and the mapping of a county in detail. This can be done by less experienced men with the work of the expert as a basis or framework on which to weave the pattern of the local geology.

Along with the detailed geology of the county the mineral deposits are examined and the possibilities of their extention and of finding new deposits of other minerals are determined. It has been learned that mineral deposits are not of haphazard occurrence but that each class of deposits is associated with certain geologic formations or conditions. Once these conditions have been determined, the limits of the areas in which lie the greatest possibilities for a certain mineral may be drawn and rules for prospecting determined, so that time, effort and money may be concentrated on these regions and not wasted in unfavorable areas.

The particular economic minerals which will be benefited by this report are as follows:

Phosphate Rock. The phosphate deposits of Middle Tennessee are the result of weathering and leaching of certain rock formations. The description of these formations becomes the basis for field mapping and limiting the area favorable for prospecting, thus saving useless work in other areas. A report on the phosphate rock deposits, based on these descriptions is now being written and will appear shortly.

Limestones. The use of limestone for chemical and agricultural purposes is dependent on its chemical character and purity. This report will serve as a basis for mapping in detail the different formations or groups of strata, collection of samples for chemical analysis and recommendations for their use.

Oil and Gas. The search for oil and gas in Middle Tennessee is continuing but is handicapped by a lack of knowledge as to the rock horizons in which these minerals are found, and the depth, in different counties, to these horizons. This is particularly true of the Highland Rim which is some distance from the outcrops of the oil horizons. This thorough discussion of the character and thickness of the rocks of the Central Basin in which oil and gas are being found will help greatly in calculations of the proper depth to which to drill.

Road Metal. Since limestones usually maintain their characteristics over large areas, tests, in a few selected places, of the suitability of the different formations for road metal and concrete aggregate will determine their usability and later detailed mapping will show the areas in which the better stones may be quarried.

Bentonite. The thin bed of volcanic ash in the upper part of the Carters formation is known commercially as "bentonite" and has many important uses. There have been many inquiries from outside the state and this report will enable us to find it at its proper horizon for sampling and investigation.

Clays. The clays of Middle Tennessee, except those along river bottoms, are the result of weathering of under-lying rocks whereby the clay material impurities have been left behind. A thorough knowledge of the under-lying rocks will help in the search for clays of commercial importance.

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ILLUSTRATIONS

View from State Capitol Looking South and Showing Central Basin with Projecting Ridges from Highland Rim and in the Distance the Rim Itself

The Stratigraphy of the Central Basin of Tennessee

By R. S. Bassler[1]

Introduction

The writer's work in Tennessee began in 1900, when he assisted Dr. E. O. Ulrich in stratigraphic studies of certain areas in the Central Basin and in mapping portions of the Columbia quadrangle. At this time large collections of fossils were made and various detailed sections were prepared. Further geologic mapping in the Central Basin was carried on under the auspices of the U. S. Geological Survey by Dr. Ulrich and the writer in the summer of 1908, when the Woodbury quadrangle was surveyed.

In 1921 the survey of the Franklin quadrangle for the Tennessee Geological Survey, under the direction of Wilbur A. Nelson, then State Geologist, was undertaken by the writer with the assistance of Richard W. Smith, then of the State Survey. Little difficulty in mapping the area was anticipated, as it was confidently believed that the sequence of strata in the Franklin quadrangle would be the same as in the adjoining Columbia quadrangle, which had been published by Hayes and Ulrich in the classic Columbia folio, No. 95, of the U. S. Geological Survey. The greater part of the mapping, in which at first the same stratigraphic units were used as in the Columbia quadrangle, was completed in six weeks in the field season of 1921.

In this mapping it was noted that eastward from the Columbia quadrangle either some of the formations changed radically in lithology or different formations replaced them. This was especially notable in the occurrence of certain dove limestones succeeding the typical phosphatic Bigby strata, whereas in the Columbia area none of these pure dove strata occurred above the phosphate beds. Upon the advice of Mr. Nelson the base of this dove limestone was determined wherever it was possible, a procedure that saved much time in the final mapping of the area. By the end of the field season certain conclusions had been reached, one of which was that the Bigby limestone of the Columbia area maintains its normal thickness throughout the Franklin quadrangle, but beyond the east side of this quadrangle it rapidly becomes thinner

[1] Published by permission of the Secretary of the Smithsonian Institution.

and finally disappears, and another was that the slight development of dove strata succeeding the Bigby in the Franklin area is the diminished representative of the Cannon limestone, a formation several hundred feet thick in the eastern part of the Central Basin. As additional work was necessary before these two points, among others, could be definitely proved by actual tracing, five weeks in the summer of 1922 under the auspices of the Tennessee Geological Survey were devoted to work upon this quadrangle together with stratigraphic studies in contiguous areas for use in future mapping.

The Bigby, Cannon, and Catheys formations, which cover wide areas in the Central Basin, are so important on account of their phosphate and limestone deposits that the need of determining their exact relationships is evident. On the problem of discriminating these formations we had the help of Mr. Nelson, who accompanied the party on many of the trips, and of Dr. E. O. Ulrich, who spent a week with us in 1922 studying the critical sections with great care. The advice and experience of Dr. Ulrich, whose researches in the Central Basin and knowledge of Tennessee geology are unsurpassed, have always been freely available to the writer. Appreciation of this help is expressed at many places in this report. The assistance for several weeks of R. D. Mesler, of the U. S. Geological Survey, skilled in collecting fossil specimens, was of great benefit in the work. R. W. Smith, assistant geologist of the State Survey, who also gave efficient assistance throughout the work, made an economic survey of the Franklin quadrangle. Through these combined efforts it is felt that a definite advance has been made in the knowledge of the stratigraphy of Central Tennessee.

As may be inferred from the above statements, the geology of the Franklin quadrangle furnishes the key to that of much of the Central Basin, and the detailed survey of this quadrangle has produced useful data for future work on the Nashville and other quadrangles.

At the end of the second field season stratigraphic work on the formations of the Central Basin had proceeded so far that Mr. Nelson believed it advisable to test the results in other parts of the Basin and suggested that two more quadrangles be mapped before the preparation of the report upon those already completed. Accordingly in the summer of 1923 the writer, with the assistance of Earl Lollar, completed the geologic survey of the Hollow Springs quadrangle and in 1924, with the aid of Robert Bassler and Earl Lollar, surveyed the Lillydale quadrangle. As the four quadrangles, the Woodbury, Franklin, Hollow Springs, and Lillydale, are so situated that a discussion of their geology, it is believed, covers most of the features that characterize the Central Basin, they are combined in the present report. Finally under the direction of Hugh D. Miser, who was appointed State Geologist upon Mr. Nelson's resignation, a few weeks in 1925 were devoted to a survey of the Byrdstown quadrangle, just east of the Lillydale, with R. P. Meacham as assistant.

As this area belongs to the Highland Rim and not to the Central Basin it has not been included in the present report.

Captain Walter F. Pond, Mr. Miser's successor as State Geologist, has taken an active interest in this work and has made possible the presentation of this report with the four accompanying geologic maps, which, it is hoped, may be found to be a useful basis for future studies upon this classic area.

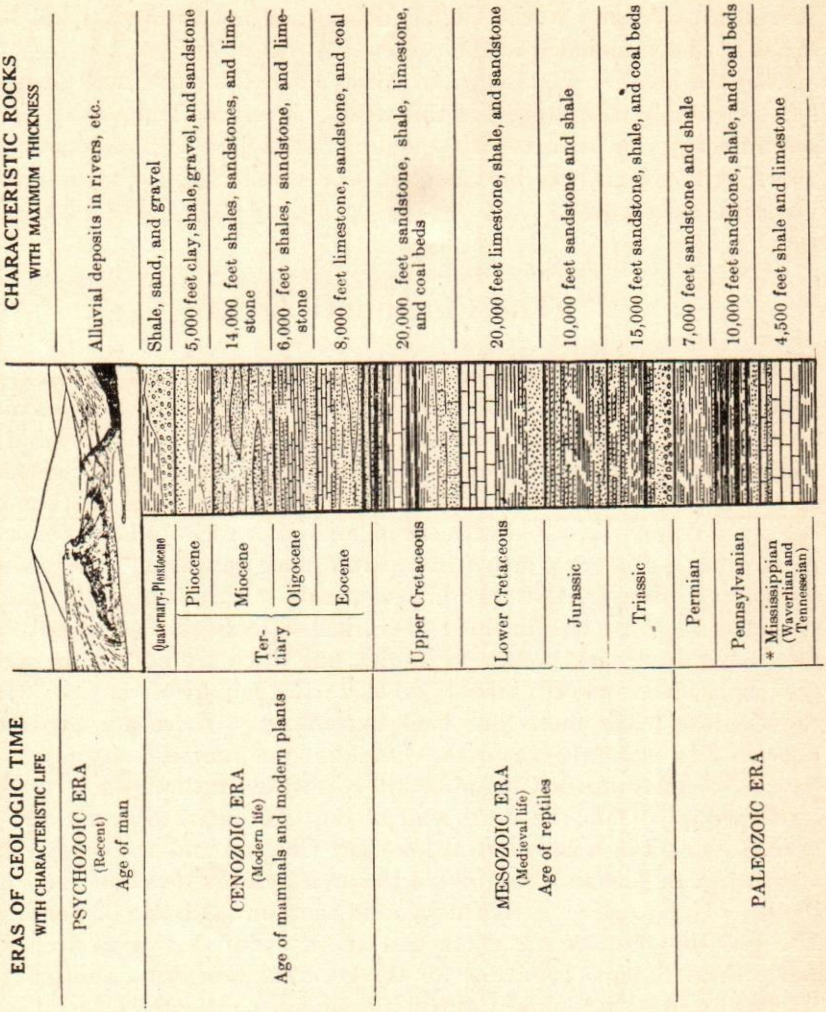
The Cincinnati Arch

Running in a general northeast direction through central Kentucky and central Tennessee is a broad fold in the strata, known as the Cincinnati arch or geanticline. This is a most important structural feature and has had much to do with the present topography and the economic resources of the Eastern Interior Low Plateau, to which this part of Tennessee belongs. When contrasted with the highly folded rocks of East Tennessee the strata of this great structural feature may be classed as horizontal. In reality, however, they are in few places strictly horizontal but are generally more or less inclined in various directions. In some places they have even been broken by faults, but these are not common, and the displacement rarely exceeds 500 feet. In the part of the arch within the Central Basin faults are very uncommon. There are apparently none of any consequence in the Franklin quadrangle, and only a few have been found in the Columbia and Nashville quadrangles.

In western Ohio the north end of the Cincinnati arch divides, one branch extending northwestward toward Chicago and the other northward through Toledo. Southward the arch extends through Cincinnati, the Blue Grass region of Kentucky, and the Central Basin of Tennessee. The two branches at the north end afford conditions in western Ohio and central Indiana favorable for the accumulation of oil and gas.

The natural division of Central Tennessee, named the Central Basin by Professor Safford, is a gently undulating surface averaging 600 feet above sea level, ellipse-like in general outline, which extends over the State in a northeast direction. The Basin is 50 to 60 miles wide and 120 miles long and has an area of 5,500 square miles. It is not strange that the Central Basin, completely surrounded by the Highland Rim 1,000 feet in altitude, has been thought to be the bed of a drained lake. However, this idea is erroneous, as the lowland area was unquestionably formed by the erosion and removal of geologic formations that once covered it. In Paleozoic time the Central Basin was occupied by a dome-shaped accumulation of limestone, shale, and sandstone, forming a part of the Cincinnati anticline, but long-continued action of the weather and streams dissolved and removed the limestone rock and left the present lowland.

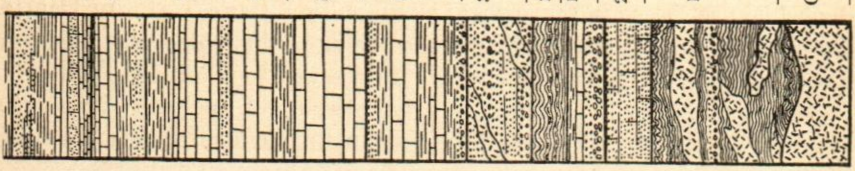
Figure 1 DIAGRAMMATIC SECTION OF EARTH'S CRUST



Due to cutting back by the streams into the Highland Rim, the outline of the Central Basin is extremely irregular, and outliers from the Rim project far out into the Basin, some as spurs and some as isolated hills. Although these outliers are more numerous along the eastern side of the basin, which is consequently greatly dissected, they occur also along the western side, conspicuous examples being the southeastward-trending ranges of hills south of Nashville. The accompanying photograph (Frontispiece), showing the view looking south from the Capitol building, illustrates the character of the Central Basin and of the ridges projecting into it from the Highland Rim.

The rock strata exposed at the surface throughout the Basin are composed of various kinds of limestone, shale, and occasionally sand-

PALEOZOIC ERA (Ancient life) Age of higher invertebrate animals	* Devonian	12,000 feet limestone, sandstone, and shale
	* Silurian	6,000 feet sandstone, shale, and limestone
	* Ordovician	6,000 feet sandstone, limestone, and shale
	Canadian	4,000 feet limestone and shale
	Ozarkian	6,500 feet massive limestone
	Cambrian	18,000 feet quartzite, sandstone, shale, and limestone
PROTEROZOIC ERA (Primitive life) Age of primitive plants (algæ) and invertebrate animals	Keweenawan	30,000 feet conglomerate and sandstone with lava flows
	Animikian	14,000 feet banded slates and cherts with iron ore
	Huronian	10,000 feet glacial conglomerates, quartzite, and limestone
	Sudburian	20,000 feet of white quartzite
ARCHEOZOIC ERA (Primal life) Age of unicellular life	Keewatin Grenville	100,000 feet sedimentary schist and gneiss with lava flows; slates, conglomerates, and limestone
PRIMITIVE CRUST	Igneous rocks	Granite and other igneous rocks



stone, all of which are of sedimentary origin, that is they were deposited under water. Originally these strata were lime, clay, and sand, which were brought down from the ancient land areas by streams and deposited in layers at the bottom of bodies of water, such as arms of the sea then extending from the ocean into Tennessee.

Formerly it was believed that such sedimentary formations were of wide extent, and it was assumed that their variations in lithology and fossil contents from place to place were due to differences in the sea bottom and depth of water and to the nature of the land that supplied the material. Careful mapping of such regions as the Columbia and Franklin quadrangles shows that many of these formations are of small areal extent and that consequently the seas or arms of the sea in which they were deposited were likewise small. The latter belief necessitates more frequent advances and withdrawals of the sea, with a consequent greater number of formations, resulting in a greater thickness of the combined deposits and an increase in the length of geologic time.

So far as known no granites or other igneous rocks are visible at the surface in any part of the Central Basin. Such rocks undoubtedly exist here but at great depths, the sedimentary rocks resting upon them one formation above another in regular sequence. These sedimentary rocks are classified into units according to the time when they were formed, which is indicated by their position upon each other. The larger divisions of time during which the sedimentary rocks of the earth's crust have been deposited are shown in the accompanying table, Figure 1. In the Central Basin the strata exposed at the surface belong to the Ordovician, Silurian, Devonian, and Mississippian epochs; if present, the Canadian and older rocks are unexposed. During all other periods of geologic history the area was a land surface, except possibly in the Pennsylvanian, the sediments of which may have been present and entirely eroded away.

The terms era, epoch, and period designate the time of deposition, and the deposits or strata are classified as systems and series, using the same names as the divisions of time. Each period is more or less plainly marked at its beginning and end by disturbances of the earth's crust brought about by folding, uplift, or mountain making. Each system of strata is divided into series, groups, and formations, the last representing a mapable unit of rocks, laid down in a division of time during which essentially the same assemblage of animals and plants lived. Deposits of the Recent period are represented along the larger streams by the alluvial flood-plain sediments, but no rocks of Mesozoic or Cenozoic age occur in the entire area.

Stratigraphic Problems of the Central Basin

The geology of the Central Basin of Tennessee furnishes such abundant opportunity for the solution of some of the difficult stratigraphic problems of larger areas that it has seemed appropriate to extend the limits of the present report and include evidence dealing with these more-general questions. The facility with which the various rock formations of the State can be traced almost uninterruptedly for great distances makes it possible by detailed mapping to obtain evidence for the solution of questions that would otherwise remain in doubt. For example: Are the local changes in the sequence of formations and in the lithology of the strata and the variations in the fossils contained therein due, as at one time widely believed, to lateral changes in relatively large seas holding various contemporaneous faunas, or are these changes due to local restriction of the Paleozoic seas produced by minor oscillation of the continent? Evidence on this question to the effect that many of the important formations are restricted to small areas and that they thin out along the old shore lines instead of passing laterally into different rock types holding distinct fossils is presented at various places in this volume. These formations maintain their lithologic characters and associated fossils with wonderful fidelity over considerable stretches of country. Where a formation does pinch out, stratigraphic evidence of associated rocks proves that it has not merged into another type of rock but has reached the strand line of its time, where marine deposition necessarily ceased. In the Franklin quadrangle proof of this conclusion is afforded by the distribution of the Bigby and Cannon limestones. In the southwest corner of the quadrangle the Bigby limestone is more than 60 feet thick, but in the southeast corner it has thinned to nothing and does not appear again farther east. Although the Cannon limestone is only a few feet thick in the southwest corner, thinning and finally disappearing westward, it has increased in the northeast corner to a thickness of 140 feet. In each part of the quadrangle the basal *Constellaria* bed of the Catheys succeeds the Cannon, and the same basal dove limestone of the Cannon follows the Bigby, so there is no evidence for lateral changes in the type of strata of the same formation.

The restriction of formations to more-localized areas rather than widespread distribution over great stretches of country would seem to increase the difficulties of stratigraphic correlation. On the contrary, however, it simplifies them, for the correlations can be made more definite with accompanying greater certainty in the recognition and mapping of the units.

Distribution is of economic importance as illustrated in this region in which phosphatic limestone was frequently deposited close to the strand line, where wave action prepared the shelly material for its formation. Phosphatic deposits are present in areas of the Bigby, Cannon, and Catheys limestone formations where they thin out to extinction—in other words, near the old shore lines.

This local distribution of the continental seas was brought about by vertical movements of the earth's crust. Investigations have shown that certain areas, although not always above water since their inception, have a tendency to be raised above sea level, whereas the areas on either side tend to sink. The regions with the upward tendency are called positive areas and those having the downward tendency are called negative areas. The major positive and negative areas of North America, as elsewhere, have been located upon structural grounds. On this basis the Cincinnati axis in central Tennessee has been determined to be a positive area. In tracing formations from their place of maximum development to the line where they thin out we find that the direction of thinning is always toward a positive area. Thus the Bigby thins eastward to the crest of the Cincinnati anticline, which in Bigby time was not submerged by the sea. The position of a limiting anticline seldom remained long stationary. For example, in the succeeding Cannon time the strand line indicated by the minimum development of the formation shifted some miles west, denoting the migration of the anticline. Sections at other places in Central Tennessee show that the apex of the axis moved repeatedly not only to the east and west but also to the north and south of some given point. It is fortunate for the stratigrapher that this shifting occurred, because as a result the formations are so deposited that the median part of the larger positive area exhibits interfingering wedges of formations overlapping each other from various directions. Without this interfingering it would often be difficult to prove the correct position of beds on opposite sides of such an area.

Another view is expressed by Professor Raymond[2], whose studies upon the Trenton strata of New York, Kentucky, and Tennessee have led him to the conclusion that the seas in which the successive formations were deposited persisted continually as shallow interior bodies of water, in which the changes of sedimentation depended upon local conditions. Thus reef building occurred in areas of agitated waters, while in the quiet lagoons dove limestones, composed of calcareous flour or ooze, were in process of formation. Different types of animals, having a preference for unlike environments, would therefore although actually contemporaneous be found as fossils in different types of rocks. The position of these various rock types would naturally change as the currents and other conditions of the sea changed. Thus, with slight changes in sea level or land elevation, islands would come into existence and modify the kinds and distribution of the marine sediments. From a theoretic standpoint this explanation would seem to be sound, but months of detailed mapping in the area show it to be erroneous.

Historical Review

Access to the rich farm land of the Central Basin, which was early sought by the pioneers crossing the Appalachians, was had either by way of Cumberland River or by a trail across the Cumberland Plateau and the Highland Rim from Cumberland Gap. Some of the early geologists who followed these routes had an opportunity to study this area, among them Featherstonhaugh, who, while on his way to the Red River area in 1834, descended the Cumberland and studied the geologic section from the Coal Measures of the Cumberland Plateau to the Ordovician limestone at Nashville.

[2] Raymond, Percy E., Trenton of Central Tennessee and Kentucky. Geol. Soc. America Bull., vol. 33, pp. 571-586, 1922.

Prior to this time, in 1831, the legislature of Tennessee by the appointment of Gerard Troost, professor of geology, mineralogy, and chemistry in the University of Nashville, as the State Geologist and Mineralogist, established the first geological survey of the State, which was, indeed, one of the first in the United States. Professor Troost continued in office until the discontinuance of the Survey in 1848. During his term as State Geologist he prepared nine reports, the first two of which seem never to have been printed, and the other seven, long out of print, are now rarely seen. In the fourth report, 1837 (37 pages), Professor Troost gives a brief general account of the geology of the State and a list of the fossils observed by him. The largest report, the fifth, 1839 (75 pages), includes a section of the formations of Middle Tennessee and a catalogue of the fossils found in the State. The sixth report (1841) likewise touches upon the general geology of the State and includes lists of fossils, and the seventh (1843) describes the formations of Davidson County, particularly those exposed at Nashville, and contains notes upon those of Middle Tennessee in general. The other reports are mainly of an economic nature.

In 1838 Troost published in French, in volume 3 of the Memoirs of the Geological Society of France, an article entitled Description d'un nouveau genre de fossiles with three plates, which is of especial interest, as it is the first contribution to the paleontology of the Central Basin. The new genus of cephalopods, *Conotubularia*, described in this article happened to have been named just the year before by Bronn as *Actinoceras*. As Troost's three plates contain interesting figures, they have been reproduced in the present report.

Troost's further paleontological contributions consisted of a manuscript containing illustrations of the fossil crinoids collected by him, which were placed in the hands of Professor James Hall for revision in 1851. Unfortunately Troost's valuable work on these fossils was not published until after Hall's death. In 1909 the U. S. National Museum printed it as Bulletin 64, A Critical Summary of Troost's Unpublished Manuscript on the Crinoids of Tennessee, by Elvira Wood.

In 1848 James M. Safford, while professor of chemistry and geology at Cumberland University, Lebanon, Tennessee, began his studies upon the geology and paleontology of Middle Tennessee, his first results being published in 1851 in volume 12, second series, of the American Journal of Science. His article describes the formations and lists the fossils, and, most important, includes a map of the Silurian Basin of Middle Tennessee. From this beginning Professor Safford extended his researches into all parts of the State.

The second Geological Survey of Tennessee was established in 1854 with the appointment of Professor Safford as State Geologist and Mineralogist, a position that he continued to hold until the Survey was abandoned at the outbreak of the Civil War. Safford's work culminated in The Geology of Tennessee, a classic volume of 550 pages with 7 plates of fossils, accompanied by a colored geological map of the State, published in 1869. Although this volume did not then receive the attention it deserved, it has since been recognized as a most valuable and authoritative work.

Previously a series of geological articles, published mainly in the Nashville Banner in 1853, was brought out by R. O. Currey in 1857 in a booklet of 128 pages entitled A Sketch of the Geology of Tennessee. Currey, a pupil of Troost and later professor at East Tennessee University, included Professor Safford's map in his volume.

In 1871 Professor Safford was again appointed State Geologist, a position that he held in connection with his professorship at Vanderbilt University at Nashville until 1900. During this time he prepared various reports, which, because he intended to accumulate data for a revised edition of the Geology of Tennessee, were not published. In 1900 Professor Safford and Dr. J. B. Killebrew issued their textbook The Elements of the Geology of Tennessee, which contains among other features new observations upon the stratigraphy of the Central Basin.

An important but little known paper, The Geology of Nashville and Immediate Vicinity, a thesis for the degree of Doctor of Science, prepared by Paul M. Jones under the guidance of Professor Safford and printed privately in 1892, contains excellent descriptions of the Ordovician formations about Nashville and includes a good local geologic map. Jones's work is particularly valuable for the descriptions of the characteristics and distribution of the minor geologic subdivisions at localities which, owing to the growth of the city, can no longer be studied. A promising career in stratigraphic geology was unfortunately cut short by the death of the author.

A few years prior to Dr. Jones's work Dr. E. O. Ulrich published four articles in volumes 1 and 2 of the American Geologist (1888) under the title A Correlation of the Lower Silurian Horizons of Tennessee and of the Ohio and Mississippi Valleys with those of New York and Canada. The description of the Ordovician section in Kentucky and southwestern Ohio was undertaken first, and before the Tennessee section could be discussed the work had grown so large that its publication could not be completed in that magazine. The latter part of the work was printed in 1897, when Dr. Ulrich included his stratigraphic observations in the introduction to part 2 of volume 3, Geology of Minnesota.

The Minnesota volume is of further interest in the present connection because of the necessity to introduce in it the descriptions and illustrations of many fossils from the classic Central Basin in order to present the evidence for the correlation of the Ordovician rocks of Minnesota with those of other States. In the chapters of this volume on paleontology, particularly the one on gastropods, Dr. Ulrich and his associates have published a most important contribution to the paleontology of

Tennessee. Many figures of species from this work are copied in the present report.

Modern knowledge of the stratigraphy and paleontology of the Central Basin dates from the publication of the Columbia folio of the U. S. Geological Atlas, by Hayes and Ulrich in 1903. This publication, containing many new features, marks such an advance upon all earlier work that it is epoch making. It was confidently believed that the Columbia folio would serve as a guide to the stratigraphy of the Central Basin, yet so intricate is geologic history that an entirely new Ordovician formation reaching a thickness of 250 feet, unrepresented in the Columbia area, has been discovered in the adjacent Franklin quadrangle.

New facts upon the stratigraphy of the Central Basin employed in subsequent publications were obtained by Dr. E. O. Ulrich and the writer in 1908, when they mapped the geology of the Woodbury quadrangle for the U. S. Geological Survey.

In his classic work Revision of the Paleozoic Systems, published in volume 22 of the Bulletin of the Geological Society of America in 1911, Dr. Ulrich included many of his observations upon Tennessee stratigraphy. Evidence on the distribution of formations of the Central Basin was employed particularly in his discussion of the criteria and principles of stratigraphic classification. The writer's mapping of other quadrangles of the Central Basin, the stratigraphic results of which were published in abstract in the Bulletin of the Geological Society of America in 1923, has already been mentioned in the introduction to this work.

The Bibliographic Index of American Ordovician and Silurian Fossils, by the author, published in 1915 as Bulletin 92 of the U. S. National Museum, is of interest to students of Tennessee geology in that it contains faunal lists, correlation tables, and other material dealing with the geology and paleontology of the State.

A geologic map and an excellent description of the geology of the central part of the Nashville dome is given in the Geology and Natural Resources of Rutherford County, Tennessee, by J. J. Galloway, published in 1919 as Bulletin 22 of the Tennessee Geological Survey.

In a paper entitled The Bryozoan Faunas of the Stones River Group of Central Tennessee, published in 1921 in the Proceedings of the Indiana Academy of Science for 1919, H. N. Coryell in addition to the subject matter included lists of fossils, paleogeographic maps, and other data concerning the various formations of this group.

An interesting contribution to Tennessee geology is the paper Volcanic Ash Bed in the Ordovician of Tennessee, Kentucky, and Alabama, by State Geologist Wilbur A. Nelson, published in the Bulletin of the Geological Society of America, volume 33, 1922, pages 605-616. In this paper the author discusses the characteristics and origin of the layers of green clay (bentonite) near the top of the Lowville limestone.

In the same number of the Bulletin, Dr. P. E. Raymond presents stratigraphic researches in the Central Basin under the title Trenton of Central Tennessee and Kentucky. In this article the author, from two weeks of field work in the States visited, puts forward an explanation of the stratigraphy so different from conclusions based upon observations of others who have spent years upon the subject that we question his opinions

In 1923 the third edition of the geological map of Tennessee, revised by Wilbur A. Nelson, was issued by the State. This map embodied the new knowledge of the stratigraphy of the State, but its small scale and lack of complete information prevented the indication of the smaller divisions of Central Basin stratigraphy.

A description of several species of ostracods from the Catheys formation appeared in the American Journal of Science (vol. 16, 5th ser., 1928), in an article by Stuart A. Kirk, entitled Ostracoda from the Trenton Limestone of Nashville, Tennessee.

PHYSIOGRAPHIC DIVISIONS OF TENNESSEE

Owing to its length and east-west position across much of the eastern part of the United States, Tennessee presents many phases of physiographic and geologic structure. The State extends from the Unaka Range of the Appalachian Mountains westward to Mississippi River, across a number of physiographic provinces or topographic divisions, most of which continue unchanged into the States lying north and south. These provinces conform to the geologic structure of the underlying strata; thus areas of flat-lying rocks develop into plains and plateaus sloping in the direction of the general dip, and highly folded strata compose the mountain areas of East Tennessee. The State is in consequence divided from east to west into seven distinct and well-defined physiographic provinces. The Unaka Range forms the most eastern province, and the others, the Valley of East Tennessee, the Cumberland Plateau, the Highland Rim, the Central Basin, the Plateau slope of West Tennessee, and the Mississippi Alluvial Plain follow from east to west in the order stated. The Unaka Range, the Valley of East Tennessee, and the Cumberland Plateau belong to the major physiographic division, the Appalachian Highlands; the Highland Rim with the enclosed Cenral Basin represent the Interior Plains, and the Plateau slope of West Tennessee corresponds to the East Gulf Coastal Plain and with the Mississippi Alluvial Plain is a part of the Atlantic Plains division.

THE UNAKA RANGE

The Unaka Range province presents the most rugged surface in the State, for it includes the western flank and foothills of the Unaka or

Great Smoky mountain range, which forms the boundary between Tennessee and North Carolina. Rising to altitudes from 4,000 to 6,650 feet above sea level, this range with many westward-projecting spurs separated by steep, narrow valleys occupies a strip ranging from two to twenty miles wide and covers an area of about 2,000 square miles. The range is really a belt of from two to four parallel ranges, which has the crest of the main axis on the North Carolina line. Chilhowee Range, the most westerly ridge, lies just within the valley of East Tennessee. The rocks of the province are granite, gneiss, schist, shale, slate, sandstone, conglomerate, and quartzite of Pre-Cambrian and Cambrian age, folded and faulted by the earth's great crustal movements of the past. Erosion of the softer and more soluble rocks has left many beautiful valleys and coves in the province, some of which can be entered only through stream gaps or by climbing the encircling mountains.

THE VALLEY OF EAST TENNESSEE

A depressed area averaging 45 miles in width between the Unakas on the east and the Cumberland Plateau on the west forms the Appalachian Valley or Great Valley of Tennessee. This depression is occupied by many long, narrow, even-crested ridges 1,200 to 1,300 feet high and broader, intervening valleys several hundred feet lower, all parallel to the Unaka Range. The underlying strata here are sedimentary rocks—limestone, sandstone, shale, and conglomerate—of Early Paleozoic, mainly Cambrian, age, so highly folded and faulted that many beds are now inclined at high angles. Differences in erosion of the soluble limestone and the resistant sandstone have given rise to the succession of parallel ridges and valleys characteristic of this province. The rich limestone soil of the valleys, which form a considerable part of the 9,200 square miles comprised in this area, makes it one of the most populous and fertile parts of the State.

THE CUMBERLAND PLATEAU

The coal region of Tennessee is a plateau or tableland 2,500 feet above sea level, capped with practically horizontal beds of sandstone and including more than 5,000 square miles of the area of the State. This province, the Cumerland Plateau, is a part of the Appalachian Plateau, which extends in a southwest direction through part of Pennsylvania, West Virginia, and Kentucky, and thence across Tennessee into Alabama. In Tennessee its east boundary is Walden's Ridge, overlooking the Valley of East Tennessee; its western edge is very irregular, owing to erosion by streams that rise on its western margin. The steep ridges thus produced project out onto the next province, the Highland Rim, in such bold relief as to give the name Cumberland Mountains to this area. The surface rocks of the plateau are sandstone, conglomerate, shale, and coal of Middle Carboniferous (Pennsylvanian) age, and under these are the Lower Carboniferous (Mississippian) limestones, which are exposed in all the valleys that cut into the tableland. A great upfold of the strata in the eastern third of the Plateau has permitted erosion down to the Ordovician and still earlier limestones, and a deep valley, the Sequatchie Valley, has thus been formed.

From Walden's Ridge westward the surface of Tennessee descends by a series of steps or escarpments marking present lines of erosion of more resistant strata. The highest and most pronounced of these escarpments forms the west edge of the Cumberland Plateau and separates it from the Highland Rim, an area averaging 1,500 feet lower altitude.

THE HIGHLAND RIM

The Highland Rim province, known also as the Rimland or Terrace lands because it forms an encircling rim around the Central Basin, has an area of 9,300 square miles, which makes it the largest natural division of the State. Bordered on the east by the steep escarpment of Cumberland Plateau, it ends in the western part of the State in high ridges overlooking the valley of the Tennessee River. Its average altitude is 1,000 feet. Although diverse in its physiographic features, because its surface has been deeply dissected by streams, the Highland Rim is in most parts nearly flat. Its roughest parts are along the edges bordering the Central Basin, for here dissection by streams has formed steep rounded hills and spurs, some projecting far into the Basin.

The Highland Rim province is divided according to its relation to the Central Basin, which it encloses, into the eastern, northern, and western portions. The formations of the Rim are all of Mississippian age beginning with the Chattanooga shale, which crops out around the edges overlooking the Central Basin and is followed by the widespread Fort Payne, Warsaw, and St. Louis limestones, which form the main surface rocks. There are smaller areas of Ridgetop shale and the New Providence formation, and the limestone, shale, and sandstone of the Chester group are developed in its eastern portion.

The Eastern Highland Rim is an undulating plain, averaging 1,000 feet in altitude, which extends from the foot of the Cumberland Plateau westward to the Central Basin, where it ends abruptly in high fringing ridges and hills. The eastern edge of the Highland Rim, forming the western boundary of the Cumberland Plateau, is very irregular owing to the streams that flow down from the Plateau, which have worn their channels backward, cutting deep valleys between remnants of the Plateau. (Pl. 49, fig. A.) These remnants form flat-topped hills, which are in places very numerous. Especially notable is Short Mountain, in Cannon County, the classic remnant of the Cumberland Plateau, which lies 25 or 30 miles west of the eastern edge of the Rim. Rising about 2,000 feet above sea level and capped by the Coal Measures, it furnishes good evidence that the Eastern Highland Rim at one time was covered by the Cumberland Plateau strata, which have since been eroded away.

The slopes from the Highland Rim up to the Plateau are very steep, and in many places vertical cliffs are present. The Coal Measures sandstone and conglomerate capping the Plateau weather very slightly, but the underlying Mississippian limestones are quickly removed by solution. The undermining of the sandstone and conglomerate layers which results, causes the strata to break off in large blocks, forming vertical cliffs. In this manner the escarpment that forms the western boundary of the Plateau is being pushed eastward, and the area of the Highland Rim is being increased.

Likewise the western escarpment of the Eastern Highland Rim is retreating eastward thus enlarging the Central Basin and leaving a belt of very hilly country at the contact of the two provinces. (Pl. 48, fig. B.) The protecting cap that has tended to preserve the Highland Rim as a plain is the Fort Payne chert, a highly siliceous limestone weathering very slowly. Although this limestone invariably forms the escarpment bordering the Central Basin, it is the main surface rock only in the western third of the Rim. East of this it occurs as a subsurface formation, through which solution progresses only slowly. The highly siliceous Fort Payne can easily be recognized by its weathered products, hard, angular fragments of chert in gray siliceous soil. In this area also occur the "Barrens". regions of thin, infertile soil bearing scrub oaks, which occupy many square miles of country. Within the Fort Payne area of outcrop occur patches of the Warsaw limestone, also usually weathered into characteristic chert and soil. The chert from the Warsaw is fossiliferous and is soft and porous, and the soil is darker and more fertile than that of the Barrens.

Farther east on the Rim the purer St. Louis limestone, characterized by sinkhole topography and a deep-red soil, is the most prominent formation, and the surface here is quite hilly. The uppermost Mississippian formations, included in the Chester group, crop out mainly on the face of the Cumberland Plateau escarpment or on the high hills of the Rim.

The northern and western portions of the Highland Rim preserve a narrow fringe of the Fort Payne chert with its characteristic "Barrens" and broad areas of the St. Louis limestone, long weathering having removed all the higher strata. The surface of the Western Rim, which is lower than the eastern and merges into the slope of West Tennessee, is maturely dissected, and the river valleys are filled with silt. The Southern Rim does not show in Tennessee, for the Central Basin extends into Northern Alabama.

THE CENTRAL BASIN

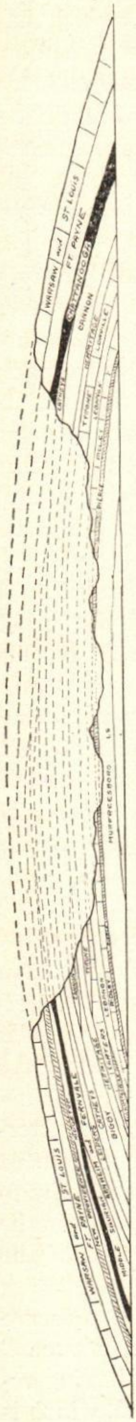


Figure 2—West-east diagrammatic section of Central Basin of Tennessee.

The Central Basin is the most important division of Tennessee as far as fertility of the soil and density of population are concerned. This division, developed on soluble Ordovician limestone, is a gently undulating, elliptical plain, lying lengthwise across the State but almost wholly within it. The long axis, extending northeast in the trend of the general Appalachian structure, measures about 120 miles; the transverse diameter is near 60 miles, and the area of the Basin is about 5,500 square miles. Its altitude is 500 to 700 feet. The Basin is extremely irregular in outline, for it is entirely surrounded by the Highland Rim, 400 or more feet higher, whose edges have been dissected in places, although a fairly abrupt escarpment is usually present. Outliers from the Highland Rim in the form of spurs and isolated hills extend far out into the Basin. (Plate 47, fig. B.) Moreover the Basin is dotted with many small rounded residual knobs, rising 200 to 300 feet above the surface—remnants which indicate the former presence of the Highland Rim. (Plate 47, fig. A.)

The three important rivers of the Basin flow from it in deep, narrow valleys, the Cumberland and Duck Rivers through the western Highland Rim and the Elk through the southern portion of the rim. Although the main surface rocks are Ordovician limestone and shale, the Central Basin formations range from Early Ordovician to Early Mississippian age.

The similarity of the Central Basin to the bed of a drained lake has led many to regard it as such, but all the evidence points to it formation by the erosion and carrying away in solution of rocks that once extended entirely across the area.

A study of the topography of the Central Basin indicates that the present surface has resulted from the erosion of a plain, which if restored would have an altitude from 1,100 to 1,300 feet above sea level and would coincide with the surface of the Highland Rim. The resistant Mississippian rocks that protect the present-day Rim from erosion undoubtedly extended across the Basin as the surface rock of this former plain. The arching of the strata due to the uplifting of the Cincinnati Anticline hastened erosion, and once the resistant rocks were removed and the more-soluble underlying Ordovician limestones were attacked, the formation of the Central Basin was rapid. Erosion along the anticline is still progressing, for at the present time the Central Basin is being enlarged by the continued retreat of the Highland Rim escarpment, and at the same time the Highland Rim surface is gaining at the expense of the Cumberland Plateau.

The elevation of the Basin to its present level occurred at several distinct times, as testified for example by the terraces along Duck River. These show that the river first cut a broad valley 400 feet below the Highland Rim, and after the uplift of the area started a narrow valley within the broad one. Later the Basin seems to have been depressed slightly, for deposits of coarse gravel appear along the streams.

Galloway, in the Geology and Natural Resources of Rutherford County, Tennessee (Tenn. Geol. Survey, Bull. 22, 1919), has discussed the stages in the topographic history of the Central Basin, showing that the recent uplift was of late Pleistocene and Recent age, the Central Basin peneplain stage was Middle Pleistocene, the High Terrace gravel stage was at the end of the Pliocene (?), and the Highland Rim peneplain stage at the end of the Eocene.

THE PLATEAU SLOPE OF WEST TENNESSEE

This province, which includes all the uplands west of the Tennessee River, is a part of the Gulf Coastal Plain, whose northern limit is in southern Illinois. It is a well-defined province of generally fertile land, third in size and second in population in the State, and extends from the hilly ridges of the Highland Rim bordering the Tennessee River in its northward course across the State to the bluffs, averaging 130 feet in height, that overlook the Mississippi bottom. This province lacks the rugged features of parts of the Highland Rim and the Cumberland Plateau, but it has a gentle slope from an altitude of about 600 feet on the east to about 300 feet at the bluffs on the west. It is not dissected by deep-cutting streams but is usually swampy along the course of its slow-moving streams. The formations of the Plateau slope consist of sand, clay, and loams and are of comparatively recent geologic age, being Cretaceous, Tertiary, and Quaternary in age. The western valley of the Tennessee River is often considered as a separate province of the State.

MISSISSIPPI ALLUVIAL PLAIN

This narrow area, being the most western province of the State and best known as the Mississippi Bottom, is part of the flood plain of the Mississippi River, and is featured by numerous lakes and marshes, by heavy forest and soil of great fertility. Having an area of only 950 square miles, it is the smallest division of the State, but when the land is reclaimed it should become the most productive division. Its average altitude is less than 300 feet above sea level, and many parts of the area are below high-water mark of the Mississippi.

GEOLOGIC SECTIONS

Before proceeding to the more detailed description of the formations present in central Tennessee, it seems advisable to give a series of geologic sections illustrating the major stratigraphic relationships in different parts of the Central Basin. These sections, most of them taken near the edge of the Basin in order to include the post-Ordovician rocks wherever possible, have been arranged for convenience of reference by counties.

Safford, in his Geology of Tennessee, in 1869, distinguished the following divisions for the Ordovician of the Central Basin.

Ordovician rocks of Central Tennessee, Safford, 1869
[Present-day equivalents in parentheses]

Nashville formation:
- Upper member
  - College Hill limestone (=Leipers and Catheys)
- Middle member
  - Cyrtodonta bed (=Cannon)
  - Coarsely crystalline, fossiliferous limestone (=Cannon)
  - Dove limestone (=Cannon)
  - Capitol limestone (=Bigby)
- Lowest member
  - Orthis bed (=Hermitage)

Trenton or Lebanon formation:
- Carters Creek limestone (=Carters limestone)
- Glade limestone (=Lebanon limestone)
- Ridley limestone
- Pierce limestone
- Central limestone (=Murfreesboro limestone)

DAVIDSON COUNTY

Nashville and its vicinity have been such classic ground for the paleontologist for almost a century that it is surprising that no detailed section of the local stratigraphy has ever been published.

Paul M. Jones, in his doctorate thesis at Vanderbilt University entitled The Geology of Nashville and Immediate Vicinity, published privately in 1892, gives the following section, which differs from Safford's earlier work mainly in nomenclature.

Geologic section at Nashville, Tenn., by Paul M. Jones, 1892
[Present-day equivalents in parentheses]

	Feet
Hudson river group:	
College Hill limestone. Dark-blue, fossiliferous limestone (=Leipers and Catheys)	150
Trenton Group:	
Sponge bed. Lumpy limestone with *Stromatocerium pustulosum* (=Catheys)	4

	Feet
Cyrtodonta and False Dove horizon. Brownish or grayish-brown limestone (=Cannon)	11
Ward limestone. Dark-blue, crystalline, heavy-bedded limestone (=Cannon)	28
Dove limestone. Dove-colored limestone at top (4 feet), blue limestone (1 foot), thin dove beds (2 feet), and dove limestone (4 feet) at bottom (=Cannon)	11
Capitol limestone. Laminated, granular limestone (=Bigby)	25
Orthis bed. Flags and shales with *Orthis testudinaria* (=Hermitage)	60
Carters Creek limestone (=Carters limestone of Black River group)	60

Essentially the same classification was adopted by Safford and Killebrew in their text-book The Elements of the Geology of Tennessee, published in 1900. With the publication in 1903, of the Columbia folio, by Hayes and Ulrich, the present nomenclature came into effect.

The upper part of the following section at Nashville beginning in the Bigby limestone, crops out along the cut of the Nashville, Chattanooga & St. Louis Railway east of St. Cloud Hill and continues to the top of this hill, where Fort Negley was excavated in the thin limestones and shales of the Leipers formation. Outcrops of practically every inch of this section occur, and fossils, although most of them worn, are abundant. The lower part, from the Lowville limestone to the top of the Bigby (Plate 34, fig. B), is exposed in the old stone quarries along the Lebanon Pike near Mount Olivet cemetery and continues in nearby cuts along the Tennessee Central Railroad to the quarry just behind the old Blind Asylum, now the City Hospital. (Plate 39.)

Geologic section of Ordovician rocks, Nashville, Tennessee

	Feet
Cincinnatian series:	
Maysville group:	
Leipers formation	
Thin-bedded blue, crystalline, nodular limestone with shale partings. Fossils abundant, particularly *Platystrophia ponderosa* in the lower part and *Orthorhyncula linneyi* and many bryozoa in the upper beds	16
Mohawkian series:	
Trenton group:	
Catheys formation	
Massive, fine-grained, argillaceous, dark-blue limestone weathering into beds 3 to 4 inches thick, emitting a fetid odor when broken	13
Dark, fetid limestone with *Cyclonema varicosum* and other gastropods, large ostracoda (*Leperditia pondi*), *Tetradium fibratum*, *Cyrtoceras* and *Orthoceras*, *Platystrophia praecursor* and *Hebertella sinuata* var.	1
Fine-grained, dark, argillaceous, fetid limestone in 3 to 4 inch beds, with a two-foot stratum of subgranular, blue-gray limestone at the top, weathering into a rough upper surface	12
Bed of granular, gray-blue limestone crowded with *Stromatocerium pustulosum* and *Rafinesquina alternata*	1.5
Thin-bedded, argillaceous, dark limestone with gastropod and cephalopod shells	2
Thin-bedded, gray-brown, argillaceous limestone crowded with *Tetradium fibratum*	2

	Feet
Granular, gray, massive limestone, laminated and cross-bedded, resembling the Bigby limestone and like it composed of comminuted fossils; upper two feet filled with clay casts of gastropods	10
Layer of fine-grained, argillaceous limestone, weathering into pot-hole-like cavities, 4 to 6 inches across	1
Laminated, subgranular, grayish limestone, crowded with bryozoa, especially *Constellaria teres*	3
Fine-grained, argillaceous limestone	4.5
Thin-bedded limestone full of *Orthorhyncula linneyi*, *Platystrophia praecursor*, *Constellaria teres* and other bryozoa and pelecypods	0.5
Massive, fine-grained, argillaceous limestone with large ostracoda, particularly *Isochilina* near *saffordi* and *Leperditia pondi*	8
Dark-gray, fine-grained limestone with layers having uneven surface and filled with *Drepanella*, *Saffordella muralis*, *Isochilina apicalis* and smaller ostracoda	2
Bluish-gray, fine-grained limestone, the lower part filled with fragmentary fossils that tend to silicify when weathering	2
Fine-grained limestone in 3 to 4 inch beds, weathering cobbly	7
Grayish, granular limestone, crowded with *Constellaria emaciata*	0.5
Shaly limestone, crowded with bryozoa, especially *Homotrypa centralis*	2.5
Subgranular, blue limestone with few fossils	1
Thin-bedded clayey limestone, weathering cobbly, crowded with bryozoa particularly *Constellaria emaciata*, *C. teres*, and *Homotrypa centralis*	3
Cannon limestone	
Massive, crystalline limestone, weathering into red clayey débris, containing *Vanuxemia hayniana*, *Platystrophia elegantula triplicata*, *Hindia parva*, *Rhynchotrema increbescens*, and *Columnaria alveolata*	6
Shaly limestone with *Eridotrypa briareus* and other bryozoa	1
Massive, irregularly laminated, subgranular, gray limestone with few fossils, weathering into impure phosphate	6
Fine-grained, argillaceous, massive limestone, weathering into clay holding siliceous fossils, particularly *Saccospongia danvillensis* and *Lophospira medialis*	1.5
Argillaceous, shaly limestone, weathering cobbly	1.5
Massive, fine-grained, argillaceous limestone, yielding silicified fossils upon weathering, especially ramose bryozoa, *Saccospongia danvillensis*, *Strophomena vicina*, *Oxydiscus cristatus*, *Lophospira medialis*, *Hindia parva*, *Bellerophon troosti*, *Hebertella frankfortensis*, and *Rhynchotrema increbescens*	2
Massive, crystalline, bluish limestone, containing *Hebertella frankfortensis*. Top plated with large *Stromatocerium pustulosum*	4
Fine-grained, bluish-gray to semidove massive limestone, weathering into porous chert and red clay, containing many silicified fossils, among which are *Saccospongia danvillensis*, *Tetradium columnare*, *Hindia sphaeroidalis*, *Zygospira recurvirostris*, *Hebertella frankfortensis*, *Rhynchotrema increbescens*, *Platystrophia amoena*, *Ctenodonta retrorsus*, *Bucania nashvillensis*, *Oxydiscus cristatus*, *Bellerophon troosti*, *B. clausus*, *Lophospira medialis*, *L. sumnerensis*, *Liospira* and *Orthoceras*	15
Bigby limestone	
Massive, coarsely granular, laminated and cross-bedded semiphosphatic grayish limestone in beds 1 to 6 feet thick, composed	

Feet

largely of comminuted fossils. A few bryozoa in the lowest foot; a fossiliferous layer with bryozoa and occasional *Dalmanella fertilis* and *Hebertella frankfortensis* present 6 feet above the base.. 22

Hermitage formation

- Blue to light-gray, granular, irregularly bedded, laminated limestone with thin streaks crowded with *Dalmanella fertilis*. The topmost 4 inches contains *D. fertilis* and a few *Hebertella frankfortensis*.......... 5.5
- Regularly laminated, massive limestone like the above with *Dalmanella fertilis* abundant throughout. Three feet above the base is a layer full of ramose bryozoa and farther down is another bed with discoidal bryozoa.......... 5.5
- Massive, granular limestone above and thin-bedded clay layers below with bryozoa in the upper part.......... 12
- Much contorted limestone and shale giving the bouldery effect upon weathering.......... 3
- Thick-bedded argillaceous limestone crowded with *Dalmanella fertilis*.......... 8
- Impure limestone, many layers filled with *Dalmanella*, becoming shaly at top.......... 8
- Thin-bedded argillaceous limestone, mainly covered, full of *Dalmanella fertilis*, with shaly partings.......... 20
- Crystalline, gray-blue, fetid limestone with *Tetradium minus*, *Dalmanella fertilis*, *Zygospira recurvirostris*, *Bucania punctifrons* and other fossils.......... 2

Black River group:

Lowville limestone:

Tyrone member

- Thin-bedded, fossiliferous, dove limestone layers separated by thin seams of yellow clay. *Rhinidictya nicholsoni*, *Phyllodictya frondosa* and other bryozoa abundant.......... 10
- Dove limestone in beds 1 to 3 inches thick, containing *Subulites*, *Cyrtodonta*, *Tetradium cellulosum*, *Phyllodictya frondosa* and other fossils.......... 1.5
- Unctuous yellow to green clay (bentonite bed).......... 1

Carters limestone member

- Slightly magnesian, mottled limestone with upper part conglomeratic; yields some white chert; surface of top layer slightly undulated.......... 6
- Finely oolitic, massive limestone, crystalline at the top.......... 4
- Massive, slightly magnesian limestone.......... 5
- Coarsely crystalline, conglomeratic limestone, containing many *Solenopora compacta*.......... 1
- Mottled, slightly magnesian limestone with few fossils.......... 6
- Conglomeratic, oolitic, banded pure limestone.......... 3
- Massive, mottled, slightly magnesian limestone with a few streaks of pure rock. Yields chert and silicified specimens of *Tetradium columnare*, *Streptelasma profundum*, *Columnaria halli*, and *Stromatocerium rugosum* upon weathering.......... 8
- Homogeneous dove and slightly magnesian, massive, unfossiliferous limestone (to bottom of quarry).......... 12

The following section, measured near Hermitage station on the hill between Stoner Creek and the Lebanon-Nashville and Central pikes, illustrates the characteristics of the Ordovician formations as developed eastward from Nashville.

Section of Ordovician formations near Hermitage station, Tennessee

	Feet
Cannon limestone	
Blue granular limestone weathered into phosphate	6
Dove limestone with *Leperditia* and *Camarocladia*	3
Shaly limestone holding *Hebertella*, *Rhynchotrema* and *Strophomena*	4
Massive, fine-grained, gray limestone with *Leperditia* and small ostracoda	2
Shaly limestone, mainly covered	5.5
Massive dove limestone	9
Clayey limestone crowded with *Tetradium fibratum*	1.5
Blue-gray granular, subcrystalline limestone	3.6
Fine-grained dove limestone	2
Fine-grained gray limestone with ostracoda	6
Blue-gray, granular, slightly phosphatic limestone	2
Massive dove limestone	3
Fine-grained gray limestone with ostracoda	1.5
Fine-grained to subcrystalline drab-gray limestone filled with gastropods, *Oxydiscus*, etc	2.6
Dove limestone	2
Bigby limestone	
Subgranular, laminated, somewhat phosphatic limestone	6
Granular, laminated, phosphatic limestone	12
Granular, crystalline limestone with a few phosphatic layers	12
Hermitage formation	
Blue siliceous, fine-grained, thin-bedded, shaly limestone weathering light brown into a sandy phosphate. Near the top is a fossiliferous bed with *Modiolodon oviformis*. About the middle is a 2 or 3 foot bed of disturbed material, the mud having been rolled into large boulders. Fossils few; *Byssonychia*, *Dalmanella fertilis* and *Rafinesquina* present	35
Thin-bedded limestone and shale crowded with *Dalmanella fertilis* and *Ctenodonta*	2
Blue siliceous to argillaceous, thin-bedded limestone weathering into light brown, very impure phosphatic rock. Fossils few; among them are *Heterorthis clytie* and *Dalmanella fertilis*	30
Lowville limestone	
Thin-bedded dove limestone with shale, containing *Strophomena*, *Leperditia fabulites*, *Phyllodictya frondosa*, *Rhinidictya nicholsoni*	5
More-massive dove limestone weathering into plates of blocky yellow chert	4

TROUSDALE COUNTY

Proceeding northeastward to Hartsville in Trousdale County it will be noted that although the Bigby limestone disappears entirely, the Cannon limestone, 37 feet thick at Nashville, increases to 110 feet. The overlying Catheys shows a fairly equal development in each section. This change in thickness of the several formations between Hartsville and Nashville is not merely of local extent and possibly the result of erosion but is gradual and is due to progressive changes in the old sea areas. Here as elsewhere in the sections presented detailed mapping has shown the gradual changes in thickness in the intervening areas.

The lower twelve beds of the section selected for Trousdale County were observed along the Gallatin-Hartsville pike one to two miles west of Hartsville, and its continuation to the Chattanooga black shale was seen in outcrops in the woods two miles north of the town. This section, made jointly with E. O. Ulrich in 1900 and revised in later years, is as follows:

Geologic section in vicinity of Hartsville, Trousdale County, Tennessee

	Feet
Mississippian:	
Chattanooga black shale at top of hill.	
Devonian:	
Onondaga sandstone.	
Massive white sandstone with *Hadrophyllum d'orbignyi*, *Zaphrentis*, *Spirifer*, *Stropheodonta*, etc.	35
Silurian:	
Several formations present.	
Ordovician:	
Cincinnatian series:	
Leipers formation. Mainly covered, but a few outcrops show the usual sequence and fossils.	
Mohawkian series:	
Catheys formation	
Covered	40
Fine-grained, argillaceous limestone with layers full of *Bellerophon*, *Orthoceras*, *Modiolopsis* and *Lophospira* at the base terminating above in a disturbed wavy layer	18
Blue crystalline limestone	20
Nodular, shaly limestone with many unsilicified specimens of *Cyclonema*, *Rafinesquina alternata*, *Platystrophia*, *Byssonychia*, *Hindia*, *Hebertella sinuata*, *Orthoceras*, *Constellaria emaciata* and other bryozoa	6
Cannon limestone	
Fine-grained dirty-gray limestone yielding when weathered silicified gastropods and bryozoa; *Lophospira bowdeni* abundant in upper part, also *Eridotrypa briareus*, *Columnaria alveolata*, *Saccospongia danvillensis*, *Oxydiscus subacuta*, *Lophospira saffordi*, *Bellerophon troosti*, etc	10
Irregularly bedded, blue crystalline limestone with a few shale layers containing *Eridotrypa briareus*	4
Granular, brown-speckled limestone weathering into impure phosphate	5.5
Massive dove and crystalline limestone, the latter with many bryozoa and gastropods, particularly *Lophospira sumnerensis* and *L. saffordi*	6
Fine-grained, massive limestone with *Lophospira saffordi*, *L. sumnerensis* and many other gastropods	8
Dove-colored, shaly limestone in thin layers, the lower beds with green specks and containing a few ostracoda	4.5

	Feet
Fine-grained, gray limestone full of gastropods	4
Dove limestone without *Scolithus* markings	1.5
Dark-gray limestone with ostracoda (*Leperditia*)	1
Massive dove limestone with small *Scolithus* markings	2
Covered, but the siliceous débris contains gastropods, particularly *Lophospira sumnerensis* and *Hebertella frankfortensis*	3
Sublaminar impure limestone with *Stromatocerium* and *Tetradium*, also crinoid stems 0.25 to 0.37 inch in diameter	5
Grayish to dove-colored limestone in part even bedded and in part nodular, weathering rapidly and exhibiting many fossils in the débris particularly large *Stromatocerium* in the lower part, *Vanuxemia hayniana* in several layers and *Lophospira sumnerensis*, *Tetradium columnare*, *Rhynchotrema increbescens* and *Hebertella frankfortensis* in the upper part	17
Nodular limestone with few recognizable fossils but contains many large examples of *Tetradium laxum*	13
Fine-grained, even-bedded limestone in 2 to 20 inch layers disintegrating rapidly on exposure and liberating many silicified gastropods, sponges, and pelecypods	13
Fine-grained, mostly crystalline limestone, the upper 2 to 4 feet filled with masses of *Tetradium columnare*	9
Hermitage formation	
Shales below and hard clayey layers above containing *Tetradium minus*. The lower foot or two crowded with massive and convoluted bryozoa (*Amplexopora convoluta*)	6.5
More or less granular impure phosphatic limestone with many *Rafinesquina alternata* in upper part	15
Sandy shale with *Dalmanella fertilis*, *Prasopora patera*, etc. (Base not seen)	22+

WILLIAMSON COUNTY

The section at Franklin and vicinity shows some changes in thickness of the several Trenton formations in this county; the Catheys has increased from 75 feet at Nashville to 115 feet at Franklin, the Cannon from 37 to 56 feet, and the Bigby from 22 to 80 feet.

This section has been prepared from various exposures in the immediate vicinity of Franklin, including outcrops along Harpeth River, quarries in the northwest corner of town near the cemetery, and outcrops on Fortification Hill just across the river. The section continues with the basal beds of the Cannon limestone at Rhodes quarry a mile and a half southwest of Franklin and ends in the Fort Payne chert at the top of the hill above the quarry. Altitude 930 feet.

The extensive quarrying carried on here by the Franklin Limestone Company has exposed an excellent section of the Cannon and Catheys formations where the strata can be studied bed by bed in detail.

Geologic section at Franklin, Tennessee, and vicinity

	Feet
Mississippian:	
Fort Payne chert	
Massive, blue to gray, siliceous limestone represented by blocky chert débris	—
Ridgetop shale	
Unfossiliferous green shale with the kidney phosphate bed at base	20
Chattanooga shale	
Black carbonaceous shale covered but presence shown by flakes in the soil	10
Ordovician:	
Trenton group:	
Catheys formation	
Massive, argillaceous limestone weathering irregularly cavernous with a few interbedded layers of yellow shale full of ramose bryozoa, including *Constellaria emaciata*, *Homotrypa* and the brachiopods *Rafinesquina alternata* and *Platystrophia precursor*	20
Argillaceous to fine-grained, dark-blue to gray, massive, fetid limestone with the trilobites *Platylichas* and *Acidaspis rebecca* and the ostracoda *Isochilina saffordi* and *Leperditia pondi*. Contains also many cross sections of gastropods and cephalopods that do not silicify on weathering and are difficult to break out of the rock	25
Fine-grained argillaceous limestone and blue crystalline, knotty limestone in beds 1 to 4 inches thick. Many layers weather cobbly, and others are full of holes. Fossils abundant, particularly *Rafinesquina alternata*, *Hebertella sinuata* and *Cyclonema varicosum*	30
Massive blue to gray, speckled, granular semiphosphatic limestone with many bryozoa in the lower beds	10
Thin clayey limestone and yellow shale with a few 4 to 6 inch interbedded, blue crystalline layers, crowded with *Constellaria emaciata* and its accompanying fauna	10
Coarsely granular, gray-blue massive limestone with brown specks; one bed three feet thick containing many examples of *Cyclonema varicosum*, but most of the layers composed of crinoidal fragments	15
Nodular, clayey limestone with *Solenopora compacta*, *Eridotrypa briareus*, *Cyclonema varicosum*, *Orthorhyncula linneyi*, *Columnaria alveolata*, *Rafinesquina alternata*, and *Hebertella sinuata* abundant	5
Cannon limestone	
Gray to blue, massive, laminated, semiphosphatic limestone full of *Rafinesquina alternata*	10
Clayey limestone made up of comminuted fossils, among which were recognized *Orthorhyncula linneyi*, *Platystrophia*, *Hebertella sinuata*, bryozoa and various species of cyclorid shells	5
Finely crystalline to argillaceous, blue to gray limestone in beds 4 to 12 inches thick, weathering cobbly and containing small ostracoda, gastropods, and *Solenopora compacta*	5
Massive, pure dove limestone with small *Scolithus* markings (*S. columbina*), many of the tubes being filled with green iron silicate	15
Massive, fine-grained, gray limestone speckled with green iron silicate grains	2
Blue to gray, massive, granular limestone with a 15-inch dove layer in the middle containing the characteristic elongate gastropod *Hormotoma columbina*	7
Massive dove limestone in beds 6 to 30 inches thick, pierced by small *Scolithus* tubes	12

	Feet
Gray to flesh-colored coarsely crystalline limestone full of *Cyrtodonta grandis*	1.5
Bigby limestone	
Coarsely granular, gray, laminated, massive limestone with few recognizable fossils except in layer near the top, which contains many large siphuncles of cephalopods (*Actinoceras*)	40
Typically gray, coarsely crystalline, brown-speckled, cross-bedded, phosphatic limestone, massive when fresh but thin-bedded and laminated when weathered. Recognizable fossils few but *Hebertella frankfortensis*, *Rhynchotrema increbescens* and bryozoa noted	30
Blue to gray phosphatic limestone weathering into brown phosphate	10
Hermitage formation	
Dark-blue and gray argillaceous limestone in layers one inch thick, separated by blue shale, with *Modiolodon oviformis* and *Dalmanella fertilis* not uncommon	10
Massive blue, subcrystalline to argillaceous limestone in three layers, streaked with zones of fine-grained dark-gray limestone and with lenses of *Dalmanella fertilis*, many 1 foot thick. Weathered surface shows the rolled effect seen in photograph (Plate 36, fig. 1). The limestone weathers cavernous, leaving the *Dalmanellas* leached out in siliceous chunks	8
Shale and thin-bedded limestone with the surface of the slab crowded with *Dalmanella fertilis*	2.5
Massive blue, coarsely crystalline limestone in layers 6 to 24 inches thick with lenses crowded with *Dalmanella fertilis*	12
Gray to blue argillaceous limestone in beds 1 to 4 inches thick, massive when fresh but weathering into thin earthy blocks with occasional bands of impure phosphate rock and finally into brown-yellow clay with shale fragments. Surface of some slabs covered with *Dalmanella fertilis* (to bed of Harpeth River)	25

MAURY COUNTY

The Ordovician stratigraphy of the western half of Maury County, the part included in the Columbia folio, is well illustrated in the sections at Columbia and Mount Pleasant that follow. The special features of this region are (1) the complete absence of the Cannon limestone, which appears along the east edge of the area as a thin dove limestone and increases in thickness eastward, and (2) the considerable development of the Bigby, which diminishes in thickness eastward and disappears, allowing the basal dove layers of the Cannon to rest upon the Hermitage.

The following section, made with E. O. Ulrich in 1900 and revised by him and the author in 1922, may be considered as exhibiting the typical expression of the Bigby and Catheys formations. In the mapping of the Columbia quadrangle by C. W. Hayes and E. O. Ulrich reference to this section was constantly made.

The upper part of the section, showing the Catheys and Leipers formations, is best exposed in outcrops that begin at West Seventh and

Armstrong Streets and continue to the top of the reservoir hill (Mount Parnassus). The Hermitage and Bigby portions commence at the Santa Fe Pike and extend southwest to the base of the upper section, and the Lebanon and Carters divisions are to be seen in the banks of Duck River. In 1922 the several divisions were still well exposed and fossils, although worn, were abundant.

Geologic section at Columbia, Tennessee

	Feet
Cincinnatian series:	
Maysville group:	
Leipers formation	
Thin-bedded, nodular, blue limestone with intercalated blue to yellow shale crowded with bryozoa and other fossils (see list on page 119)	15
Mostly covered, but limestone similar to underlying bed with the upper layer granular, grayish and cavernous	28
Impure, thin-bedded limestone with few fossils except in top layer, which is full of broken shells and bryozoa	12
Shaly, impure limestone in thin layers, crowded with *Rafinesquina alternata* and *Platystrophia ponderosa*	6
Mohawkian series:	
Trenton group:	
Catheys formation	
Rough-bedded, dark, thin, argillaceous limestone weathering cavernous (small holes) with the ground strewn with cavernous blocks; fossils few and scarcely determinable	14
Fossiliferous, shaly limestone crowded with a massive bryozoan, *Cyphotrypa tabulosa*	4
Unevenly-bedded, granular and subgranular blue limestone used for macadam. Fossiliferous in upper part with *Escharopora falciformis* var	16
Bluish massive, subcrystalline limestone with *Cyclonema varicosum*	4
Heavy-bedded, fine-grained, gray or blue clayey limestone with many fossils, including gastropods, pelecypods, *Lophospira bowdeni*, *Orthorhynchula linneyi*, *Tetradium columnare*, and small examples of *Stromatocerium pustulosum*	4
Shaly nodular and subcrystalline limestone crowded with bryozoa, especially *Escharopora flabellaris*, *Heterotrypa parvulipora*, and *Homotrypa centralis*	16
Granular and crinoidal limestone with specimens of *Solenopora compacta* 1 to 2 inches in diameter abundant	5
Nodular, blue clayey limestone with two layers (one at base and the other above the middle) particularly striking for the abundance and large size of *Stromatocerium pustulosum*. Many other fossils in this bed	18
Finely granular, laminated, unfossiliferous phosphatic limestone; much quarried	6
Phosphatic limestone in thin beds, the top layer plated with *Constellaria grandis* and other bryozoa	6
Blue granular limestone crowded with *Constellaria teres* and *C. emaciata*	2

	Feet
Blue to yellow shale with many bryozoa, especially *Constellaria teres* and *C. emaciata*	4
Shaly limestone with few fossils	2
Bigby limestone	
Gray to blue granular limestone crowded with *Rafinesquina*	1
Granular limestone with a few *Rafinesquina* and other fossils, hemispheric bryozoa and *Eridotrypa briareus* at the base	5
Granular gray-blue limestone filled with *Rafinesquina*	2
Subgranular, unfossiliferous limestone	2
Gray granular limestone filled with *Rafinesquina* and several layers charged with *Ctenodonta subrotunda, Bellerophon clausus* var., *Lophospira* species, *Rhynchotrema increbescens, Dalmanella* (large species), and *Hebertella frankfortensis*. One foot of unfossiliferous shale at base	6
Thin-bedded, subgranular grayish limestone yielding a little chert upon weathering. *Rafinesquina* abundant, *Dalmanella* few; cyclorids present	17
Hermitage formation	
Blue even-bedded, subcrystalline limestone crowded with *Dalmanella fertilis*	50
Impure, blue clayey limestone, fine grained in upper half. *Dalmanella fertilis* scarce but *Prasopora patera* not uncommon	15
Black River group:	
Lowville limestone	
Carters limestone member	
Massive, magnesian limestone, easily recognized by white color of outcrop	12
Mottled thick-bedded limestone high in magnesia. Locally rather fossiliferous with *Maclurea bigsbyi, Stromatocerium rugosum, Columnaria halli, Lophospira bicinata,* and *Dystactospongia minor* recognizable	18
Single bed of mottled, fine-grained, dove nearly pure limestone with yellowish magnesian spots. Fossils locally present	4
Massive, fine-grained, mottled, rather pure dove limestone with fossils weathering out siliceous, particularly *Streptelasma profundum, Columnaria halli, Stromatocerium rugosum,* and *Maclurea bigsbyi*	6
Pitted, yellowish massive limestone, low in magnesia. No fossils observed	3
Massive, finely granular, yellowish nearly pure limestone, weathering out many examples of *Stromatocerium rugosum, Columnaria halli, Tetradium columnare, T. carterensis* and *Lichenaria carterensis*	5
Fine-grained, yellowish limestone without fossils	1.5
Chazyan series:	
Stones River group:	
Lebanon limestone	
Thin-bedded dove limestone separated in places by shaly layers. The topmost bed a dove layer closely cemented to lowest bed of Carters, forming a single block. Fossils abundant (to bed of Duck River).	

The numerous exposures due to phosphate mining at Mount Pleasant give an excellent section of the Hermitage and Bigby limestones.

Section at Mount Pleasant, Tennessee, and vicinity

	Feet
Mississippian:	
Ridgetop shale	
Gray-blue shale usually unfossiliferous but with abundant ostracoda (*Ctenobolbina loculata*, etc.) at several horizons	10+
Maury shale	
Green shale with glauconite grains and containing kidney phosphatic nodules	6
Chattanooga black shale (thin or absent).	
Hardin sandstone	
Represented by a bed of blue phosphate with a thin layer of phosphatic sandstone at base crowded with conodonts	1.5
Ordovician:	
Cincinnatian series:	
Maysville group:	
Leipers formation	
Argillaceous blue limestone with *Cyrtoceras*, pelecypods and gastropods	35
Yellowish shaly limestone holding *Orthorhynchula linneyi* and other fossils	6
Greenish crystalline limestone with occasional grains of greensand. Fossils few, mainly *Allonychia*	5
Shale and shaly limestone with many bryozoa	12
Mohawkian series:	
Trenton group:	
Catheys formation	
Shaly limestone with large *Heterotrypa* in the upper part and abundant *Rafinesquina alternata* in the lower beds	28
Shaly limestone crowded with fossils	10
Subcrystalline blue limestone, the upper half with *Bucania lindsleyi* and other gastropods	15
Blue limestone with *Stromatocerium pustulosum* and *Tetradium columnare* abundant (*Stromatocerium* bed)	5
Siliceous blue limestone weathering into small plates and disks of light, porous, granular chert	20
Yellow shale and shaly limestone crowded with bryozoa, particularly *Constellaria emaciata*, *Heterotrypa parvulipora*, *Escharopora*, etc. (*Constellaria* bed)	10
Bigby limestone	
Subcrystalline blue limestone with *Rafinesquina alternata* in upper layer	30
Sandy phosphate	2
Lens of coarsely crystalline limestone and disturbed material	4
Sandy phosphate	4.5
Shale and limestones weathering into yellow clay and abundant chert	8
Massive, granular, phosphatic limestone weathering into good phosphate	12
Blue limestone with yellow clay above	6

	Feet
Phosphate rock in thick plates (4.5 feet) overlain by clay (1.5 feet)	6
Much disturbed, conglomeratic, impure, shaly limestone holding gastropods in places	0.6
Hermitage formation	
Shaly limestone with *Zygospira recurvirostris*, *Dalmanella fertilis*, and *Hebertella borealis*. The bryozoa *Prasopora simulatrix*, *Dekayella trentonensis*, and *Hallopora multitabulata* are present	12
Heavy-bedded blue limestone composed almost entirely of *Dalmanella fertilis*	4
Siliceous blue limestone with *Tentaculites obliquus* in the lower beds and *Dalmanella fertilis* throughout; weathers into platy chert. Secondary phosphate along the line of outcrop	11
Crystalline limestone lens composed of disturbed material; *Lophospira* present	0.7
Argillaceous limestone with ostracoda (*Ceratopsis*, etc.) and *Leptobolus lepis*	1
Thin-bedded, argillaceous limestone with interbedded shale (to level of Sugar Creek)	6

The section exposed a few miles east of the Columbia quadrangle is instructive in showing diminished thicknesses of the several formations.

Section along Bear Creek pike on the west side of Loftin Hill, 8 miles east of Columbia, Tennessee

	Feet
Mississippian:	
Fort Payne limestone. Represented by chert débris.	
Chattanooga black shale	5
Ordovician:	
Cincinnatian series:	
Maysville group:	
Leipers formation	
Nodular, earthy, calcareous shale with *Platystrophia ponderosa*	13
Shaly blue limestone crowded with bryozoa	4.5
Impure limestone with large *Platystrophia ponderosa* and *Strophomena planoconvexa*	7
Shaly limestone, not well shown, full of *Tetradium fibratum*, mollusca, and *Platystrophia ponderosa*	7
Grayish-blue limestone with no recognizable fossils, the upper layer cavernous on its upper face	10
Blue limestone with *Bucania*, *Hebertella sinuata*, and *Platystrophia ponderosa*	8
Mohawkian series:	
Trenton group:	
Catheys formation	
Shaly limestone with bryozoa	2
Laminated, granular limestone	4
Argillaceous limestone and shale holding *Columnaria alveolata*, *Stromatocerium pustulosum*, and *Tetradium fibratum*	4
Laminar, granular limestone	4.5
Gray subcrystalline limestone	3

	Feet
Shale and clayey limestone weathering cherty at the top; *Stromatocerium pustulosum*, *Tetradium fibratum*, and *Columnaria alveolata* abundant in weathered débris	5.5
Bluish subcrystalline limestone and shale crowded with bryozoa particularly *Constellaria emaciata* and *C. teres*	4
Cannon limestone	
Laminar, granocrystalline limestone weathering into thin platy phosphate	10
White and grayish oolitic limestone crowded with fossils particularly the gastropods *Lophospira sumnerensis*, *Bucania*, and *Oxydiscus*	10
Granocrystalline, phosphatic limestone	9
Dove limestone	8
Bigby limestone	
Gray subcrystalline limestone	2+

GILES COUNTY

The following section begins at the big spring north of the public square in Pulaski with the lower part of the Cannon limestone and continues to the top of the hills beside the road running north. The dove beds of the Cannon and the underlying formations were observed south of Pulaski particularly in the vicinity of Aspen Hill.

Geologic section at Pulaski, Tennessee, and vicinity

	Feet
Mississippian:	
Fort Payne chert in place, resting upon the Fernvale formation.	
Silurian (Richmondian):	
Fernvale formation	
Brown-yellow shale with *Platystrophia acutilirata* but other fossils few	8
Gray shale containing bryozoa and *Rhynchotrema capax*	10
Blue and pink limestone	20
Ordovician:	
Cincinnatian series:	
Maysville group:	
Leipers formation	
Nodular, irregular, blue fossiliferous limestone below with *Strophomena maysvillensis* and other typical Leipers fossils	25
Mohawkian series:	
Trenton group:	
Catheys formation	
At top dirty-gray to dove-colored argillaceous limestone pierced by *Scolithus* tubes 0.3 inch in diameter	7
Heavy-bedded, fine-grained, bluish limestone weathering cobbly; *Hebertella* abundant	10
Massive, subgranular, blue-gray limestone, crowded with colonies of *Tetradium columnare*	4
Massive, fine-grained limestone weathering laminated	5.5
Blue limestone weathering cobbly	2
Granular blue and shaly limestone full of ramose bryozoa particularly *Constellaria emaciata* and *C. fischeri*	4

	Feet
Cannon limestone	
Covered interval with much platy chert probably derived from blue to gray massive limestone	25
Blue shale crowded with fossils particularly *Eridotrypa briareus*, sponges, and gastropods	15
Covered interval	5
Granular blue limestone full of *Solenopora compacta*	5
Massive, granular, semiphosphatic, gray-blue speckled limestone	15
Thin-bedded, fossiliferous, clayey limestone and shale with many *Rhynchotrema increbescens*, massive bryozoa, etc	8
Massive gray-brown speckled, granular limestone laminated and cross-bedded, much resembling the Bigby	15
Dove limestone layers filled with *Scolithus* markings	1
Bigby limestone	
Massive, laminated and cross-bedded, coarsely crystalline, blue and gray phosphatic limestone	60
Hermitage formation	
Shale and shaly limestone, the upper beds slightly phosphatic. *Dalmanella fertilis* abundant	50
Black River group:	
Kimmswick limestone (?)	
Massive, coarsely crystalline, gray limestone, weathering without chert into rounded boulders, crowded with fossils particularly *Columnaria*, *Solenopora*, and *Echinospherites*. A few mottled dove limestone beds 12 to 20 inches thick occur in the lower part	35
Lowville limestone	
Tyrone member	
Thin-bedded dove and bluish shaly limestone	10
Thin-bedded dove and fucoidal limestone weathering into small fragments full of holes	10

MARSHALL COUNTY

The outcrops seen along the old road between Belfast and Petersburg give a good idea of the stratigraphic sequence in this county. The absence of the Bigby limestone and the Leipers formation is a feature of this part of the Central Basin.

Section along old road to Petersburg, between points 1 to 3½ miles south of Belfast, Marshall County, Tennessee

	Feet
Mississippian:	
Fort Payne chert.	
Chattanooga black shale	10+
Ordovician:	
Trenton group:	
Catheys formation	
Covered in part to Chattanooga black shale	150
Shale and nodular limestone crowded with branching bryozoa (*Eridotrypa briareus*, *Constellaria emaciata*, and *Homotrypella* sp.)	6.5

	Feet
Cannon limestone	
Granular and crystalline limestone with *Columnaria alveolata*, *Tetradium columnare*, and *Stromatocerium pustulosum*..........	5.5
Blue-gray limestone with few fossils..........................	6
Mostly unfossiliferous shale but with the lower three feet a laminar limestone..	16
Very cherty fine-grained limestone weathering into a red soil containing many silicified *Columnaria* and *Stromatocerium*.........	9
Dove limestone layer..	2
Clay bed filled with *Tetradium fibratum*........................	1
Dove limestone with numerous ostracoda (*Leperditia*)............	2
Dove limestone separated by clay layers. A dove layer with many *Scolithus columbina* at the base	15
Limestone filled with gastropods mainly *Lophospira*, *Bucania*, and *Hormotoma salteri*..	4.5
Dove limestone with *Scolithus columbina*........................	2
Blue-gray fine-grained limestone with ostracods (*Leperditia*) and *Tetradium fibratum*...	4
Massive dove limestone the upper half marked with *Scolithus columbina*..	8
Dark blue-gray limestone with ostracoda (*Isochilina*)..............	3
Blue to brown clayey limestone in 8 to 12 inch layers with thinner partings. *Tetradium fibratum* and *Stromatocerium pustulosum* very abundant as well as *Cyrtodonta* and gastropods............	9
Hermitage formation	
Shale and nodular shaly limestone (listed in detail in the discussion of the Hermitage formation)	53
Black River group:	
Lowville limestone	
Tyrone member	
Thin-bedded dove limestone and shale, underlaid by massive dove limestone.	

BEDFORD COUNTY

Although the greater part of Bedford county exposes Stones River strata at the surface, the following section, taken southeast of Shelbyville, shows the features of the higher Ordovician rocks, particularly the absence of the Bigby limestone and the Carters member of the Lowville.

Section 4½ miles southeast of Shelbyville, Tennessee

	Feet
Ordovician:	
Trenton group:	
Cannon limestone	
Massive, impure dove limestone interbedded with dark-blue granular limestone to top of hill. *Tetradium laxum* bed near base and *Cyrtodonta grandis* bed 10 feet higher.	
Earthy, knotty limestone crowded with *Tetradium fibratum* in the lower part and with trilobite fragments in the upper............	10

	Feet
Hermitage formation	
Argillaceous, rather thin-bedded limestone yielding many specimens of *Lichenaria* upon weathering	10
Yellow shaly and sandy unfossiliferous strata	20
Black River group:	
Lowville limestone	
Tyrone member	
Topmost stratum a 2 or 3 inch capping of dove limestone, which is worm burrowed, sun cracked, and changed to chert along its outcrop	0.25
Dove limestone in layers 1 to 4 inches thick with interbedded thin shaly dove strata. Bryozoa and other fossils in the upper part and pelecypoda in the lower beds	8
Unctuous green clay with a sandy clay bed in the middle (upper bentonite bed)	2
Thin-bedded dove limestone interbedded with thin layers of gray clayey limestone full of fucoid-like markings, which upon weathering yields fragments full of holes. In the upper part occurs a zone of *Rhinidictya* and other bryozoa, below this a reef of *Tetradium cellulosum*, then a layer with many small ostracoda, next a layer with gastropods and pelecypods, and finally at the base a zone of *Leperditia fabulites*	20
Green to yellow clay with coarse feldspathic sand grains (lower bentonite bed)	0.7
Massive pure dove limestone with a few magnesian layers in strata 1 to 2 feet thick. Fossils few but weathering yields chert (to base of exposure along road).	

RUTHERFORD COUNTY

Rutherford, the central county of the State, is also the center of the Nashville Dome and exposes the oldest rocks of this physiographic province. The following general section was made from outcrops in various parts of the county, the Murfreesboro and Pierce limestone portions being from the type areas.

Geologic section in Rutherford County, Tennessee

	Feet
Trenton group:	
Hermitage formation	
Sandy shale and brown laminated impure phosphatic limestone	70
Black River group:	
Lowville limestone	
Tyrone member	
Thin-bedded to massive dove limestone weathering into chert and red-clay soil with *Tetradium cellulosum*, *Streptelasma profundum*, *Columnaria halli*, etc., not uncommon	80

	Feet
Stones River group:	
Lebanon limestone	
Thin-bedded, flaggy, in many parts shaly, fine-grained, bluish or dove-colored limestone with a heavy-bedded layer about 3 feet thick near the middle and another near the base. Some of the layers extremely fossiliferous	120
Ridley limestone	
Dense blue-gray limestone in thick beds, weathering to red-brown clay soil usually with little chert	100
Pierce limestone.	
Thin-bedded, platy, argillaceous blue-gray limestone separated by thin shaly partings, containing thin layers of coarsely crystalline, gray fossiliferous limestone, with the surface crowded with small ramose and bifoliate bryozoa	19
A single layer of dense fine-grained, bluish-gray, almost unfossiliferous limestone resembling the underlying Murfreesboro limestone	3 to 4
Unfossiliferous, dense gray-blue limestone in thin layers	2
Massive, unfossiliferous drab limestone weathering slightly cherty	3
Murfreesboro limestone	
Dense, massive, light-blue to dove-colored mainly unfossiliferous limestone weathering into chert but with a layer or two yielding chert that contains *Salterella billingsi*, *Stromatocerium*, and gastropods	20
Dense, gray-blue fine-grained limestone	1.5
Dense, massive, drab unfossiliferous limestone yielding much chert on weathering. (Base of formation not seen.)	20

The southwest corner of Rutherford County has afforded the following section illustrating the nature of the strata now eroded away from most of this region. This section starts in the Louisville & Nashville Railroad cut under the first overhead bridge about a mile south of Allisona and continues to the top of the hill on the east. It lies just southeast of the east edge of the Franklin quadrangle and is interesting in showing the extension of the strata in that direction.

Section one mile south of Allisona, Rutherford County, Tennessee

	Feet
Mississippian:	
Chattanooga black shale fragments and Fort Payne chert noted near top of hill above the Catheys formation, but no beds exposed.	
Ordovician:	
Trenton group:	
Catheys formation	
Covered, but scattered boulders show presence of granular blue and dark argillaceous limestone with trilobite remains near the base	40
Granular, unfossiliferous blue limestone weathering into chert	30
Blue, granular, massive limestone with many fossils particularly *Columnaria alveolata*, *Hebertella sinuata*, *Peronopora*, *Platystrophia*, *Constellaria*, *Lophospira bowdeni*, and *Heterotrypa parvulipora*. Near the base is an argillaceous bed 10 inches thick, filled with ostracods, and at the bottom a pothole layer with depressions 1 to 3 inches wide	10

	Feet
Irregular, knotty, blue argillaceous limestone with many shells of the brachiopods *Rafinesquina alternata* and *Hebertella sinuata*. *Constellaria emaciata* and *Stromatocerium pustulosum* occur 10 inches from the top	30
Cannon limestone	
Gray-blue granular limestone with *Goniophora* at the top and *Solenopora* (variety with concentric base) at the bottom	10
Massive, coarsely crystalline, brown specked blue limestone with the *Cyrtodonta* bed developed near the top. *Hebertella frankfortensis*, *Lophospira sumnerensis* and other gastropods well developed	35
Argillaceous brown limestone yielding abundant chert. Gastropods occur at the top and *Dinorthis ulrichi* and *Strophomena vicina* are abundant in the lower portion	8
Irregularly bedded, grayish fine-grained limestone yielding abundant *Rhynchotrema increbescens*	2.5
Shaly layers with a 10-inch impure dove limestone in the middle	2
Subgranular, fine-grained, massive limestone with clay seams and chert nodules. *Hebertella frankfortensis* abundant	5
Massive dove limestone in six or seven layers, the upper half thinner bedded. Small *Scolithus* (*S. columbina*) markings present throughout, and the lower part contains a *Tetradium* reef. The ostracods *Leperditia*, species, and *L. columbina* not uncommon	17
Massive, grayish blue granular limestone crowded with valves of *Cyrtodonta grandis*	3
Massive dove limestone with *Tetradium laxum*	2
Fine-grained, dark-blue granular limestone showing many gastropods on the surface	2
Dove limestone	1
Cross-bedded, fine-grained limestone with edgewise conglomerate developed in upper half	6
Massive, pure dove limestone containing the large gastropod, *Hormotoma columbina*. Basal part shaly but lowest layers full of chert and gastropods	13
Hermitage formation	
Massive, laminated, sandy limestone with a few layers exhibiting *Dalmanella fertilis*, weathering into sand, sandy blocks, and impure sandy phosphate	20
Dark-blue unfossiliferous shale (to bottom of railroad cut)	5

COFFEE COUNTY

The western edge of the Highland Rim in Coffee County gives the following section for this region. The total absence of the Leipers and Catheys formations and the Bigby limestone is to be noted.

Section 4½ to 5 miles north of Tullahoma on road to Normandy, Tennessee

	Feet
Mississippian:	
Warsaw limestone	
Limestone weathering into characteristic rather incoherent chert and red residual clay with many specimens of *Spirifer*, *Rhipidomella dubia*, and fenestellid bryozoa	25

	Feet
Fort Payne chert	
Gray-blue siliceous limestone weathering into irregular platy and nodular chert in the upper third and at the base chert nodules in irregularly stratified masses	90
Thin-bedded blocky chert	8
Dark-brown arenaceous residual clay with sandy, soft brown to black chert in irregular nodules and siliceous geodes	2
Greenish shale with a layer of 2 to 4 inch geodes at the top with an inch of phosphatic sandstone in places at the base	1.5
Chattanooga shale	
Typical fissile black shale in close contact with underlying Ordovician limestone	22
Ordovician:	
Trenton group:	
Cannon limestone	
Thick-bedded blue-gray fine-grained and subcrystalline limestone, the top layer of which is decomposed making irregular the contact with the overlying black shale. Ostracoda, *Hebertella*, *Rafinesquina alternata*, *Orthorhynchula linneyi*, *Constellaria* and other bryozoa present	11
Shaly limestone, some layers filled with pelecypods, ostracoda (*Isochilina*), and other fossils	5
Irregularly-bedded, argillaceous limestone full of fossils especially pelecypods and gastropods (*Lophospira*, etc.)	5
Fine-grained, light-dove limestone with green splotches	1
Gray argillaceous and subcrystalline limestone of usual Cannon type of limestone with some dove layers (shown on road to Normandy)	100
Hermitage formation	
Sandy and argillaceous shales.	

CANNON COUNTY

Two sections are given for Cannon county, one along the Highland Rim and the other in the northwest corner. The Bigby and Leipers are absent in both, and along the Rim the Catheys also is not developed. In the first section the Lebanon and Lowville formations were noted just south of Woodbury, the Hermitage about a mile south of the town, and the rest of the section along the road southeast to Bell Hill.

General section near Woodbury, Cannon County, Tennessee

	Feet
Mississippian:	
Fort Payne chert	
Yellowish to gray, dull, argillaceous, massive limestone weathering into usual chert (to top of hill).	
Coarsely crystalline, light-blue crinoidal limestone	8
Green shale representing the usual basal deposit (Maury green shale)	8
Chattanooga shale	
Fissile black shale without Hardin sandstone phase at bottom or kidney phosphatic nodules at top	35

	Feet
Ordovician:	
Trenton group:	
Cannon limestone	
Massive, yellow to gray argillaceous limestone with the top layer, slightly undulated by erosion, followed by the black shale. *Tetradium*, *Rafinesquina*, and other fossils present	50
Mottled, argillaceous, massive limestone with the middle and upper beds weathering cherty and containing the usual Cannon gastropod fauna	100
Massive limestone similar to the beds above but containing various dove layers particularly at the base	50
Hermitage formation	
Rubbly, yellowish clay limestone weathering into small irregular rounded masses and containing the coral *Lichenaria*	12
Dirty-blue irregular limestone with intervening shales; small pelecypods not uncommon	15
Mudstone and shaly beds with five or more equally distributed granular, blue phosphatic to dark clay limestones in beds 3 to 12 inches thick, full of small pelecypods mainly *Ctenodonta*	17
Sandy shaly beds weathering into small fragments with four or five layers, 1 to 3 inches thick, of rusty-colored mudstone in distinct bands; large branched fucoids the only fossil	17
Thin-bedded, blue, granular, fossiliferous limestone with intercalated yellow shale weathering into small blocky fragments. Fossils numerous, *Heterorthis clytie* and *Dinorthis pectinella* characteristic	6
Black River group:	
Lowville limestone	
Tyrone member	
Thin-bedded dove limestone in layers 1 inch or less thick with white clay-shale partings. Although fossils are few the usual Tyrone species may be found	17
Dove-colored limestone in beds 6 inches to 2 feet thick, filled with a branching fucoid one-third of an inch in diameter arranged in horizontal layers in the rock but some of the stems penetrating from bed to bed. Weathers into dark platy to porous chert with many fossils	20
Massive dove and dove-colored brecciated limestone with an earthy dolomitic layer here and there weathering into chert. *Stromatocerium*, *Streptelasma profundum*, and gastropods not uncommon	10
Light-blue to dove limestone, massive when fresh but weathering into layers 1 to 3 inches thick, full of fragmentary fossils and resembling a microscopic breccia. *Columnaria halli*, *Tetradium cellulosum*, and gastropods not uncommon. Weathers into thin platy chert	15
Gray-blue fine-grained dolomite	5
Stones River group:	
Lebanon limestone	
Thin-bedded, fine-grained bluish and dove-colored limestone	45
Heavy-bedded, subcrystalline limestone	3
Thin-bedded layers as in upper part. (Base not seen.)	

Section on hill 1½ miles east of Milton, Cannon County, Tennessee

	Feet
Mississippian:	
Fort Payne chert overlying Chattanooga black shale as usual in this area.	
Ordovician:	
Catheys formation	
Irregular, thin-bedded, blue granular limestone weathering cobbly. Contains *Cyclonema varicosum, Hebertella sinuata, Platystrophia, Constellaria emaciata, C. teres, Orthorhynchula linneyi,* etc.	40
Cannon limestone	
Rather even-bedded impure limestone with mollusca	17
Argillaceous limestone with ostracoda *Leperditia frankfortensis* and other species	15
Massive, granular limestone containing gastropods (*Lophospira*) and cephalopods	10
Massive, gray argillaceous limestone containing large ostracods (*Isochilina ampla*) and a species of *Tetradium* with tubes arranged in small meshes (*T. laxum*)	20
Gray argillaceous limestone layers with *Isochilina ampla* and a species of *Tetradium* with single tubes	1
Argillaceous limestone full of *Stromatocerium pustulosum* and *Tetradium columnare*	25
Gray argillaceous limestone with mollusca and ostracoda (*Isochilina ampla*) abundant in lower part and *Tetradium fibratum* in upper	15
Massive, dark-blue, fine-grained limestone in 3 to 12 inch beds alternating with gray argillaceous limestone, much of the latter full of ostracoda. *Cyrtodonta* bed occurs fifty feet above base	70
Hermitage formation	
Granular, crinoidal, slightly phosphatic limestone	3
Sandy, argillaceous beds, limey layers near top with many bryozoa; *Dalmanella* few	25
Clay limestone with *Modioldon oviformis*	1

DeKALB COUNTY

Although the general section at Snow's Hill on the edge of the Highland Rim in DeKalb County was published by Safford in 1869, the details of the Ordovician part are given below to show the occurrence of the several formations distinguished since that time.

Section at Snow's Hill, 4 miles east of Liberty, Dekalb County, Tennessee

	Feet
Mississippian:	
Chattanooga shale	20+
Ordovician:	
Trenton group:	
Catheys formation	
Thin-bedded argillaceous and blue crystalline limestone with many fossils particularly *Hebertella sinuata, Orthorhynchula linneyi, Holopea nashvillensis, Byssonychia,* and *Rafinesquina alternata* in the upper half	42
Clayey and thin-bedded blue limestone with *Constellaria emaciata* and other bryozoa (partly covered)	25

Cannon limestone — Feet

Blue and gray limestone with *Hebertella*, *Isochilina ampla*, *Leperditia tumidula* and gastropods 30

Massive, gray to blue, granular limestone with many gastropods, *Lophospira sumnerensis* and other species 6

Massive dove limestone with scattered green specks 4

Nodular argillaceous limestone with poorly preserved bryozoa 10

Heavy-bedded blue limestone with brachiopods (*Zygospira recurvirostris* and *Hebertella*) in the upper part and large *Cyrtodonta* in the lower part 14

Thin-bedded blue limestone with crinoid columns, *Rhynchotrema* and *Hebertella* 4

Massive, blue, granular limestone containing *Hormotoma salteri* and *Cyrtodonta grandis* 6

Gray to blue limestone in 2 to 10 inch layers 16

Hermitage formation

Shales and thin-bedded argillaceous limestone (to base of hill) ...... 11+

SEQUATCHIE VALLEY—MARION AND SEQUATCHIE COUNTIES

East of the Central Basin the older formations are under cover of the higher rocks to the point where they reappear in the Sequatchie Valley, in the eastern third of the Cumberland Plateau. Erosion of the great upfold of strata has here cut deeply into the section, exposing older rocks than those farther west. The following section was compiled from notes furnished by E. O. Ulrich and Charles Butts.

General section in Sequatchie Valley, Tennessee

Mississippian: — Feet

Chattanooga black shale 20

Silurian:

Brassfield limestone

Massive, cherty green-specked limestone with *Lindstroemia gainesi*, *Orthis flabellites* and other fossils 50

Ordovician:

Cincinnatian:

Maysville group:

Sequatchie formation

Thin-bedded argillaceous limestone weathering into shale, with some thin red limestone and shale beds. Thick-bedded limestone with *Platystrophia ponderosa* and *Cyphotrypa* in the lower part 235

Mohawkian:

Catheys formation

Rather thin-bedded, coarsely crystalline, bluish-gray fossiliferous limestone. *Constellaria teres*, *Heterotrypa parvulipora*, *Eridotrypa briareus*, *Hebertella sinuata*, *Orthorhynchula linneyi*, *Platystrophia* sp., *Zygospira recurvirostris* and *Lophospira bowdeni* noted among the fossils 300

Cannon limestone — Feet

Thin-bedded bluish limestone weathering into chert, especially in the upper part. *Hebertella frankfortensis*, *Rhynchotrema increbescens*, *Cyrtodonta grandis*, and *Hormotoma* and other gastropods abundant.. 175

Hermitage and Curdsville formations (each present but not separated).

Thin-bedded blue limestone with *Cupulocrinus jewetti*, *Bucania halli*, *Modiolodon ganti*, *Lophospira obliqua*, *Bellerophon similis*.......10-40

Lowville limestone

Thick-bedded blue and dove limestone interbedded with thin argillaceous layers, cherty in the upper part, capped with a bed of green clay (bentonite) and having another bed of green clay near the top. Among the fossils are *Tetradium cellulosum*, *Phyllodictya frondosa*, *Streptelasma profundum*, *Orthis tricenaria*, *Stromatocerium rugosum*, and *Rafinesquina minnesotensis*........ 500

Stones River group:

Lebanon limestone

Thin-bedded blue and dove limestone separated by thin yellow clay layers and weathering into thin slabs. Fossils numerous; among them *Batostoma libana*, *Helopora spiniformis*, *Rhinidictya trentonensis*, *Orthis tricenaria*, *Scenidium halli*, *Dinorthis deflecta*, *Conradella grandis* and other gastropods, *Leperditia fabulites*, *Eurychilina subradiata* and other ostracods.................... 150

Ridley limestone

Massive, finely crystalline to granular, dark-gray limestone with *Protorhyncha ridleyana*, *Hebertella bellarugosa* and *Camarella varians*.. 90

Murfreesboro limestone.

Thick-bedded blue and dove fine-grained limestone with here and there a layer covered with *Salterella billingsi*, *Helicotoma tennesseensis*, *H. declivis*, and *Lophospira*....................... 500

Canadian:

Beekmantown (Pelham) limestone

Massive beds, dove-colored to gray alternating with coarsely granular blue limestone and with dolomite weathering into chert, with *Ceratopea keithi*, *Hormotoma artemesia*, *Ophileta compacta*, and *O. complanata*...1,000+

BLUE GRASS REGION OF KENTUCKY

North of the Central Basin the Ordovician rocks next appear at the surface in the Blue Grass region of Kentucky. The section in this area is reproduced below for comparison.

General section of Ordovician strata in central and northern Kentucky

Maysville group: — Feet

McMillan formation (Mount Auburn member with *Platystrophia ponderosa* bed at top, Corryville member, and Bellevue member at base). Thin more or less argillaceous irregularly bedded limestone weathering shelly or cobbly, alternating with light-blue shale weathering yellow...................... 100

Fairview limestone (Fairmount beds and Mount Hope beds below). Closely interbedded, highly fossiliferous, subcrystalline limestone and yellow to blue shale with the limestone bands 3 to 12 inches thick in the upper 80 feet (Fairmount beds) underlain by about 50 feet composed of thick beds of crystalline and argillaceous limestone separated by equally thick beds of blue to yellowish arenaceous shale (Mount Hope beds) with a thick bed of massive limestone at the base crowded with *Dalmanella* forming a basal conglomerate. The lower sandy beds change to sandstone in central Kentucky forming the Garrard sandstone.................................. Feet 130

Eden group:

McMicken member. Soft blue shale with thin crystalline limestone interbedded in the ratio of seven of the former to one of the latter. Fossils extremely abundant, mainly of the ramose bryozoa *Dekayella ulrichi*, *Coeloclema alternatum*, *Batostoma jamesi*, and *Hallopora sigillarioides*................. 60

Southgate member. Light blue to yellow shale with few fossils in upper fourth underlain by similar shale with thin limestone bands crowded with *Hallopora onealli*, *Bythopora arctipora*, *Batostoma implicatum*, *Dalmanella multisecta*, and *Ctenobolbina ciliata*. Lower division composed of shale with rather thick subcrystalline limestone bands crowded with ramose bryozoa. Below this is soft blue shale with few limestone layers in which bryozoa are few, but mollusca and trilobites are present 120

Economy member. Shales with thin limestone layers containing *Amplexopora petasiformis*, *Monotrypa subglobosa*, and *Hemiphragma whitfieldi* as characteristic fossils... 10

Shale with few limestone beds containing *Mastigograptus tenuiramosus*, *Protoscolex covingtonensis*, and other worms, *Trinucleus bellulus*, etc.......... 15

Shale and thin limestone crowded with bryozoa particularly *Crepipora venusta* and *Coeloclema commune*.. 25

Fulton member. Greenish-gray calcareous shale with *Triarthrus becki*, regarded as the overlapping southwestward extension of a phase of the Utica shale of New York...0-20

Trenton group:

Cynthiana limestone

Rogers Gap member. Bluish soft calcareous shale and bluish crystalline, subcrystalline, and crinoidal limestone interbedded with shale, with a massive conglomeratic crinoidal layer at the top. *Eridotrypa mutabilis*, *E. briareus*, *Cyclonema cincinnatiense*, *Aspidopora calycula*, *Ceratopsis intermedius*, *Constellaria emaciata*, *Eridorthis rogersensis*, and *Clitambonites rogersensis* among the fossils present.............................30-40

Gratz shale member. Yellowish to drab shale and calcareous shale with argillaceous fossiliferous limestone containing *Whiteavesia cincinnatiensis*, *Leptaena gibbosa invenusta*, *Trinucleus concentricus*, etc................ 30

Bromley member. Heavy-bedded blue limestone at top underlain by interbedded limestone and shale with calcareous drab or blue shale at the base. *Lingulops norwoodi*, *Whiteavesia cincinnatiensis*, *Whiteavesia pulcher*, *Cyrtolites retrorsus*, and *Trinucleus concentricus* among the fossils.. 40

Greendale member. Thin-bedded argillaceous limestone weathering rubbly with *Constellaria emaciata* and other fossils of the Catheys of Tennessee.. 50

Perryville (upper Birdseye) limestone:

Cornishville member. Grayish crystalline limestone with a *Stromatocerium* reef and a recurrence of the *Strophomena vicina* fauna of the Benson member of the Flanagan limestone................................7–10

Salvisa member. Massive dove limestone with large ostracoda (*Isochilina jonesi*) and *Orthorhynchula linneyi*................................. 10

Faulconer member. Massive limestone weathering into chert crowded with gastropods, particularly, *Bellerophon troosti* and *Lophospira sumnerensis*. Feet 5–8

Flanagan limestone

Woodburn member. Highly phosphatic, cross-bedded granular limestone with *Columnaria halli*, *Constellaria teres*, and *Cyclora minuta* and associated dwarfed mollusca.. 40

Brannon member. Siliceous limestone weathering into chert and yielding *Brachiospongia digitata* and *Strobilospongia aurita*.................... 15

Benson member. Thin-bedded grayish argillaceous limestone with *Stromatocerium pustulosum*, *Cyphotrypa frankfortensis*, *Strophomena vicina*, and *Dinorthis ulrichi*.. 70

Jessamine (Wilmore) formation

Thin-bedded grayish crystalline and argillaceous limestone with interbedded shaly layers in many places. *Prasopora simulatrix*, *Hallopora multitabulata*, *Dekayella trentonensis*, *Homotrypella granulifera* and other bryozoa abundant.. 80

Hermitage (Logana) formation

Fine-grained, noncrystalline, siliceous limestone and shale with *Heterorthis clytie* and other layers crowded with *Dalmanella fertilis*............... 30

Curdsville limestone

Massive crystalline grayish limestone weathering into porous chert and yielding many fossils among them *Dinorthis pectinella*, *Orthis tricenaria*, various crinoids and cystids, and *Streptelasma profundum*.............. 10

Black River group:

Decorah shale. Locally developed as a thin clay bed.

Lowville limestone

Tyrone member. Thin-bedded dove limestone and shale with *Tetradium cellulosum* and other characteristic fossils. A layer of bentonite at the top and another 25 to 30 feet below.............................. 90

Oregon (Carters) dolomite member. Fine-grained, unfossiliferous, massive dolomitic limestone with a pinkish tinge and bearing fucoid markings..15–25

Stones River group:

Camp Nelson limestone (=Lebanon and Ridley)

Fine-grained blue to pure dove limestone, massive in fresh outcrops but weathering into beds 1 to 6 inches thick; fossils rare, but branching fucoid markings are not uncommon. A zone with fossils of the Tennessee Pierce limestone (*Protorhyncha ridleyana*, *Mitoclema cinctosum*, etc.) occurs near the base and another 80 feet from the top contains Lebanon limestone fossils.. 285

STEWART COUNTY (WELLS CREEK UPLIFT)

Westward from the Central Basin most of the Ordovician formations disappear entirely, for in the Wells Creek uplift, in Stewart County, Silurian strata rest upon the Hermitage, which overlies the Lowville. Stones River strata are entirely absent, for the Lowville is underlain by the Wells chert of Canadian age. All the Stones River, Trenton, and Cincinnatian divisions except the Hermitage are thus seen to be absent. The Silurian, Devonian, and Mississippian portions of the Wells Creek section are essentially the same as in the next westward area of outcrop, the Tennessee River Valley of West Tennessee, where again the same Ordovician formations are absent. As erosion throughout this area could hardly have been so complete as to cause the absence of many formations, the region west of the Central Basin must have been above water throughout the major part of the Ordovician.

DESCRIPTION OF GEOLOGIC FORMATIONS

CANADIAN SYSTEM

The Canadian system as first defined by Dana in 1875 included the Calciferous and Chazy limestones of New York and the Quebec group of Canada. This division formed the middle third of his Lower Silurian, the Primordial now the Cambrian being the lowest and the Trenton being the highest third. Subsequent work has shown that the Chazy lies unconformably upon the Calciferous, forming a part of the Lower Ordovician, and that the Calciferous itself contains a great time break, the lower part belonging to the Ozarkian system of Ulrich. As thus restricted the Canadian system lost a considerable part of its thickness, but the time represented by the remainder is fully equal to that in other systems. Ulrich in his Revision of the Paleozoic Systems and Schuchert in the Paleogeography of North America have discussed the limits of the Canadian system and have stated the general facts concerning it.

The type sections and faunas upon which the Canadian system was originally founded are in the Champlain and St. Lawrence Valleys and northwestern Newfoundland. Distinct faunal assemblages are found in the rocks of each of these areas, and the lithology of each area differs considerably from that of the others. In the Champlain Valley only the calcareous facies known as the Beekmantown limestone is exhibited, whereas in the St. Lawrence Valley shale strata called the Levis shale, in which graptolites are the prevailing life forms, are alone developed. These graptolites occur in distinct zones, each having its characteristic species with an appropriate name for the bed in which the species occurs. On account of the world-wide distribution of the graptolites these zones are useful in intercontinental correlation. In the Hudson River Valley graptolite shales of the same age occur and form the middle part of the Hudson River slate, now separated as the Deep Kill shale.

The Newfoundland facies of the Canadian, originally called the Quebec group, consists chiefly of limestone with faunas unusual in North America. However, enough Beekmantown species are present in them to make the correlation of the rocks with the Canadian of the Champlain Valley quite certain.

The Beekmantown limestone continues southwestward throughout the Appalachian Valley, and its equivalents are found farther west in various parts of the Mississippi Valley and the Rocky Mountain region.

Erosion has not penetrated as deep as the Canadian strata in the Central Basin, but in the Sequatchie Valley anticline east of the Basin in the Cumberland Plateau, underlying the Murfreesboro limestone, is a thick formation of alternating beds of limestone and dolomite which from its contained fossils is assigned to this system. Among the fossils are the gastropod shells *Ophileta complanata*, *O. compacta*, *Hormotoma artemesia*, and *Ceratopea keithi*, all indicative of the well-known Beekmantown limestone of New York and various Appalachian Valley States. In the Wells Creek Basin, west of the Central Basin, another limestone of Canadian age, the Wells limestone, crops out. It is probable, therefore, that similar massive limestones and dolomites underlie the Murfreesboro limestone, the oldest formation cropping out in the Central Basin itself. As deep drilling will strike this formation this short description is included here.

According to the researches of E. O. Ulrich and Charles Butts, the limestone and dolomite of Canadian age in the Sequatchie Valley have a total thickness of a thousand or more feet. These strata consist of massive, brittle limestone, much of it dove colored like much of the Stones River group in central Tennessee. The dolomite is likewise thick bedded but is gray and of coarsely granular structure. These rocks when exposed at the surface weather into soil containing an abundance of gray, dense brittle chert.

WELLS LIMESTONE

The Wells Creek basin, described by Safford in 1869[3], is a low domelike uplift in the midst of the western Highland Rim about 35 miles northwest of the west edge of the Central Basin. Sufficient study has not been placed upon its structure to determine whether this area is similar to the Central Basin in origin or whether it belongs to the cryptovolcanic structures described by Bucher[4]. However, the area is particularly instructive stratigraphically in that it gives information as to the westward extension of formations of the Central Basin and exposes still older rocks—a Canadian formation called the Wells limestone.

A small domelike hill stands at the center of the basin formed as a result of the cropping out and weathering of the siliceous magnesian Wells limestone into chert. A deep residual clay soil and porous sandy chert covers the limestone, but some of the chert layers are highly fossiliferous and indicate the geologic age of the rocks without doubt.

[3] Safford, J. M., Geology of Tennessee, p. 147, 1869.

[4] Bucher, Walter H., Geol. Soc. America Bull., vol. 32, No. 1, pp. 74-76 (abstract).

The fossils collected here by the writer twenty years ago have not yet been described, but they are mainly mollusca belonging to the genera *Hormotoma*, *Coelocaulus*, *Holopea*, *Ophileta*, *Maclurea*, and *Helicotoma* among the gastropods, and *Orthoceras*, *Protocycloceras*, *Cameroceras*, and *Cyrtoceras* among the cephalopods.

ORDOVICIAN SYSTEM

The stratigraphic series in Central Tennessee begins in the lower part of the Ordovician system with the Murfreesboro limestone. Succeeding this formation are so many of those of the general time scale that there is perhaps no area in the world where Ordovician strata and their contained fossils can be studied to better advantage. The Stones River and Trenton groups are particularly well represented, so that Central Tennessee has been classic ground for the study of these divisions. Nevertheless there are great gaps in the series, as shown by the stratigraphic sequence elsewhere. Thus the uppermost or Cincinnatian group of the Ordovician is represented by a single formation, and the Upper Chazyan, thousands of feet thick in the Valley of East Tennessee, is here entirely absent.

The relation of the Ordovician to the other systems of geologic time is shown on page 4. The smaller divisions of the system and the several formations present in both the eastern and western parts of the Central Basin and their thickness are tabulated below.

Ordovician formations of the General Time Scale and of the Central Basin

GENERAL TIME SCALE	CENTRAL BASIN
Maysville group	
McMillan formation	(Absent)
Fairview formation	Leipers formation
Eden group	
Frankfort shale	(Absent)
Utica shale	(Absent)
Trenton group	
Cynthiana formation	Catheys formation (0–100 feet)
Perryville limestone	Cannon limestone (0–300 feet)
Flanagan limestone	
Bigby limestone	Bigby limestone (100 feet)
Jessamine limestone	(Absent)
Hermitage formation	Hermitage formation (100 feet)
Curdsville limestone	(Absent)
Black River group	
Kimmswick limestone	(Absent)
Decorah shale	(Absent)
Watertown limestone	(Absent)
Lowville limestone	Lowville limestone
Tyrone member	Tyrone limestone (0–100 feet)
Carters member	Carters limestone (50 feet)

GENERAL TIME SCALE	CENTRAL BASIN
Blount group	
Ottosee shale	(Absent)
Tellico formation	(Absent)
Athens shale	(Absent)
Holston marble	(Absent)
Stones River group	
Lebanon limestone	Lebanon limestone (100 feet)
Ridley limestone	Ridley limestone (80 feet)
Pierce formation	Pierce formation (27 feet)
Mosheim limestone	(Absent)
Murfreesboro limestone	Murfreesboro limestone (70+ ft.)
St. Peter sandstone	(Not exposed or absent)

BUFFALO RIVER SERIES

The name Buffalo River Series was proposed by Ulrich to include four pre-Chazyan formations of the Mississippi Valley, of which the St. Peter sandstone is the best known. The three other formations are especially well developed in Arkansas. A description of this series and its component parts is included in a work on the stratigraphy of the Early Paleozoic of Oklahoma now in preparation by Dr. Ulrich.

ST. PETER SANDSTONE

Wells drilled to a depth of 700 feet at Cincinnati, Ohio, reach a water-bearing sandstone composed of rounded quartz grains cemented together by calcareous material. This rock is so similar in nature and stratigraphic position to the St. Peter sandstone of the upper Mississippi Valley that correlation of the two formations seems well founded. A similar sandstone has been found in many wells in central Kentucky, and it is possible that deep drilling in the Central Basin may pass through such a formation before entering the underlying Canadian dolomite.

CHAZYAN SERIES

Although named from outcrops in the Lake Champlain region of New York, the Chazyan series of early Ordovician strata is perhaps nowhere better developed than in eastern and central Tennessee. In the latter area, where the several divisions of the Stones River group of the Chazyan are typically developed, this group is overlain immediately by strata of the Black River group. In the Valley of East Tennessee, however, the interval between the Stones River and Black River groups is occupied by several thousand feet of shale, limestone, and marble, forming the upper Chazyan or Blount group. There is, therefore, a great gap in this part of geologic history in Central Tennessee, which was probably a land area during this long period of time. The line of unconformity between the two series is scarcely evident, for in many places, as at Columbia, the uneven line of contact separating the two divisions of time occurs in the middle of one layer of limestone and can only be seen by close examination. (Plate 32, fig. B.) Differences in the faunas and lithologic characters of the two groups readily distinguish them, but the occurrence of the thick Blount group between them is demonstrable only in the Appalachian Valley.

STONES RIVER GROUP

Although the type locality of this group is in Rutherford County, where the most complete sections are exposed in bluffs along Stones River, its formations in general crop out on the crest and slopes of the Nashville dome in many counties of the Central Basin. The map of Rutherford County published by the State Geological Survey in 1919 shows practically all the known outcrops of the lower Stones River formations, the higher formations being exposed in adjoining areas.

This name for the division was proposed by Professor Safford in 1851 (American Journal of Science and Arts, series 2, vol. 12, p. 352), but in 1869, under the misapprehension that the group was the equivalent of the well-known Trenton group of New York, it was abandoned. The true position of the Stones River group was recognized by Winchell and Ulrich in 1897 (Geology of Minnesota, vol. 3, pt. 2, p. xc), and since then it has been accepted as one of the larger divisions of the stratigraphic column. The Carters limestone, originally a part of the Stones River group, was transferred to the Black River by Bassler in 1915, when study in collaboration with E. O. Ulrich showed that it formed the lower part of the widespread Lowville limestone.

In the Valley of East Tennessee the oldest formation of Stones River age is the Mosheim limestone, which, although not found in the same section with the other divisions of the group, was believed either to form a part of the Murfreesboro limestone or to underlie it as a distinct formation. Recent stratigraphic studies in Lee County, Virginia, by E. O. Ulrich and Charles Butts have demonstrated that the Mosheim limestone lies between the Murfreesboro and the Lenoir, thus giving evidence as to the relationships of the Stones River formations of the Appalachian Valley and those of the Central Basin. The Mosheim limestone is not developed in either the Sequatchie Valley or the Central Basin.

The several Stones River formations of Central Tennessee were deposited in an arm of the sea that came in from the ancient Gulf of Mexico and spread north and northeast, covering first an area that reached Central Tennessee and later extending to New York and Canada.

The Stones River rocks of Oklahoma and adjacent areas are so distinct in their lithologic character and contained fossils that it is evident they originated in another arm of the sea, probably an embayment from the Pacific Ocean. The typical Chazyan rocks of the Champlain Valley, likewise, had their origin in a different sea, an arm of the Atlantic Ocean.

MURFREESBORO LIMESTONE

The lowest Stones River division and the oldest formation exposed in the Central Basin is a massive limestone cropping out in the very center of the State. It was, therefore, designated the Central limestone by Safford in his Geology of Tennessee, but later, when the rule to name formations after definite localities became established, Safford and Killebrew renamed the formation Murfreesboro limestone from the typical area of outcrop around Murfreesboro. Outcrops of the Murfreesboro limestone along Stones River (Plate 30, fig. B) in the typical area show the following section, published by Galloway in 1919.

Section of Murfreesboro limestone, Murfreesboro, Tennessee

	Feet
Light-blue or dove-colored, dense, massive nonfossiliferous limestone in layers 2 to 4 inches thick, separated by thin, yellowish sandy-looking partings. Chert and fucoids common	20
Grayish-blue, finely laminated, dense, fine-grained limestone, jointed every inch or two; weathers faster than rocks above and below making a terrace	0.5 to 1.5
Massive, dense, drab nonfossiliferous limestone; joints 6 to 8 feet apart; chert and fucoids common	20

The general section of the Murfreesboro limestone in the vicinity of Murfreesboro shows the upper twenty feet of strata described above underlain by 5 or 6 feet of thin-bedded limestone in layers 1 to 3 inches thick with *Salterella billingsi* and other fossils covering their surface and these strata by 30 or 40 feet of massive drab unfossiliferous limestone. A maximum of 70 feet is shown in Rutherford County, but the entire thickness can not be determined for the base is not exposed.

In his maps accompanying the Geology and Natural Resources of Rutherford County, Tennessee (Bull. 22, Tenn. Geol. Survey, 1919), Galloway has plotted the outcrop of the Murfreesboro limestone, showing its occurrence in a number of small areas in this county, amounting to about 15 square miles, instead of a single broad area as believed before. This limestone does not crop out elsewhere in the Central Basin, and its exposure here is due to the overlying strata being eroded away on local small domes.

Although its outcrop is so small in Central Tennessee, the Murfreesboro limestone has a wide extent, for east of this area it is again encountered in the Sequatchie Valley uplift, where a thickness of 500 feet is shown. Farther east it crops out in the western part of the Appalachian Valley, although still farther east in the Valley the formation has disappeared. West of the Central Basin no surface outcrops of the Murfreesboro or any other Stones River formation are known in Tennessee, so probably they thin out to extinction before the Mississippi River is reached.

When freshly quarried this formation is a dense, fine-grained, dark-blue to bluish-gray, brittle, massive limestone in layers several inches to 4 feet thick without chert or any recognizable fossils visible. When broken the rock emits an oily odor. After long weathering the limestone dissolves away, leaving the impurities of the rock as a reddish-brown clay soil, highly adapted to the growth of cotton. This soil varies in depth from place to place with an average of about 4 feet. When little developed, the soil has rounded knobs of unweathered limestone protruding at the surface. Mixed with the soil are layers of white to red chert in nodules and plates, which is of especial interest to the paleontologist, because embedded in it or loose in the soil are found almost the only fossils that have been discovered in the formation. These fossils are, of course, present in the unweathered limestone, but the great density of the rock and their similarity in color obscures them so that they are practically invisible. In the process of weathering silica replaces the lime of the fossils, and when the lime is completely removed they are left free in the soil or attached to the plates of chert. Certain layers are more abundantly fossiliferous than others, and the plates of chert that result from their weathering show a multitude of shells, which give an erroneous impression as to their abundance in the formation. These fossils, particularly the shells, are so well preserved that they have long interested the paleontologist with the result that a considerable number of species has been described. Illustrations of characteristic species whereby the formation can be identified are shown on Plate 4, and a list of the described species is given below. The occurrence of the elongate shell *Salterella billingsi* on the chert blocks is alone sufficient to identify the formation.

Fossils of the Murfreesboro limestone

Sponges: *Zittelella varians* (Billings).

Brachiopods: *Dinorthis deflecta* (Conrad), *Orthis tricenaria* Conrad, *Pianodema subaequata* (Conrad), *Strophomena filitexta* Hall.

Gastropods: *Bucania emmonsi* Ulrich and Scofield, *Cyclonema praeciptum* Ulrich, *Cyrtospira tortilis* Ulrich, *Eccyliomphalus contiguus* Ulrich, *Ectomaria prisca extenuata* Ulrich, *Ectomaria canalifera* Ulrich, *E. labiosa* Ulrich, *Helicotoma declivis* Ulrich, *H. subquadrata* Ulrich, *H. tennesseensis* Ulrich and Scofield, *Liospira abrupta* Ulrich and Scofield, *L. americana* (Billings), *L. decipiens* Ulrich, *L. progne* (Billings), *L. subconcava* Ulrich, *Lophospira bicincta* (Hall), *L. centralis* Ulrich, *L. perangulata* (Hall), *L. procera* Ulrich, *L. (?) trochonemoides* Ulrich, *Maclurites magnus* Lesueur, *M. nitidus* Ulrich and Scofield, *Ophiletina sublaxa depressa* U. and S., *Raphistomina modesta* Ulrich, *Salterella billingsi* Safford, *Tetranota bidorsata* (Hall), *Trochonema bellulum* Ulrich.

Pelecypods: *Ctenodonta gibberula* Salter, *Modiolopsis (?) consimilis* Ulrich, *Whiteavesia saffordi* (Ulrich).

Cephalopods: *Cyrtoceras (?) stonense* Safford, *Gonioceras occidentale* Hall, *Plectoceras bondi* (Safford).

Ostracoda: *Leperditia fabulites* (Conrad).

Trilobites: *Pterygometopus troosti* (Safford).

PIERCE LIMESTONE

The dense massive limestone strata of the lower part of the Stones River group are so similar lithologically that they would be considered as a unit were it not for an intervening formation of platy, thin-bedded, fossiliferous limestone with some massive, coarse, granular layers, in all about 25 feet in thickness. This intermediate formation, separating the Murfreesboro limestone below from the Ridley limestone above, was termed the Pierce limestone from its outcrops along Stones River at Pierce's Mill 7½ miles north of Murfreesboro. (Plate 30, fig. A.) A section made at this point by E. O. Ulrich and the writer in 1899 is as follows:

Section of Pierce limestone at type locality 7½ miles north of Murfreesboro, Tennessee

	Feet
Ridley limestone	
Dense, blue-gray limestone in thick beds, weathering to red-brown clay soil	10+
Pierce limestone	
Thin-bedded, platy, argillaceous, blue-gray limestone separated by thin shaly partings and with occasional thin layers of coarsely crystalline, gray, fossiliferous limestone; many of their surfaces crowded with small ramose and bifoliate bryozoa	19
Single layer of dense, fine-grained, bluish-gray limestone almost unfossiliferous and greatly resembling the underlying Murfreesboro limestone	3 to 4
Unfossiliferous, dense, gray-blue limestone in thin layers	2
Massive, unfossiliferous drab limestone weathering slightly cherty	3
Murfreesboro limestone	
Dark-colored, dense massive limestone weathering into chert and showing *Stromatocerium* and usual fossils	8

Years ago an excellent section of the Pierce exposed along Lytle Creek in Murfreesboro, back of the jail, yielded many fossils. This section, as determined by E. O. Ulrich and the writer in 1901, also given by Galloway in 1919, is interesting in showing thin-bedded limestones crowded with bryozoa at both the top and bottom.

Section of Pierce limestone, in Murfreesboro, Tennessee

	Feet
Ridley limestone	
Massive, dense blue-gray limestone	6
Pierce limestone	
Argillaceous, gray knotty limestone in thin layers with thin blue granular beds crowded with bryozoa	6
Massive light-blue limestone weathering into thin beds. Fossils rare except brachiopods, which are abundant	10
Coarse, granular, massive blue limestone with many brachiopod fragments	2
Dove-colored, thin-bedded platy limestone with shale partings. Lower part abounding in bryozoa	10
Murfreesboro limestone	
Massive limestone in bottom of creek.	

On account of its slight thickness and its stratigraphic relations, the Pierce limestone has little areal outcrop, being seen only in irregular areas around the small domes that bring the Murfreesboro limestone to the surface. The soil that results from the weathering of the formation is not unlike that of the adjoining formations except that much of it contains thin slabs of limestone and very little contains chert.

The Pierce limestone is locally rich in fossils, and many of the thin limestone slabs are fairly matted with branching and ribbon-like bryozoa. These with other bryozoa from the Stones River of Tennessee have been made the subject of a special study by Coryell[5].

The list of Pierce limestone fossils is as follows:

Fossils of the Pierce limestone

Corals: *Columnaria alveolata* Goldfuss, *Tetradium syringoporoides* Ulrich.

Crinoids: *Palaeocrinus sulcatus* Safford.

Brachiopods: *Dinorthis deflecta* (Conrad), *Hebertella bellarugosa* (Conrad), *Orthis tricenaria* Conrad, *Pianodema stonensis* (Safford), *P. subaequata* (Conrad), *Protorhyncha ridleyana* (Safford), *Rafinesquina incrassata* (Hall), *Strophomena filitexta* Hall, *Zygospira saffordi* Winchell and Schuchert.

Bryozoa: *Anolotichia explanata* Coryell, *Batostoma confertum* Coryell, *B. dendroideum* Coryell, *B. inutile* Coryell, *B. ramosum* Coryell, *B. subcrassum* Coryell, *Ceramoporella grandis* Coryell, *C. ingenua* Coryell, *Chasmatopora sublaxa* (Ulrich), *Coeloclema consimile* Coryell, *C. inflatum* Coryell, *C. pierceanum* Coyrell, *Constellaria lamellosa* Coryell, *Corynotrypa delicatula* (James), *C. tennesseensis* Bassler, *Diplotrypa catenulata*, Coryell, *Escharopora angularis* Ulrich, *E. confluens* Ulrich, *Graptodictya dendroidea* Coryell, *G. fruticosa* Coryell, *Hallopora florencia* Coryell, *H. spissata* Coryell, *Helopora spiniformis* (Ulrich), *Hemiphragma irrasum* (Ulrich), *Heterotrypa patera* Coryell, *H. stonensis* Coryell, *Mesotrypa crustulata* Coryell, *M. dubia* Coryell, *Monticulipora compacta* Ulrich and Bassler, *M. discula* Ulrich and Bassler, *M. intersita* Ulrich and Bassler, *Nicholsonella frondifera* Coryell, *N. pulchra* Ulrich, *Orbignyella multitabulata* Coryell, *O. sublamellosa* Ulrich and Bassler, *Pachydictya* species, *P. senilis* Coryell, *Rhinidictya nashvillensis* (Miller), *R. tabulata* Coryell, *Stictoporella cribrilina* Coryell, *Stromatotrypa incrustans* Coryell, *S. lamellata* Coryell, *S. regularis* Coryell.

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[5] Coryell, H. N., Bryozoan faunas of the Stones River group of Central Tennessee: Indiana Acad. Sci. Proc. for 1919, pp. 261-340.

Gastropods: *Eccyliomphalus contiguus* Ulrich, *Liospira americana* (Billings), *L progne* (Billings), *Lophospira bicincta* (Hall), *Maclurites magnus* Lesueur, *Tetranota bidorsata* (Hall).
Ostracoda: *Eurychilina subradiata* Ulrich, *Leperditia fabulites* (Conrad).
Trilobites: *Pterygometopus troosti* (Safford).

RIDLEY LIMESTONE

More than half of Rutherford County consists of a level central plain, whose fertile brick-red soil yields a rich cotton crop. The surface rock of the plain is the massive, dense, dove-colored limestone of the Ridley formation, so named by Safford from its occurrence at Judge Ridley's Mill, now called Davis Mill, near Old Jefferson. Thirty feet of the formation is visible at this locality, and the entire thickness is passed over in going half a mile south. The Ridley continues as the surface rock in parts of Davidson, Wilson, Cannon and Bedford Counties but passes beneath the surface before reaching Williamson County, where the oldest rock is the succeeding Lebanon limestone. The 95 to 120 feet of limestone forming the Ridley is so similar to the Murfreesboro limestone in all its physical characters, even to weathering into platy chert layers, that were it not for the difference in fossil contents and for the presence of the intervening thin-bedded strata of the Pierce formation they could not be separated.

The full section of the Ridley may be seen on the east side of Marshall Knob, 5 miles south of Murfreesboro.

Section of Ridley limestone, Marshall Knob, Rutherford County, Tennessee
(After Galloway, 1919)

	Feet
Ridley limestone	
Massive, drab, dense limestone weathering gray and granular; some chert; fossils generally rare, some layers contain *Rafinesquina*, *Hebertella bellarugosa*, ostracods, small cephalopods, and gastropods	80
Thin-bedded, dove-colored limestone with shaly partings	10
Drab limestone like the upper beds	20
Pierce limestone	
Massive and platy fossiliferous limestone.	

Plate 31, fig. A, depicts an outcrop of the Ridley limestone near Murfreesboro and shows particularly the deep soil that results from its weathering.

The fossils of the Ridley are more abundant but not so well preserved as those of the Murfreesboro, and like the latter are nowhere a conspicuous feature of the limestone. In places a massive granular limestone occurs from which fossils of the following species can be hammered out, or the soil may yield silicified specimens, free or attached to chert fragments.

Fossils of the Ridley limestone

Sponges: *Zittelella varians* (Billings).
Hydrozoa: *Stromatocerium* cfr. *rugosum* Hall.
Corals: *Columnaria alveolata* Goldfuss, *Tetradium syringoporoides* Ulrich.
Brachiopods: *Camerella varians* Billings, *Dinorthis deflecta* (Conrad), *Hebertella bellarugosa* (Conrad), *Orthis tricenaria* Conrad, *Pianodema subaequata* (Conrad), *Protorhyncha ridleyana* (Safford), *Rafinesquina incrassata* (Hall), *Strophomena filitexta* Hall, *Zygospira saffordi* Winchell and Schuchert.
Bryozoa: *Anolotichia explanata* Coryell, *Chasmatopora sublaxa* (Ulrich), *Dekayella ridleyana* Coryell, *Escharopora subrecta* (Ulrich), *Helopora spiniformis* Ulrich, *Nicholsonella frondifera* Coryell, *Rhinidictya salemensis* Coryell.
Gastropods: *Eccyliomphalus contiguus* Ulrich, *Liospira americana* (Billings), *L. convexa* Ulrich and Scofield, *L. progne* (Billings), *Lophospira bicincta* (Hall), *Maclurites magnus* Lesueur, *Tetranota bidorsata* (Hall).
Cephalopods: *Gonioceras anceps* Hall.
Trilobites: *Pterygometopus troosti* (Safford).
Ostracoda: *Ctenobolbina subcrassa* Ulrich, *Drepanella ampla* Ulrich, *Eurychilina aequalis* Ulrich, *Leperditia fabulites* (Conrad).

LEBANON LIMESTONE

This formation is the predominating rock of the Central Basin cedar glades, and it was therefore originally named the Glade limestone by Safford in 1869. The change to Lebanon limestone, from Lebanon in Wilson County, where there are many outcrops, was made in 1900 by Safford and Killebrew in their Elements of the Geology of Tennessee, when it became desirable to apply a geographic name. Prior to this the entire Stones River group, including the Carters limestone, had been designated the Lebanon series. No type section of the Lebanon limestone was given by Safford, and at Lebanon, only a portion of the formation is exposed, the lower part being buried. In his original description Safford gives the section near Readyville on the boundary line between Cannon and Rutherford Counties, where the Ridley limestone crops out in the bluff on the east fork of Stones River, and the Lowville limestone occupies the upper 50 feet of the hills. This section gives a thickness of 118 feet for the Lebanon formation, which is described by Safford as thin-bedded, flaggy limestone containing a heavy-bedded layer about 3 feet thick near the middle and another near the base. These two heavy layers may be followed for miles and afford a clue to the structure of the region. For example, on the north slope of the hill, 2½ miles southeast of Hall's Hill, Rutherford County, the heavy middle layer forms the slope of the hill from the altitude of 670 to that of 710 feet, affording a fine example of dip slope. The details of the formation are well shown in Galloway's section at Kittrell, Rutherford County, reproduced below with a correction of the Carters to the Tyrone member of the Lowville.

Section half a mile south of Kittrell, Tennessee, from Cripple Creek to top of hill

	Feet
Hermitage formation	
10. Blue, laminated, calcareous sandstone, weathering yellow	15
Lowville limestone (Tyrone member)	
9. Massive, gray or dove limestone, *Tetradium cellulosum* abundant	80
Lebanon limestone	
8. Granular, gray and dense, dove, unfossiliferous beds 1 to 3 inches thick, separated by thin films of shale	40
7. Gray, compact, laminated, unfossiliferous limestone in beds 6 inches thick	10
6. Gray, finely granular, massive limestone, containing lenses up to 4 inches thick of ramose bryozoa	2
5. Granular gray and compact blue, unfossiliferous limestone in beds 1 to 6 inches thick	16
4. Knotty drab limestone in beds half an inch thick, separated by thin layers of shale; some fossils	6
3. Gray, granular slabs of limestone and shale, averaging 2 inches thick; few fossils	14
2. Irregularly bedded, gray, coarse limestone and shale, rill and ripple marks, and wave-marks 4 feet long and 6 inches deep; few fossils	7
Total Lebanon	95
Ridley limestone	
1. Massive beds 4 feet thick of compact drab limestone weathering mottled and full of holes (fucoids)	12

The rapid erosion of the limestone results in flat areas as a rule, although it occurs in some hilly districts where the resistant overlying Lowville limestone protects it from weathering. The weathering of the rock into thin flaggy slabs, ideal material for building fences, has added the additional characteristic of stone fences to the glade area.

The Lebanon limestone has an average thickness of about 100 feet and consists almost entirely of thin-bedded dove limestone in layers 1 to 6 inches thick, separated by seams of blue or yellow clay shale a fraction of an inch thick. The prevailing color is more usually blue than dove-colored, and many of the layers are finely granular. Some of the layers are unfossiliferous but others, particularly certain beds that are granular and crystalline, are crowded with fossils such as small brachiopods, bryozoa, and the large bean-shaped ostracods (*Leperditia fabulites*). In the lower part of the formation a single massive layer of dense unfossiliferous limestone from 2 to 11 feet thick occurs as a conspicuous stratum in the otherwise thin-bedded platy layers.

Ripple and wave marks are not uncommon on the surfaces of these thin-bedded strata, so that this limestone is undoubtedly a shallow-water deposit. As the formation has not been studied in detail over any considerable portion of the Central Basin, it is not yet known whether it was deposited uniformly over this entire area or exhibited some of the characteristics of the later formations by its deposition in ancient bays. The fact that it occurs almost unchanged as far north as High Bridge, Kentucky, eastward to the Appalachian Valley and westward to a north-south line somewhere between the Central Basin and the Tennessee River valley of west Tennessee, makes it probable that this shallow-water formation was of rather wide distribution.

Fossils occur in abundance on the surface of many of the thin-bedded layers throughout this formation, but as most of them are small and inconspicuous, careful search is necessary to find them. Other layers are barren of organic remains. In some localities the thin shaly partings between the layers are fossiliferous and upon weathering leave the freed specimens strewn on the surface. Many of the layers are filled with the clayey casts of intertwined fossil sea weeds, which rapidly weather away upon exposure leaving the matrix full of holes and appearing to be worm-eaten. Upon further weathering such limestones break down into small slivers of rock, with which the fossils are mixed. .(Plate 31, fig. B.) Chert is seldom produced in the weathering of the Lebanon limestone, although occasionally the fossils become silicified in the process. The fossils of the Lebanon, some of which are illustrated on Plates 5 and 6 are as follows:

Fossils of the Lebanon limestone

Algae, etc.: *Solenopora compacta* (Billings), *Licrophycus libana*, n. sp.

Sponges: *Camarocladia implicatum*, n. sp.

Corals: *Columnaria alveolata* Goldfuss, *Fletcheria incerta* (Billings), *Streptelasma (?) parasiticum* Ulrich, *Tetradium syringoporoides* Ulrich.

Crinoids: *Cleiocrinus tessellatus* (Troost).

Starfish: *Hudsonaster narrawayi* (Hudson).

Bryozoa: *Arthroclema striatum* Ulrich, *Batostoma libana* (Safford). *Chasmatopora sublaxa* Ulrich, *Corynotrypa delicatula* (James), *Escharopora briareus* Ulrich, *E. libana* (Safford), *E. ramosa* Ulrich, *Hemidictya lebanonensis* Coryell, *Helopora spiniformis* Ulrich, *Orbignyella nodosa* Coryell, *Rhinidictya basalis* Coryell, *R. lebanonensis* Coryell, *R. trentonensis* (Ulrich), *Trigonodictya irregularis* Coryell.

Brachiopods: *Camarotoechia orientalis* (Billings), *Dinorthis* (*Valcouria*) *deflecta* (Conrad), *Hebertella borealis* (Billings), *H. bellarugosa* (Conrad), *Orthis tricenaria* Conrad, *Pianodema subaequata* (Conrad), *Sowerbyella* (*Plectambonites*) *lebanonensis* Bassler, *Rafinesquina incrassata* (Hall), *Scenidium halli* Safford, *Strophomena filitexta* Hall, *Zygospira saffordi* Winchell and Schuchert.

Gastropods: *Eccyliomphalus undulatus* Hall, *Liospira americana* (Billings), *L. progne* (Billings), *Lophospira bicincta* (Hall), *L. peracuta* Ulrich and Scofield, *Maclurites magnus* Lesueur, *Phragmolites grandis* (Ulrich), *Pterotheca saffordi* (Hall), *Subulites nanus* Ulrich, *Tetranota bidorsata* (Hall), *T. sexcarinata* Ulrich and Scofield, *Trochonema eccentricum* Ulrich, *T. umbilicatum latum* Ulrich.

Trilobites: *Ceraurinus scofieldi* (Clarke), *Pterygometopus troosti* (Safford).

Ostracoda: *Drepanella elongata* Ulrich, *D. macra* Ulrich, *Eurychilina subradiata* Ulrich, *Leperditia fabulites* Conrad.

Most of the well-known glades of Central Tennessee lie on Lebanon limestone areas, so that mention of them at this point is appropriate. They are usually flat areas of rock, on which the soil is either entirely absent or is present only in the joint planes where the trees and grass take root. The red cedar is the most important tree of these glades and enables them to support an important lumbering industry. The extent of the cedar glades is so great that in Rutherford County alone they occupy about 160 square miles.

Galloway in his Geology and Natural Resources of Rutherford County, Tennessee (Tennessee Geol. Survey Bull. 22, 1919), has discussed the glades and their origin in some detail. He explains that the thin-bedded Lebanon limestone weathers mainly at the surface, and the clay formed is carried away by each rain, leaving the rock bare. After the glade has become practically level the rainwater runs off so slowly that a thin soil can be accumulated.

BLOUNT GROUP

In Central Tennessee the Lebanon limestone, being there the topmost formation of the Early Chazyan Stones River group, is immediately overlain by the well-known and widely distributed Lowville limestone, which forms the basal division of the Black River group. The Stones River and Lowville limestones are so similar lithologically that in Central Tennessee they appear to be in conformable relationship, in fact, as indicated in the view on Plate 32, figs. A and B, the two formations are in contact in the same stratum of limestone. In the Appalachian Valley of East Tennessee, however, the Stones River is succeeded by a maximum of 9,000 feet of shale, limestone, and marble of late Chazyan age, designated the Blount group by Ulrich, and this is followed by the Lowville limestone. The wide distribution of the Lowville and its overlapping features has, therefore, made this formation of great value in fixing the age of underlying beds. Furthermore, the development of the thick Blount group in the Appalachian Valley of Tennessee presents an excellent example of an addition to the geologic column. Finally, the thickness of the Blount formation in Tennessee is several times as great as that of the equivalent beds farther north in the Champlain valley, where the Upper Chazyan was first described, so that the Appalachian Valley deposits give the more complete record of this group. A generalized section of the Blount group in the type area is presented below.

Generalized section of the Upper Chazyan Blount group in Blount, Knox, and contiguous counties in East Tennessee

	Feet
Lowville limestone	
Dove-colored limestone with argillaceous beds.	
Blount group:	
Ottosee shale	
Mainly gray and yellow shale with rarely a yellow calcareous shaly band filled with small ramose bryozoa. Thin-bedded shaly limestone at several horizons and near the base shale bands containing dendroid graptolites	2,600

Tellico formation	Feet
Calcareous sandstones, blue when fresh but deep red when weathered, and grayish sandy shale in the upper 300 feet with pink, gray, and red marble forming the lower 700 feet	1,500
Athens shale	
Bluish-black to black even-bedded, hard, compact, impure limestone in 1 to 6 inch bands in the upper third and gray to black fissile shale with a few interbedded limestone bands, the shale in many places filled with graptolites in the lower two-thirds	4,000
Whitesburg limestone	
Gray crystalline limestone in 2 to 6 inch layers and some shale, the limestone containing *Agnostus* and other trilobites	600
Holston marble	
Light to dark red massive marble beds with occasional intervening shaly beds. Fossils abundant especially in the shales	350
Stones River group:	
Lenoir limestone	
Argillaceous nodular limestone with dense and dark bluish-gray medium-grained limestone much of it speckled with crinoidal fragments; some of the beds of the cobbly type	100
Mosheim limestone	
Fine-grained dove limestone with crystalline stringers through it and often a conglomerate resting on an undulating unconformity at its base. Fossils few, mainly gastropods of the genus *Lophospira*, which weather out on the surface. Weathering of limestone under cover gives a characteristic gray chalky crust	50
Canadian system:	
Fine-grained dolomites.	

MOHAWKIAN SERIES

BLACK RIVER GROUP

In Professor Safford's classification of Central Basin formations, the Carter's Creek limestone, succeeding the Lebanon limestone, constituted the uppermost member of his Stones River group. This assignment was held in Dr. Ulrich's Revision of the Paleozoic Systems in 1911, but in 1915 in the Bibliographic Index of American Ordovician and Silurian fossils, on the evidence of its contained fossils and relationship to other strata, the Carters limestone, the term shortened thus for convenience, was placed by Ulrich and the writer as the basal member of the next great division of the geologic column, the Black River group, which formerly had been believed to be unrepresented in Central Tennessee. The rocks of the Black River group, representing a long period of earth history, consist of at least four distinct formations, several of wide areal distribution and each well developed in its typical area of outcrop. In ascending order these formations are (1) the widespread Lowville limestone, (2) the Watertown limestone of New York, (3) the Decorah shale of Minnesota and Iowa, and (4) the Kimmswick limestone of Missouri.

The Lowville limestone in New York, Kentucky, and Canada consists of three divisions well defined lithologically and faunally. The topmost member is the massive dove Leray limestone of New York and Ontario, which weathers cherty and yields many species of gastropods and other fossils, the middle member, a thin-bedded dove and shaly division, to which in Kentucky the name Tyrone has been applied, and the lower, a massive magnesian limestone division with comparatively few fossils, designated in Kentucky the Oregon dolomite. The lowest division, the typical Carter's limestone, is the only formation of Black River age that crops out in the Columbia quadrangle area of Tennessee where this limestone received its name. Divisions of the Black River strata other than the Carters limestone are represented in Central Tennessee, but until recently all have been referred to the Carters limestone. Eastward and northward from the type area of outcrop along Carters Creek near Columbia the Carters limestone is followed by thin dove and shaly layers of Black River age, containing fossils of the Tyrone member of the Lowville. The massive, very fossiliferous Leray limestone is apparently little developed in Kentucky and Tennessee. This succession of a lower, massive division (Carters) and a thin-bedded upper division (Tyrone) obtains for the greater part of the western side of the Central Basin and it is, therefore, curious that Professor Safford selected a name from an area where the lower division alone is developed. As both divisions are represented in the widespread Lowville limestone and so far have been mapped together in Tennessee, the latter name is adopted.

Although the Carters and Tyrone divisions of the Lowville limestone are the only known Black River formations in the greater part of the Central Basin, there is a possibility that one other formation of this group may be represented in Tennessee. In the southern part of the State, particularly south of Pulaski, the uppermost Black River formation of the general time scale, the Kimmswick limestone, typically developed in eastern Missouri, is believed to be represented in massive, gray, coarsely crystalline strata, 35 feet or more thick, immediately underlying the Hermitage formation and overlying thin-bedded dove limestone. These massive strata contain the peculiar ball cystid *Echinosphaerites* and other fossils of Kimmswick age.

The very fossiliferous shaly layers that occur between the Tyrone member of the Lowville and the typical Hermitage south of Belfast, placed with the Decorah shale in the correlation tables of the Bibliographic Index of American Ordovician and Silurian fossils (U. S. National Museum Bull. 92), are now thought to be better placed at the base of the Hermitage.

The divisions of the Black River group and their distribution in Tennessee are therefore as follows:

Black River group	Kimmswick limestone (occurs only if at all in southwestern part of Central Basin)		
	Decorah shales (extend to central Kentucky but are apparently absent in Tennessee)		
	Watertown limestone (absent in Tennessee)		
		Lowville limestone	Leray member (absent or only locally present in Tennessee)
			Tyrone member (absent in Columbia region only)
			Carters member (present only on west side of Central Basin)

LOWVILLE LIMESTONE

As already stated the name Lowville limestone is adopted for the dove-colored pure and the gray magnesian limestones of Central Tennessee that usually occur between the Lebanon limestone and the Hermitage formation. Although not separated on the maps, two members, the Carters and Tyrone limestones are recognized.

Outcrops of the Lowville, one of the most persistent and uniformly developed formations of the United States, are known from southern Canada to Alabama and from the Appalachian Valley as far west as Minnesota. Throughout this stretch of country its lithologic features, light dove-colored pure, more or less massive limestone penetrated by small calcite strings and breaking with a conchoidal fracture, remain unusually constant. In fact the Lowville is perhaps the most notable of all Paleozoic formations for constancy of lithologic characters and wide extent. Although in weathering certain of the beds, especially those in the upper part, split up into thin uneven layers separated by shaly rocks, fresh exposures indicate that massive beds are the rule. The heaviest beds, some of which are 2 feet thick, occur in the lower portion, the Carters member. The calcite strings are coarsely crystalline calcite instead of homogeneous dove material. Rock penetrated by them exhibits in cross section the appearance that gave the early name Birds-eye limestone to this formation. These strings are usually the tubes of the characteristic fossil coral *Tetradium cellulosum*. Cherty layers in the upper part of the formation are so well developed in New York and Canada that the name Leray member has been applied to them. In Tennessee these cherty beds are seldom seen and in places where this member is absent, either by erosion or more probably by lack of deposition, the top of the Lowville is usually formed by the thin-bedded Tyrone member.

Carters Limestone Member

The Carters limestone was named by Professor Safford from its occurrence along Carters Creek, the stream north of Columbia, where its strata are well exposed. Here and at various places along other streams in the vicinity of Columbia, including Duck River, its heavy-bedded layers weather into turret-like projections, and its massive strata in many places present a castellated effect. (Plate 35, fig. B.) In flat areas the exposures usually consist of white rounded masses projecting from the dense red-clay soil that results from its decomposition. Exposures of the Carters limestone near Columbia, which is situated for the greater part upon this formation, show the details of the section better than those in the type area.

Section of Black River strata at Columbia, Tennessee

	Feet
Hermitage formation of Trenton group.	
Black River group:	
Lowville limestone	
Tyrone member (absent)	
Carters member	
Massive magnesian limestone, easily recognized by white color of outcrop	12
Mottled, thick-bedded limestone, high in magnesia. Locally rather fossiliferous with *Maclurea bigsbyi*, *Stromatocerium rugosum*, *Columnaria halli*, *Lophospira bicinata*, and *Dystactospongia minor* recognizable	18
Single bed of mottled, fine-grained, dove, nearly pure limestone with yellowish magnesian spots. Fossils locally present	4
Massive bed of fine-grained, mottled, rather pure dove limestone with fossils weathering out siliceous, particularly *Streptelasma profundum*, *Columnaria halli*, *Stromatocerium rugosum* and *Maclurea bigsbyi*	6
Pitted, yellowish, massive limestone, low in magnesia. No fossils observed	3
Massive layer of finely granular, yellowish, nearly pure limestone weathering out examples of *Stromatocerium rugosum*, *Columnaria halli*, *Tetradium columnare*, *T. carterense* n. sp., and *Lichenaria carterensis*	5
Fine-grained yellowish limestone without fossils	1.5
Stones River group:	
Lebanon limestone to bed of Duck River.	

The thickness given above, about 50 feet, which is the average for the member, and its characteristic massive limestone, usually magnesian, are typical for it wherever exposed, even as far away as central Kentucky. Fossils are not common, few species other than those mentioned in the section being found. Specimens are rare except those of *Columnaria* and *Stromatocerium*, and good examples can seldom be obtained unless weathering has freed them from the rock, leaving them silicified.

Northward along the west side of the Central Basin the Carters member continues to be well represented, but the thin shaly beds of the Tyrone member appear a short distance beyond the Carters Creek area. In the vicinity of Franklin, the shaly beds although still thin are quite fossiliferous. At Nashville their thickness is only 11 feet, whereas the underlying Carters limestone still has a thickness of more than 43 feet. The section taken at the old stone quarries near Mount Olivet Cemetery is as follows (Plate 34, fig. B):

Section of Lowville limestone in the vicinity of Nashville, Tennessee

	Feet
Lowville limestone	
Tyrone member	
Thin-bedded fossiliferous, dove-limestone layers separated by thin seams of yellow clay. In the upper 3 or 4 inches the surface of the slabs are often matted with bifoliate bryozoa. Fossils abundant, among them *Rhinidictya nicholsoni*, *Phyllodictya frondosa*, and *Subulites regularis*..............	10
Unctuous yellow to green clay (bentonite bed).........................	1
Carters member	
Slightly magnesian, mottled limestone with upper part conglomeratic, yielding some white chert upon weathering..........................	6
Massive, finely oolitic, limestone crystalline at the top..................	4
Massive, slightly magnesian limestone................................	5
Coarsely crystalline conglomeratic limestone, containing many specimens of *Solenopora compacta*, which appear as white concretions...............	1
Slightly magnesian, mottled limestone with few fossils..................	6
Conglomeratic, oolitic, and banded pure limestone......................	3
Massive, mottled, slightly magnesian limestone with a few streaks of pure rock, weathering into chert and silicified specimens of *Tetradium columnare*, *Streptelasma profundum*, *Columnaria halli*, and *Stromatocerium rugosum*..	8
Massive, homogeneous, dove and slightly magnesian, unfossiliferous limestone (to bottom of quarry).......................................	12

In Tennessee the Carters limestone is found only along the western side of the Cincinnati axis. Proceeding eastward its strata decrease in thickness and finally disappear while the overlying thin-bedded Tyrone limestone and shales increase and form the only representative of the Lowville limestone east of the axis.

In Kentucky a nonfossiliferous, massive, magnesian limestone, early described as the Kentucky River marble, separates the thin-bedded dove limestone of the Tyrone above from the more massive Stones River formation below. This occupies the same stratigraphic position as the Carters limestone of which, no doubt, it is the equivalent. As shown in the High Bridge, Kentucky, section on page 64, much of this limestone has a light pinkish tinge, which with its marble-like features made it formerly prized in Kentucky as a material for monuments and pillars. This limestone was described in 1905 by A. M. Miller as the Oregon bed.

Tyrone Member

The thin-bedded upper division of the Birdseye or Lowville limestone in Kentucky, separated in 1905 by A. M. Miller as the Tyrone bed, has since been found to be the most important and widespread division of the Lowville, at most places in fact making up the entire formation. Its absence in the region of the Columbia quadrangle and its slight development along the west side of the Central Basin have been noted in the discussion of the Carters member. At Nashville the occurrence of a bed, not exceeding 15 feet in thickness, of thin fossiliferous dove layers alternating with thin seams of yellow clay, containing the typical Tyrone bryozoa and gastropod faunas, is characteristic for the west side. The separation of the Carters from the Tyrone by a thin bed of unctuous green clay of volcanic origin is likewise typical for this part of the Basin.

The Tyrone is a pure nonmagnesian limestone, in part somewhat argillaceous. In its upper 5 to 20 feet it is white and so thin bedded as to be shaly, and below this it is bluish, finely granular for the most part, and more cherty.

The typical Carters is easily distinguished lithologically from the Tyrone by its more-magnesian composition, its nearer-white color, especially in natural outcrops, and its more-massive beds. Of the Carters fossils the Tyrone contains only *Columnaria*, *Streptelasma*, and *Stromatocerium*. The numerous species known in the Tyrone of Kentucky and the eastern half of the Central Basin of Tennessee are unknown in the Carters, the absence of the most diagnostic fossil, *Tetradium cellulosum*, being particularly noteworthy.

The oldest exposed rocks of the Cincinnati dome in Kentucky are exhibited in the gorge of the Kentucky River at the classical locality of High Bridge, Kentucky. Before proceeding to the discussion of the Tyrone in the eastern part of the Central Basin the following section at High Bridge, prepared by E. O. Ulrich in 1908, is introduced for comparison with preceding sections.

Geologic section at High Bridge, Kentucky

	Feet
Logana (Hermitage) limestone.	
Curdsville limestone (lowest Trenton). Represented by residual reddish clay with porous chert containing *Dinorthis pectinella*, *Orthis tricenaria*, *Streptelasma profundum*, crinoids, particularly *Cupulocrinus jewetti* and cystids	10
Black River group:	
Decorah shale. Locally developed as a thin clay bed.	
Lowville limestone	
Tyrone member	
Upper bentonite bed. Impure unctuous green clay...............	3
Thin-bedded dove limestone with some shaly layers. One layer has silicified gastropods at the top and a reef of *Tetradium cellulosum* in the middle..	28

	Feet
Lower bentonite bed. Soft, unctuous, light-green clay	5
Light and dark colored, thin-bedded dove limestone, the top formed by plates of chert 2 to 4 inches thick and several of the lower beds weathered into platy chert	30
Thin-bedded dove limestone with thin interbedded shales crowded with *Rhinidictya nicholsoni* and its accompanying fauna	4.5
Dove limestone with a few granular layers. A bed with mollusca in the middle part	35
Oregon dolomite (=Carters limestone)	
Massive dolomitic limestone	2
Massive, rather pure, bluish limestone with fucoidal markings	7
Highly magnesian fine-grained, light pinkish-gray limestone in two layers	5
Fine-grained pinkish-tinged dolomite weathering white	4.5
Stones River group:	
Lebanon limestone	
Thin-bedded, pure, dove limestone 3 to 6 inches thick in upper part and 1 to 3 inches thick below. Near the base a zone with fossils of the Pierce limestone occurs, but the top of the division can not be distinguished.	

In places the thin-bedded dove-limestone layers of the Tyrone formation, particularly at a zone 40 feet above the base, contain fifty or more species of fossils, most of which have been found in the same division of the typical Lowville of New York. A partial list of these fossils is given here for comparison with those in the beds in Tennessee referred to the Tyrone member.

Partial list of Tyrone fossils found at High Bridge, Kentucky

Corals: *Streptelasma profundum* Conrad, *Tetradium cellulosum* Hall, *T. halysitoides* Raymond, *Dermatostroma tyronensis* Foerste, *Stromatocerium rugosum* Hall, *Columnaria halli* Nicholson.

Brachiopods: *Orthis tricenaria* Conrad, *Zygospira recurvirostris* Hall, *Strophomena incurvata* Shephard, *Valcouria deflecta* Conrad, *Pianodema subaequata* Conrad, *Rafinesquina minnesotensis* Winchell.

Bryozoa: *Rhinidictya nicholsoni* Ulrich, *Phyllodictya frondosa* Ulrich, *P. labyrinthica* Hall, *Orbignyella wetherbyi* Ulrich, *Escharopora ramosa* Ulrich, *Homotrypa arbuscula* Ulrich.

Gastropods: *Lophospira serrulata* (Salter), *L. oweni* Ulrich and Scofield, *Helicotoma verticalis* Ulrich, *H. granosa* Ulrich, *H. planulatoides* Ulrich, *Liospira vitruvia* Billings, *L. progne* Billings, *Hormotoma gracilis angustata* Hall, *Subulites regularis* Ulrich and Scofield, *S. nana* Ulrich, *S. parvus* Ulrich, *Pterotheca attenuata* Hall.

Pelecypods: *Cyrtodonta huronensis* Billings, *Plethocardia umbonata* Ulrich.

Cephalopods: *Actinoceras tenuifilum* Hall, *Orthoceras tyronensis* Foerste.

Crustacea: *Drepanella ampla* Ulrich, *D. crassinoda* Ulrich, *Isochilina armata* Walcott, *Leperditia fabulites* Conrad, *Primitiella constricta* Ulrich, *Leperditella tumida* Ulrich, *Krausella arcuata* Ulrich, *Bathyurus extans* Hall, *B. spiniger* Hall, *Pterygometopus confluens* Foerste.

Perhaps the most interesting section of the Tyrone along the east side of the Central Basin is that shown on the Dixie Highway southeast of Shelbyville. (Plate 34, fig. A.) Here the usual bentonite bed is followed normally by the thin-bedded layers containing *Rhinidictya*, and the latter are succeeded by a second bentonite bed.

Section of Lowville limestone at Singleton, 4½ miles southeast of Shelbyville, Tennessee

	Feet
Black River group:	
Lowville limestone (Tyrone member)	
Topmost stratum, a 2 or 3 inch capping of dove limestone, which is worm burrowed, sun cracked, and changed to chert along its outcrop	0.2
Dove limestone in layers 1 to 4 inches thick with interbedded thin shaly dove strata. Bryozoa and other fossils in the upper part and pelecypoda in the lower beds	8
Unctuous green clay with a sandy clay bed in the middle (upper bentonite bed)	1.7
Thin-bedded dove limestone interbedded with thin layers of gray clayey limestone full of fucoid-like markings, which upon weathering yields fragments full of holes. In the upper part occurs a zone of *Rhinidictya* and other bryozoa, below this a reef of *Tetradium cellulosum*, then a layer with many small ostracoda, next a layer with gastropods and pelecypods, and at the base a zone of *Leperditia fabulites*	20
Green to yellow clay with coarse feldspathic sand grains (lower bentonite bed)	0.7
Massive, pure, dove limestone with a few magnesian layers in strata 1 to 2 feet thick. Fossils few, but weathering yields chert (to base of exposure along road).	

North of this area, in the western part of Cannon County, more or less massive dove limestone crowded with a branching fucoid (Plate 33, fig. B), composes at least a third of the thickness, and gray to dove-colored rather unfossiliferous shales are conspicuous at the top. This section follows:

Section of Tyrone member in western part of Cannon County, Tennessee

	Feet
Hermitage limestone	
Argillaceous, arenaceous limestone, blue when fresh and dirty yellow when weathered, with extremely fossiliferous layers full of *Ctenodonta* and other pelecypods.	
Lowville limestone. Tyrone member	
Gray and dove-colored rather unfossiliferous shale without limestone bands	14
Massive dove-colored limestone, crowded with a branching fucoid, one-third inch in diameter (*Buthotrephis inosculata*, n. sp.)	8
Massive dove limestone in part conglomeratic and cherty, in beds 3 inches to 2 feet thick with *Columnaria halli* and *C. alveolata*, *Streptelasma profundum*, *Dalmanella*, and *Stromatocerium rugosum*	10
Dove limestone with *Tetradium cellulosum*	8
Dove limestone with *Vanuxemia* in some of the layers	10
Fucoidal beds much like those in upper part	10
Lebanon limestone	
Thin-bedded dove and blue limestone.	

South and east of Woodbury the upper fucoid bed is equally well developed, but the lower part of the section is somewhat changed.

Section of Lowville limestone near Woodbury, Tennessee

	Feet
Black River group:	
Lowville limestone. Tyrone member	
Thin-bedded dove limestone in layers 1 inch or less thick with white clay-shale partings. Rather unfossiliferous, but the usual Tyrone species may be found	17
Dove-colored limestone in beds 6 inches to 2 feet thick, filled with a branching fucoid one-third of an inch in diameter, arranged in horizontal layers but passing from bed to bed. Weathers into dark platy to porous chert with many fossils	20
Massive dove and brecciated dove limestone with here and there an earthy dolomitic layer, weathering into chert. *Stromatocerium, Streptelasma profundum, Columnaria halli* and gastropods not uncommon	10
Light-blue to dove limestone, massive when fresh but weathering into layers 1 to 3 inches thick, full of fragmentary fossils and resembling a microscopic breccia. *Columnaria halli, Tetradium cellulosum,* and gastropods not uncommon. Weathers into thin platy chert	15
Gray-blue fine-grained dolomite	5
Stones River group:	
Lebanon limestone	
Thin-bedded, fine-grained, bluish and dove-colored limestone	45

East of the Central Basin the Lowville limestone is found well developed in the Sequatchie Valley, where it consists of thick-bedded blue and dove limestone with thin argillaceous layers, cherty in the upper part. This is capped with a bed of green clay (bentonite), and there is another bed of green clay near the top. *Tetradium cellulosum, Streptelasma profundum, Stromatocerium rugosum, Phyllodictya frondosa,* and other fossils found in the formation in the Central Basin occur here also and indicate that the strata belong to the Tyrone member. The formation again crops out and has a wide distribution in the Appalachian Valley.

The fauna of the Tyrone member may perhaps be best collected in the outcrops around Nashville. In this vicinity the layers just above the bentonite bed have yielded the following species.

Fauna of Tyrone member, 1 to 6 inches above bentonite bed near Nashville, Tennessee

Corals: *Columnaria halli* Nicholson, *Streptelasma profundum* Conrad, *Tetradium cellulosum* (Hall).

Hydrozoa: *Dermatostroma tyronensis* Foerste.

Bryozoa: *Escharopora subramosa* Ulrich, *Escharopora subrecta* Ulrich, *Graptodictya proavia* Eichwald, *Homotrypa arbuscula* Ulrich, *Orbignyella wetherbyi* Ulrich, *Phyllodictya frondosa* Ulrich, *Rhinidictya nicholsoni* Ulrich.

Brachiopods: *Orthis tricenaria* Conrad, *Strophomena filitexta* Hall, *Zygospira recurvirostris* (Hall).

Gastropods: *Hormotoma gracilis angustata* (Hall), *H. salteri tennesseensis* Ulrich, *Lophospira perangulata* Hall, *Omospira laticincta* Ulrich, *Pterotheca undulata* Hall, *Subulites regularis* Ulrich and Scofield.

Pelecypods: *Cyrtodonta huronensis* Billings.
Cephalopods: *Actinoceras tenuifilum* (Hall), *Orthoceras tyronensis* Foerste.
Ostracoda: *Eurychilina subradiata* Ulrich, *Krausella arcuata* Ulrich, *Leperditella tumida* Ulrich, *Leperditia fabulites* Conrad, *Primitiella constricta* Ulrich.
Trilobites: *Bathyurus extans* (Hall).

The topmost layers of the Tyrone on the western side of the Basin are in many places so crowded with bryozoa that they may be separated as the bryozoan beds. This zone is well shown at the road crossing Watrous Branch half a mile southwest of McConico Church (about 3 miles east-south-east of Franklin), where the thin-bedded dove limestone of the Tyrone shows an excellent development of the bryozoan beds also well exhibited around Nashville. The surface of these slabs is matted with narrow ribbon-like bifoliate bryozoa, chiefly *Rhinidictya nicholsoni*, and shows in addition many small ostracods. The fauna so far identified here is as follows:

Fauna of bryozoan beds near top of Tyrone member 3 miles east southeast of Franklin, Tennessee

Corals: *Streptelasma profundum* Hall, *Tetradium cellulosum* Hall.
Brachiopods: *Strophomena filitexta* Hall, *Zygospira recurvirostris* Hall.
Bryozoa: *Arthroclema* sp., *Escharopora subramosa* Ulrich, *Graptodictya*, *Helopora sp.*, *Homotrypa arbuscula* Ulrich, *Orbignyella wetherbyi* Ulrich, *Phyllodictya frondosa* Ulrich, *Phylloporina*, *Rhinidictya nicholsoni* Ulrich, *Stictoporella* sp.
Ostracoda: *Eurychilina subradiata* var. Ulrich, *Leperditella constricta* Ulrich, *Leperditella tumida* Ulrich, *Leperditia fabulites* Conrad.
Trilobites: *Bathyurus spiniger* (Hall), *Ceraurus*, *Encrinurus*.

One layer of the Tyrone is particularly rich in gastropods. This gastropod bed crops out at various places south of Nashville in the Franklin quadrangle. Usually the fossils are embedded in the thin-bedded but hard dove limestone and have to be cracked out of the rocks. At the crossroads 2 miles north of Peytonsville and 1 mile east of Thomas Church these beds are more argillaceous, and weathering frees the gastropods. Well preserved specimens of the following species were obtained here.

Fauna of gastropod bed in the Tyrone member, 2 miles north of Peytonsville, Tennessee

Bryozoa: *Arthroclema* and other species, *Escharopora subrecta* Ulrich, *Helopora*.
Brachiopods: *Strophomena filitexta* Hall
Gastropods: *Helicotoma granosa* Ulrich, *H. planulatoides* Ulrich, *Hormotoma gracilis angustata* Hall, *H. salteri tennesseensis* Ulrich, *Liospira vitruvia* Billings, *Lophospira obliqua* Ulrich, *L. perangulata* Hall, *Omospira laticincta* Ulrich, *Pterotheca undulata* Hall, *Raphistoma lapidicida* Salter, *Subulites regularis* Ulrich and Scofield.
Cephalopods: *Orthoceras tyronensis* Foerste.
Ostracoda: *Eurychilina subradiata* Ulrich, *Krausella arcuata* Ulrich, *Leperditella tumida* Ulrich, *Primitiella constricta* Ulrich, *Tetradella quadrilirata* Hall and Whitfield.

Bentonite beds.—A greenish, unctuous, sticky clay, which when wet resembles soft soap, occurs at one and sometimes at two horizons of the Lowville formation in various parts of Kentucky and Tennessee. The presence of this clay has long been noted but only recently has it been identified as bentonite. Investigations undertaken by Wilbur Nelson, (Geol. Soc. America Bull., vol. 33, pp. 605–616, 1922), and by others, show that bentonite is a decomposed rhyolitic ash altered into a material allied to leverrierite and montmorillonite, minerals which when put into water swell and break down into a doughy mass.

The peculiar properties of bentonite make it of value for many purposes, and its occurrence in Tennessee at and near the surface adds a new economic asset to the State. The easy determination of the bentonite bed in drilling makes it a good horizon marker, and the driller, to whom it is known as the "Pencil cave" formation, watches for it carefully. This name is derived from its tendency to give trouble in drill holes by caving and rolling up on the bit in thin pencil-like rolls. An excellent review of bentonite and its uses has recently been published by the U. S. Bureau of Mines[6].

The southernmost outcrop of bentonite in the Lowville limestone occurs at Bessemer, Ala., and the northernmost at High Bridge, Ky., covering a distance of about 335 miles. As its thickness at both places is considerable, the ash bed must have originally extended still farther north and south. As noted in our sections the principal ash fall occurred before the close of Lowville time and so does not mark the unconformity between the Black River and Trenton groups. The deposit, which in the section at Singleton, Bedford County, Tenn., is 21 inches thick, reaches a thickness of 5 feet at High Bridge, Ky. At the latter place a second bed of bentonite occurs above the main deposit, which indicates a possible reworking and redeposition of the primary bed deposited on some contiguous land. At Singleton the upper 10 inches of the bentonite deposit is green with nearly vertical streaks of white calcareous carbonate. Below this the next 5 inches is yellow and sandy, containing biotite, mica, feldspar, and rounded quartz grains, and the basal 6 inches consists of the green bentonite. This bentonite bed rests on a smooth surface of dark-blue crystalline limestone, but its contact with the overlying thin-bedded dove limestone is irregular, showing that wave or current action was effective immediately after its deposition.

The location of the ancient volcano that furnished this ash deposit has been discussed by Nelson, who concludes with good reason that it existed somewhere in Kentucky between Fayette and Elliott Counties. That this ash was ejected in one of the greatest eruptions of all time is assumed by Nelson from a computation of the quantity of material comprised in the known extent of the bentonite bed. Krakatoa in 1883

[6] Davis, C. W., and Vacher, H. C., Bentonite, its properties, mining, preparation, and utilization: Bur. Mines Tech. Paper 438, 1928.

and Katmai in June, 1912, each yielded about 5 cubic miles of material, but the ash from the Lowville volcano at a minimum amounted to 66 cubic miles.

Leray Member

Massive dove limestone that crops out in New York and Ontario at the top of the Lowville, weathering cherty and yielding many species of gastropods and other fossils, has been designated the Leray member. Locally in central Kentucky such a limestone has been noted, containing species of *Ctenodonta*, *Lophospira*, *Omospira*, *Oxydiscus*, and other mollusca characteristic of this member. Years ago Professor Safford collected such mollusca at several unknown localities, although probably in the vicinity of Lebanon, which gives rise to the belief that the Leray member is locally present in the Central Basin. The areas and sections studied by the writer have, however, shown no evidence on this point.

KIMMSWICK LIMESTONE

In Missouri the Plattin limestone, correlated with the Lowville of the general time scale, is followed by a massive, coarsely crystalline, gray to white limestone, locally known as the Receptaculites limestone, its most conspicuous fossil being the sunflower coral by that name. This limestone was registered by Ulrich as the topmost member of the Black River group and was named by him the Kimmswick limestone from Kimmswick, Missouri. Its thickness increases from west to east. From a point 20 miles west of St. Louis, where it is 40 feet thick, it increases to 100 feet at St. Louis, as is shown in a deep well at that place, and 5 miles east of the Mississippi River another well shows a thickness of 200 feet.

Except at one place the Kimmswick is unknown east of western Illinois. This locality is on the southwest flank of the Nashville dome, near Aspen Hill, Giles County (Plate 33, fig. A), where 35 feet of coarsely crystalline, gray, massive limestone occurs between the typical Lowville and equally typical Hermitage formations. Although the characteristic *Receptaculites* has not been found here, the occurrence of the equally diagnostic ball cystid *Echinospherites* indicates that the reference of these strata to the Kimmswick was probably correct. The geologic section in this newly found area of occurrence is as follows:

Section along and near the Louisville & Nashville Railroad south of Aspen Hill, Tennessee

	Feet
Trenton group:	
Hermitage formation	
Shales and shaly limestone, the upper beds slightly phosphatic. *Dalmanella fertilis* abundant	50
Black River group:	
Kimmswick (Lowville ?) limestone	
Massive, coarsely crystalline, gray limestone weathering into rounded boulders, without chert, crowded with fossils particularly *Columnaria alveolata*, *Solenopora compacta*, *Streptelasma profundum*, and *Echinospherites*. A few mottled dove limestone beds 12 to 20 inches thick occur in the lower part	35
Lowville limestone (Tyrone member)	
Thin-bedded dove and fucoidal limestone weathering into small fragments full of holes. Fossils not uncommon, among them *Rhinidictya nicholsoni*, *Escharopora ramosa* var., *Pachydictya* cfr. *everetti*, *Orthis tricenaria*, *Streptelasma profundum*, and *Solenopora compacta*	10

In spite of the similarity to the Kimmswick in lithology and fossil contents of this Black River limestone, it is quite possible that these beds are only a phase of the Lowville limestone. The fauna of these coarsely crystalline limestones is as follows.

Fauna of Kimmswick (?) limestone, 1 mile south of Aspen Hill, Tennessee

Calcareous algae: *Solenopora compacta* Billings.

Hydrozoa: *Stromatocerium rugosum* Hall.

Corals: *Columnaria* (two small-celled species), *C. alveolata* Goldfuss, *Streptelasma profundum* Hall, *Tetradium* n. sp.

Bryozoa: *Dianulites* cfr. *cumulata*, *Eurydictya* cfr. *montifera*, *Escharopora* cfr. *confluens*, *Nicholsonella* cfr. *ponderosa*, *Phylloporina* cfr. *sublaxa*, *P.* cfr. *reticulata*.

Brachiopods: *Strophomena* cfr. *scofieldi*, *Rhynchotrema minnesotensis* Sardeson, *Rafinesquina* cfr. *minnesotensis*.

Cystids: *Echinospherites*.

Trilobites: *Amphilichas* sp., *Bumastus*.

TRENTON GROUP

The Central Basin, having many excellent outcrops of unusually fossiliferous strata of Trenton age, is unexcelled in the opportunity that it presents to study the details of the stratigraphy and paleontology of this, the upper half of the Mohawkian series. The divisions of the Trenton group in the Central Basin are as follows:

Trenton group	Catheys formation. Well developed over all the Basin except the eastern side south of northern Cannon County.
	Cannon limestone. Absent in Columbia area and thin on the western side but reaching 300 feet in thickness on the east.
	Bigby limestone. Restricted to west half of Basin.
	Jessamine limestone. Doubtfully present in Tennessee.
	Hermitage formation. Widespread over the Basin but differing in lithology on the two sides.
	Curdsville limestone. Possibly present locally in northern part.

CURDSVILLE LIMESTONE

Although no trace of the Curdsville limestone has been noted in any of the Tennessee quadrangles mapped thus far, a short description of it is included in this report, because typical examples of the characteristic crinoid *Cupulocrinus jewetti* and other Curdsville fossils were collected by Mr. Nelson in loose pieces of limestone, along the railroad north of Gordonsville, Tennessee. As careful search by the writer has failed to reveal any Curdsville strata in the section of this region, it is thought that these specimens were derived from ballast along the track. It is probable that during Curdsville time the Nashville dome was above water and received no deposits, although a small area on its northern flank may have been occupied by an arm of the sea that covered Kentucky and more northern areas.

The Curdsville limestone, so named from Curdsville, Kentucky, a station on the Cincinnati Southern Railroad, is the oldest formation of the Trenton group in the Ohio Valley and is best developed in its typical area of outcrop in central Kentucky. Here it consists of massive, blue to gray, crystalline, fossiliferous limestone reaching 30 feet in thickness, quite different lithologically and sharply separated from the underlying dove limestone of the Lowville and the shaly strata of the overlying Hermitage formation. Faunally the Curdsville limestone is quite unique, owing to its unusual number of peculiar crinoids and other echinoderms, which are known elsewhere only in southern Canada. Among the crinoids *Cupulocrinus jewetti* is not uncommon.

In fresh exposures the Curdsville limestone shows few fossil remains in its massive strata, but upon weathering the rock is reduced to a red clay soil, containing considerable vesicular chert and many silicified fossils. Among the sixty or more species collected in Kentucky may be mentioned the following to show the difference in faunal characters from the associated formations.

Fossils from the Curdsville limestone of Kentucky

Sponges (?): *Receptaculites occidentalis* Salter.

Corals: *Columnaria* small cells, *Streptelasma corniculum* Hall, *S. profundum* Hall.

Brachiopods: *Dinorthis pectinella* (Hall), *Orthis tricenaria* Conrad, *Platystrophia amoena longicardinalis* McEwan, *P. precedens* McEwan, *P. trentonensis* McEwan, *P. trentonensis perplana* McEwan, *Plectambonites curdsvillensis* Foerste, *Rhynchotrema subtrigonale* Hall, *Strophomena filitexta* Hall, *Zygospira recurvirostris* Hall.

Crinoids: *Carabocrinus ovalis* Miller and Gurley, *C. radiatus* Billings, *Cleiocrinus sculptus* Springer, *Cremacrinus kentuckyensis* Miller and Gurley, *Cupulocrinus jewetti* (Billings), *Dendrocrinus acutidactylus* Billings, *Glyptocrinus priscus mercerensis* Miller and Gurley, *G. ramulosus* Billings, *Hybocrinus conicus* Billings, *H. tumidus* Billings, *Palaeocrinus angulatus* Billings, *Porocrinus kentuckyensis* Miller and Gurley, *P. smithi* Grant, *Retiocrinus alveolatus* Miller and Gurley.

Cystoids: *Aesiocystites priscus* Miller and Gurley, *Amygdalocystites florealis* Billings, *A. huntingtoni* Wetherby, *A. radiatus* Billings. *Belmnocystites wetherbyi* Miller and Gurley, *Edrioaster bigsbyi* Billings, *Hybocystites problematicus* Wetherby, *H. eldonensis* Parks, *Pleurocystites mercerensis* Miller and Gurley.

Gastropods: *Bellerophon subglobosus* Ulrich, *Bucania halli* Ulrich and Scofield, *Phragmolites similis* Ulrich and Scofield, *Lophospira obliqua* Ulrich, *Raphistomina denticulata* Ulrich, *Sinuites pervolutus* Ulrich and Scofield, *Tetranota obsoleta* Ulrich and Scofield, *T. bidorsata minor* Ulrich.

Pelecypods: *Cyrtodonta canadensis* Billings, *C. obesa* Ulrich, *C. rotulata* Ulrich, *Plethocardia umbonata* Ulrich, *Vanuxemia gibbosa* Ulrich, *V. umbonata* Ulrich.

Cephalopods: *Endoceras proteiforme* Hall, *Orthoceras amplicameratum* Hall, *O. arcuoliratum* Hall, *Spyroceras bilineatum* (Hall), *Tripteroceras* sp., *Colpoceras gracile* Wetherby.

HERMITAGE FORMATION

Succeeding the dove-colored Lowville limestone in central Tennessee is a formation of thin-bedded, blue, impure limestone weathering brown, with thin interbedded shales. Safford in 1869 called this formation the "Orthis bed", describing it as "a group of blue, siliceous, and sandy limestones, some layers of which are literally made up of *Orthis testudinaria*." This particular fossil, a brachiopod now termed *Dalmanella fertilis*, is so abundant in these strata that its presence in the soil is a reliable indication of the occurrence of the formation. As geographic terms are now used exclusively in designating formations, Hayes and Ulrich in the Columbia folio gave the Orthis bed the new name Hermitage formation, "derived from the station of that name, situated near the old home of President Jackson on the Tennessee Central Railroad, where a good section was secured." This section, made in 1899 by E. O. Ulrich and the writer, is as follows:

Section of Hermitage formation near Hermitage station, Davidson County, Tennessee

	Feet
Ordovician:	
Bigby limestone	
Granular and subgranular phosphatic laminar limestone	30
Hermitage formation	
Blue, siliceous, fine-grained, thin-bedded, shaly limestone, weathering light-brown into a sandy phosphate. Near the top is a fossiliferous bed with *Modiolodon oviformis*. Near the middle is a 2 or 3 foot bed of disturbed material, the mud having been rolled into large boulders. Fossils few; *Byssonychia*, *Dalmanella fertilis*, and *Rafinesquina* are present	35
Thin-bedded limestone and shale crowded with *Dalmanella fertilis* and *Ctenodonta hermitagensis*	2
Blue, siliceous to argillaceous, thin-bedded limestone, weathering into light-brown very impure phosphatic rock. Fossils few, but among them are *Heterorthis clytie* and *Dalmanella fertilis*	30
Lowville limestone	
Thin-bedded, shelly, dove limestone with shale, containing *Strophomena*, *Leperditia fabulites*, *Phyllodictya frondosa*, *Rhinidictya nicholsoni*, etc.	5

	Feet
More-massive dove limestone, weathering into plates of blocky yellow chert	4
Massive dove limestone, weathering into red soil with chert fragments. Silicified fossils in the weathered débris with *Columnaria halli* and *Tetradium columnare* in the upper half and *Streptelasma profundum* in the lower	17

The section at the type locality does not exhibit the full development of the Hermitage, for, as indicated later, two additional faunal zones occur above the *Modiolodon* bed and one below the *Heterorthis clytie* bed, which here forms the basal part.

Disconformable relations.—As noted in the above type section, the Hermitage lithologically consists of about 67 feet of thin-bedded, siliceous to argillaceous, blue limestone, weathering light brown, with thin interbedded shales. Impure sandy phosphate often results from its weathering. The abrupt change in lithology from the underlying Lowville indicates its disconformity with that formation, which is substantiated elsewhere, as in central Kentucky, by the intercalation of the Curdsville limestone between the two. Evidence of this disconformity is shown at many Tennessee localities in other ways. For example, the Hermitage as exposed along Dixon Creek near Dixon Springs, Smith County, commences with a 3 to 6 inch layer of ferruginous conglomerate, which contains *Dalmanella fertilis* and in places includes silicified fossils of the underlying Lowville limestone, indicating subareal weathering at the end of the Lowville to form the silicified fossils and the red soil that contains them. Again in Bedford County, 4½ miles southeast of Shelbyville, the uppermost bed of the Lowville is a 2 or 3 inch capping of dove limestone, which is worm burrowed, suncracked, and changed to chert along its outcrop. Again as at Columbia, Tennessee, the thin-bedded Upper Lowville (Tyrone) is absent, either by erosion or by non-deposition, and the Hermitage rests upon the lower, massive, Carter limestone member of the Lowville.

The Hermitage is also in disconformable relationship with its overlying beds in central Tennessee, where it is succeeded in places by the Bigby and elsewhere by the Cannon limestone. In Kentucky the Jessamine (Wilmore) formation, 80 feet thick, occupies a position between the Hermitage and the next higher formation. In Kentucky, therefore, the depositional record of the early Trenton is more complete than in central Tennessee.

Distribution of Hermitage.—The Hermitage is one of the most widespread formations not only of the Central Basin but also of contiguous regions and thus gives evidence of comparatively broad areas of sea at the time of its deposition.

West of the Mississippi River the formation is unknown, but eastward it is found well developed in the Wells Creek Basin and in the Tennessee River Valley of west Tennessee, where the interesting brachiopods *Leptobolus lepis cliftonensis* Foerste, *Lingula waynesboroensis* Foerste, *Schizocrania* (?) *rudis* Hall, and *Trematis punctostriata* Hall were discovered. Widespread throughout the Central Basin it appears again in the Sequatchie Valley. Passing under the Appalachian coal field the shaly strata of the Hermitage still increase in thickness, for in southwest Virginia 150 feet of strata having the characteristic fossils occur between the typical Lowville below and granular blue limestone above, correlated with the Cannon limestone. The western part of the Appalachian Valley from southwest Virginia to Alabama forms its eastern boundary. In the Central Basin this formation with other Paleozoic rocks dips southward under the Gulf Coastal Plain, and on the north undoubted Hermitage strata are not known north of north-central Kentucky. From these boundaries it is evident that the waters that deposited this formation entered the continental basin through the Mississippi embayment, a conclusion also supported by the nature of the fauna, which is of the Gulf type. As it occupies the definite area just outlined, in which Lower Trenton rocks of contiguous areas seem never to have been deposited, the relationship of the Hermitage to the formations of similar age in New York, Canada, Minnesota, and elsewhere can not be determined.

Because it is a possible future source of phosphate and of cement material together with the fact that it weathers into rather rich farm lands, the formation deserves more detailed study than has so far been put upon it. Several interesting paleontologic and stratigraphic problems are connected with this formation, but these can be treated only briefly at this time. In the type areas east of Nashville the formation consists entirely of thin-bedded argillaceous limestone and calcareous shale. At Nashville the upper 23 feet of a possible thickness of 64 feet is massive, granular, irregularly bedded, laminated limestone quite similar save for fossil contents to the overlying Bigby limestone. At Franklin thin-bedded, blue limestone at the top, containing the *Modiolodon oviformis* fauna, are underlain by heavy granular disturbed layers. (Plate 36, A.) At Columbia the *Prasopora patera* bed, 15 feet thick, forms the base, and the top of the formation is of blue even-bedded, subcrystalline, limestone 50 feet thick, crowded with *Dalmanella fertilis*. At Peytonsville, on the northeast in Williamson County, 80 feet of unfossiliferous clay and sandy shale, with sandstone layers at the top, are developed. (Plate 35, A.)

In Trousdale County, as shown in the Hartsville section on page 24, the Hermitage begins with sandy shales having *Dalmanella fertilis* and *Prasopora patera*, followed by 15 feet of more or less granular phosphatic limestone with many *Rafinesquina*, and ends with 6.5 feet of shaly and hard clay layers containing *Tetradium minus*.

In Bedford County, 4½ miles southeast of Shelbyville, the formation has assumed the characters shown on the eastern side of the Basin, for here 20 feet of yellow shale and sandy unfossiliferous strata occur at the base and thin-bedded argillaceous limestone, 10 feet thick, with *Lichenaria* above.

East of Lebanon a new phase of the Hermitage is encountered, for, in addition to the usual shales and thin-bedded clay limestones of the lower part, a richly fossiliferous bed is introduced near the top having many species of bryozoa, and the topmost bed is crowded with the coral *Tetradium minus*. The following section illustrates this phase of the Hermitage.

Section of Hermitage formation 2½ miles south of New Middleton, Smith County, Tennessee

	Feet
Cannon limestone	
Massive blue to gray limestone	250
Hermitage formation	
Massive argillaceous limestone crowded with *Tetradium minus*	4
Nodular, argillaceous, blue limestone and shale the upper part crowded with bryozoa, corals (*Lichenaria grandis*, etc.), and other fossils listed below; the lower part with *Dalmanella fertilis* abundant	8
Soft shale, fossils scarce	10
Impure phosphatic, argillaceous limestone weathering into shale	4
Shale having few fossils	5
Shaly limestone with *Modiolodon oviformis* and *Rafinesquina hermitagensis*	1
Brown shale	2
Lowville limestone	
Dove limestone and shale.	

The upper beds of the Hermitage here and at other outcrops in Smith County, particularly 4 and 6 miles northwest of Carthage, have yielded the fossils listed below.

Fossils of Lichenaria grandis bed of upper Hermitage, in Smith County, Tennessee

Plants (algae): *Solenopora compacta cerebrum* n. var.

Sponges: *Hindia sphaeroidalis* Duncan var.

Corals: *Tetradium minus* Safford, *Streptelasma* cfr. *corniculum*. *Columnaria crenulata* n. sp., *Lichenaria grandis* n. sp., and *L. globularis* n. sp., *Aulopora trentonensis* Winchell and Schuchert.

Brachiopods: *Platystrophia hermitagensis* McEwan, *P. extensa* McEwan, *Dalmanella fertilis* Bassler, *Rhynchotrema increbescens* (Hall), *Rafinesquina hermitagensis* n. sp.

Bryozoa: *Bythotrypa laxata* Ulrich, *Stellipora stipata* n. sp., *Corynotrypa inflata* Hall, *Rhinidictya* sp., and various species of massive and ramose bryozoa.

Pelecypoda: *Modiolodon ganti* Safford, *M. winchelli* Safford, and other species.

Trilobites: *Ceraurus* cfr. *pleurexanthemus*, *Calymene* sp.

Ostracoda: *Kloedenia praenuntia* Ulrich and Bassler, *Ceratopsis intermedia* Ulrich, *Tetradella quadrilirata* (Hall and Whitfield), *Eurychilina*, and other species.

In the southern part of the Central Basin the basal beds contain an unusual fauna, which seems to ally them to the early Trenton shales, not found elsewhere in Tennessee but occurring in Minnesota and Iowa.

Section of Hermitage along old road to Petersburg, 1 to 3½ miles south of Belfast, Marshall County, Tennessee

	Feet
Cannon limestone	
Dove and blue limestone mainly (see divisions of Cannon limestone for details)	250
Hermitage formation	
Shale and nodular limestone with many ramose and small massive bryozoa, *Lichenaria grandis* and *L. globularis* n. sp., and crowded with *Rhynchotrema increbescens* (Hall)	12
Shaly nodular limestone without fossils	6
Slightly phosphatic arenaceous shale and limestone	1
Somewhat arenaceous shale	14
Soft shale with *Ctenodonta* in upper part	4
Soft shale with a layer at top crowded with the branching sponge *Camarocladia*	8
Blue calcareous shale crowded with *Constellaria varia* and the other fossils listed below	3
Thin-bedded blue limestone composed of crinoidal fragments	4
Gray to red granular limestone of comminuted material and containing small boulders of Lowville limestone and shale	0.3 to 0.5
Lowville limestone	
Thin layer of dove limestone, suncracked and much of it changed to chert	0.1 to 0.3
Thin-bedded dove limestone with *Rhinidictya nicholsoni* and other Tyrone fossils	1
Massive dove limestone with a few thin beds. *Tetradium cellulosum* and gastropods abundant	3
Massive grayish limestone in two layers, composed of small conglomeratic fragments	2
Massive dove and magnesian limestone with no fossils apparent.	

The fauna of the lower fossiliferous bed of the Hermitage at this place is large, and the identified species are listed below.

Fauna of Constellaria varia bed of the lower Hermitage, 2½ miles south of Belfast, Tennessee

Sponges: *Dystactospongia* n. sp.

Corals: *Aulopora trentonensis* Winchell and Schuchert, *Columnaria alveolata minor* n. var.

Bryozoa: *Phylloporina reticulata* Hall, *Calloporina parva* Ulrich and Bassler, *Constellaria varia* Ulrich, *Corynotrypa inflata* Hall, and various species of *Cyphotrypa*, *Prasopora*, *Homotrypella*, *Amplexopora*, *Phaenopora*, *Pachydictya*, *Nematopora*, *Eridotrypa*, and other bryozoa.

Brachiopods: *Heterorthis clytie* Hall, *Dinorthis pectinella* Emmons, *Dalmanella fertilis* and var., *Rhynchotrema increbescens* Hall, *Platystrophia extensa* McEwan, *Rafinesquina alternata* var., *Zygospira recurvirostris* Hall, *Orbiculoidea lamellosa* Hall, *Scenidium anthonense* Sardeson.

Gastropods: *Conradella dyeri cellulosa* Ulrich and Scofield, *Cyclora minuta* Hall, and accompanying dwarfed species.

Cephalopods: *Spyroceras bilineatum* (Hall).

Vermes: *Cornulites* sp.

Trilobites: *Calymene* sp.

Ostracoda: *Leperditella* and other species.

In the Woodbury quadrangle and elsewhere along the eastern side of the Central Basin the Hermitage consists of argillaceous and arenaceous limestone, blue when fresh and dirty yellow or gray when weathered. It contains extremely fossiliferous layers up to 1 inch thick in which *Ctenodonta* and other pelecypods are extremely abundant. A characteristic section in this part of Tennessee is as follows:

Section of Hermitage in Woodbury quadrangle along McKnight Branch, 7 miles northwest of Woodbury, Tennessee

	Feet
Cannon limestone	
Massive gray and blue limestone to top of hill.	
Hermitage formation	
Nodular, argillaceous, blue limestone with abundant fossils. *Solenopora compacta cerebrum*, *Lichenaria grandis* and *L. globularis*, bryozoa, etc.	20
Blue limestone weathering dirty yellow in 1 to 4 inch beds crowded with small pelecypods	25
Slightly phosphatic, sandy to argillaceous limestone weathering like bed above but with few fossils	40
Shale and thin shaly limestone crowded with *Dalmanella fertilis*. A layer an inch or two thick near the base contains *Dinorthis pectinella* and *Heterorthis clytie*	5
Lowville limestone	
Usual thin shale, limestone, and shale of Tyrone division to creek bed.	

South of Woodbury the following section holds for a considerable area.

Section of Hermitage 1 mile south of Woodbury, Cannon County, Tennessee

	Feet
Hermitage formation	
Rubbly, yellowish clay limestone weathering into small, irregular, rounded masses and having the coral *Lichenaria*	12
Dirty-blue, irregular limestone with intervening shale. Small pelecypods not uncommon	15
Mudstone and shaly beds with five or more equally distributed, granular, blue phosphatic to dark clay limestones in beds 3 to 12 inches thick, full of small pelecypods mainly *Ctenodonta*	17
Sandy shaly beds, weathering into small fragments, with four or five layers, 1 to 3 inches thick, of rust-colored mudstone in distinct bands; large branched fucoids the only fossils	17
Thin-bedded, blue, granular, fossiliferous limestone with intercalated yellow shale, weathering into small blocky fragments. Fossils numerous, *Heterorthis clytie* and *Dinorthis pectinella* characteristic with *Rhynchotrema increbescens*, *Prasopora patera*, and other bryozoa abundant	6
Lowville limestone	
Thin-bedded dove limestone with white clay shale.	

Soil and Phosphates.—As indicated in the sections that have been listed, the Hermitage formation is everywhere made up in part of slightly phosphatic, sandy, or argillaceous strata. Although there are few places where the phosphate has accumulated in large enough quantities and is pure enough to mine, such as in Maury and Williamson Counties, where deposits test as high as 74 per cent. of lime phosphates, the Hermitage, as a rule, enriches the soil by the weathering of its beds giving very fertile lands. In the localities along the west side of the Basin, where it has been profitable to mine the phosphate, the material occurs in the form of tufaceous deposits on the hill slopes just at or slightly below the outcrop of the bed. Toward the east the sand content increases so that the percentage of lime phosphate is rarely more than 50.

In various parts of the Basin the Hermitage itself forms the surface of gently rolling tracts that make very fine farming lands. Soils with sandy beds predominating that lie close to streams have a tendency to wash badly.

Faunal zones.—A study of the preceding and other sections throughout the Basin indicates that at least eight distinct faunal zones can be recognized in the Hermitage, not all, of course, being developed in the same region. In the typical section at Hermitage station five of these zones are present, the upper two and the basal zones being undeveloped. Although absent along the western part the two upper zones are well developed in the northeastern, eastern, and southern parts of the Basin. The basal zone is found only in the southern areas. Named after the characteristic fossils these zones are as follows:

Faunal zones of Hermitage formation in central Tennessee

Tetradium minus bed. Massive argillaceous limestone crowded with the small-celled *Tetradium* (*T. minus*) and locally the bryozoan *Amplexopora convoluta*.

Lichenaria grandis bed. Nodular, argillaceous, blue, fossiliferous limestone and shale, containing many ramose byrozoa and small massive, rounded corals, *Lichenaria grandis* and *L. parva*.

Modiolodon oviformis bed. Shale and clayey limestone with *Modiolodon oviformis* abundant.

Ctenodonta hermitagensis bed. Thin layers of blue clay limestone and hard shale crowded with small pelecypoda, especially *Ctenodonta hermitagensis*.

Dalmanella fertilis beds. Even-bedded, argillaceous to siliceous, blue limestone and shale in thin layers, in which *Dalmanella fertilis* although not restricted to this bed, occurs in great abundance.

Prasopora patera bed. Impure fine-grained limestone in thin layers. The discoid bryozoan *Prasopora patera* not uncommon.

Heterorthis clytie bed. Thin-bedded, blue granular limestone and yellow shale with many brachiopods, particularly *Heterorthis clytie* and *Dinorthis pectinella*.

Constellaria varia bed. Blue calcareous shale crowded with fossils, particularly small ramose and discoid bryozoa among which *Constellaria varia* is characteristic.

The fauna of the topmost bed is small, consisting mainly of the small-celled species of the so-called coral *Tetradium*. Locally the convoluted bryozoan, *Amplexopora convoluta*, occurs in great numbers here. The underlying *Lichenaria grandis* bed is crowded with fossils, many of which, particularly the bryozoa, remain unstudied. This fauna is listed under the New Middleton section on page 76. The *Modiolodon oviformis* bed is not so fossiliferous, although the bed has a wide distribution and in many places forms the top of the Hermitage especially on the western side of the Basin. Besides the characteristic pelecypod giving the name to the bed the brachiopods *Dalmanella fertilis* and *Rafinesquina* are usually the only other fossils.

The underlying hard shale and blue clay limestone crowded with small pelecypods, especially *Ctenodonta hermitagensis*, which commonly have slight thickness, have a wide distribution. Although these layers are usually one mass of small ctenodontas, silicification of the fossils in many places leaves a considerable number of them scattered in the resulting soil. Among these species are the following:

Fauna of the Ctenodonta hermitagensis bed

Brachiopods: *Rhynchotrema increbescens* Hall, *Rhynchotrema* small species, *Zygospira recurvirostris* Hall.

Pelecypods: *Ctenodonta hermitagensis* n. sp. and various other small species of the genus; *Whiteavesia*, *Byssonychia*, *Modiolodon*, *Orthodesma*.

Gastropods: *Conyadella dyeri cellulosum* Ulrich and Scofield, *Cyrtolites retrorsus* Ulrich, *Lophospira* sp., *Tentaculites obliquus* Ulrich.

Cephalopods: *Spyroceras bilineatum* (Hall).

The next two beds, although quite fossiliferous, contain few species. The *Heterorthis clytie* bed is distinguished for its abundant and well preserved brachiopods. Here is found *Rafinesquina hermitagensis* in its best development. At the base, in the southern part of the Basin only, is found the *Constellaria varia* bed with a large fauna, part of which is listed on the page following the Belfast section.

JESSAMINE (WILMORE) LIMESTONE

Because of the possibility of its occurrence in the northeastern part of the Central Basin in Tennessee a brief statement concerning the Jessamine limestone and its fossils is here included. In the Blue Grass region of Kentucky this very fossiliferous formation, 80 to 100 feet thick, crops out between the Hermitage formation and the equivalent of the Bigby limestone. It is composed of thin-bedded, dark-blue, subcrystalline limestone with rough surface separated by shaly partings. Although lithologically or paleontologically similar strata are now unknown in Tennessee, a close study may prove that the very fossiliferous shaly limestone at the top of the Hermitage formation in the northeastern part of the Basin is its equivalent. With this possible exception the entire Central Basin was land during Jessamine time.

The fauna of the Jessamine limestone consists largely of bryozoa.

The hat-shaped species, *Prasopora simulatrix*, and the solid branching form *Hallopora multitabulata*, being especially abundant. More than 50 species are known, of which the following are most often seen.

Partial list of fossils in the Jessamine limestone

Brachiopods: *Dalmanella bassleri* Foerste, *Hebertella frankfortensis* Foerste, *Platystrophia* sp., *Rhynchotrema increbescens* Hall.

Bryozoa: *Dekayella trentonensis* Ulrich, *Eridotrypa mutabilis* Ulrich, *E. trentonensis* Nicholson, *Hallopora multitabulata* Ulrich, *Homotrypella granulifera* Ulrich, *Pachydictya acuta* Hall, *Prasopora simulatrix* Ulrich, *Rhinidictya multipora* Ulrich, *R. neglecta* Ulrich.

Gastropods: *Conradella compressa* Ulrich, *Cyrtolites retrorsa* Ulrich, *Fusispira subfusiformis* Hall, *Lophospira* sp.

Pelecypods: *Lyrodesma* sp.

BIGBY LIMESTONE

The most important phosphate deposits of the Mount Pleasant area are developed in the massive laminated limestone now called the Bigby. In 1869 Professor Safford separated this limestone as the second division of the Nashville series, giving it the name "Capitol" limestone because it was well exposed in the old State quarry in sight of the Capitol and was used in constructing that building. As this name was not based on a geographical locality it was changed by Hayes and Ulrich in 1903 in the description of the Columbia folio to the name Bigby.

The authors described the formation in the Columbia quadrangle as consisting of a nearly uniform series of semi-oolitic or granular, crystalline, laminated, phosphatic limestone, of gray or bluish color, and 30 to 100 feet thick with the upper part in many places shaly or arenaceous and the lower part in places shaly but nowhere sandy. Where the Bigby is at the surface it weathers into gently undulating land with extremely productive soil, which is valuable for wheat and forms the best of the bluegrass region of the Central Basin. The Bigby limestone in general has much the appearance of a laminated sandstone and is, in fact, composed of calcareous sands, in which the sand grains are the fragmentary remains of brachiopods and bryozoa, and mingled with them are also innumerable shells of the minute *Cyclora* and related gastropods. This material evidently accumulated along an old sea beach, on which the waves arranged the fragmentary fossils in more or less regular laminae. The usually quite massive beds are easily quarried and polished and in the early days furnished much of the building stone used in and around Nashville. The time that has elapsed since these buildings were erected has brought out the defects of the rock as a building stone, the chief of which is that it weathers rapidly into thin laminae, so that it is only a question of years before buildings made of it should be condemned.

Cross stratification and irregular bedding from different types of current action are well exhibited in this limestone and tend also to its rapid disintegration under weathering. (Plate 37, figs. A and B.) Hayes and Ulrich stated that northeast toward Nashville and thence eastward to Hartsville the granular structure and phosphatic nature of the Bigby are lost, and that the beds assume different characters and increased thickness possibly because deposited in deeper water.

Detailed mapping in the Central Basin has shown that the supposed change of the phosphatic Bigby limestone northward and eastward into strata of different character is not a fact, but that this limestone actually thins out in these directions and finally disappears. This observation is readily proved by the occurrence of the basal dove layers of the supposed equivalent formation, now separated as the Cannon limestone, on top of the typical and fully developed Bigby phosphatic beds along the eastern edge of the Columbia quadrangle and their continuation on the thinning layers of the Bigby eastward until that limestone disappears, whereupon the dove beds rest upon the underlying Hermitage formation. The eastern edge of the Bigby limestone has been noted at a number of places, and the decrease in thickness of the limestone may be followed on the geologic map of the Franklin quadrangle to its disappearance in the southeast corner.

In the present report, therefore, the Bigby limestone is restricted to the phosphatic and associated beds between the Hermitage and Catheys formations as developed in the Columbia quadrangle. Here is shown no trace of the dove and succeeding strata, the Cannon limestone, which elsewhere intervene.

The Bigby limestone crops out at the surface just east of Mount Pleasant in a low dome, which is drained by streams deep enough to give ideal conditions for the weathering of the phosphatic limestone beds by solution into layers of high-grade phosphate. Furthermore, the process is aided by the presence of easily dissolved cavern-forming limestone beneath the phosphatic layers, which increases the circulation of underground water. Lastly the undecomposed Bigby layers in this area contain a larger percentage of phosphatic material than those in other areas where they are pure limestone.

Although the formation takes its name from Big Bigby Creek near Mount Pleasant, the exposures on the creek are not as suitable for study as those at Mount Pleasant. At the latter place the phosphate mines, especially those where the phosphatic material has been removed exposing the bare limestone, show the following sequence of strata.

Section of Bigby limestone at Mount Pleasant, Tennessee

	Feet
Mohawkian (Trenton):	
Catheys formation	
Bigby limestone	
Subcrystalline blue limestone with *Rafinesquina alternata* in upper layer	30
Granular, cross-bedded, laminated limestone yielding sandy phosphate on weathering	2
Lens of coarsely crystalline limestone and disturbed material	4
Laminated coarse-grained limestone weathering into sandy phosphate	4.5
Shale and limestones weathering into yellow clay and abundant chert	8
Massive, granular, phosphatic limestone weathering into good phosphate	12
Blue limestone with yellow clay beds above	6
Laminated limestone yielding phosphate rock in thick plates (4.5 feet) with an overlying clay bed (1.5 feet)	6
Much-disturbed, conglomeratic, impure, shaly limestone having gastropods in places	0 to 6
Hermitage formation.	

It will be noted that not all the beds of the Bigby limestone weather into good phosphate and that many ordinary blue limestone layers and an occasional clay bed are present. The main mass of the 78 feet exposed here yields more or less phosphatic material but less than one-third of this thickness is mined.

At Columbia, where the several divisions of the Bigby are fairly well exposed, there is less tendency toward the development of phosphatic limestone.

Section of Bigby limestone at Columbia, Tennessee

	Feet
Mohawkian (Trenton):	
Catheys formation	
Argillaceous limestone and shale with *Constellaria* bed near base	2
Bigby limestone	
Gray to blue granular limestone crowded with *Rafinesquina*	1
Granular limestone with few *Rafinesquina* and other fossils. Hemispheric bryozoa and *Eridotrypa briareus* at the base	5
Granular gray-blue limestone filled with *Rafinesquina*	2
Subgranular, unfossiliferous limestone	2
Gray granular limestone filled with *Rafinesquina* and several layers crowded with *Ctenodonta subrotunda*, *Bellerophon clausus* var., *Lophospira oweni* var., *Rhynchotrema increbescens*, *Dalmanella* (large species), and *Hebertella frankfortensis*. One foot of unfossiliferous shale at base	6
Thin-bedded, subgranular, grayish limestone yielding a little chert upon weathering. *Rafinesquina* abundant, *Dalmanella* few, cyclorids present	17
Hermitage formation.	

A section of the Catheys and Bigby formations, interesting for the development of cephalopods (*Orthoceras*, etc.) at the top of the latter, is shown at the junction of the roads at Dry Fork, near Jameson, in Maury County.

Section at Dry Fork, 3 miles southwest of Jameson, Maury County, Tennessee

	Feet
Catheys formation	
Massive, argillaceous, fetid and granular limestone, the former filled with mollusca showing only in cross sections (to top of hill)	10
Thin-bedded, blue crystalline limestone, surface of the layers crowded with bryozoa, particularly *Constellaria fischeri* and *Heterotrypa parvulipora*	25
Finely crystalline argillaceous limestone in layers 2 to 5 inches thick, weathering into slabs with uneven surface and yielding many silicified masses of *Columnaria alveolata* and *Stromatocerium pustulosum*	20
Bigby limestone	
Massive gray to flesh-colored phosphatic limestone composed of comminuted fossils weathering into beds up to 18 inches thick. *Eridotrypa briareus* not uncommon. The uppermost 4 to 6 inches crowded with cephalopods (*Orthoceras* and *Cyrtoceras*) and algae (*Solenopora compacta*)	40
Massive blue granular limestone crowded with *Rafinesquina*	8
Blue granular slightly phosphatic limestone in layers 3 to 12 inches thick with thin shale partings. Fossils weather out silicified, among them *Eridotrypa briareus*, *Rhynchotrema increbescens*, *Dalmanella* sp., and hemispheric bryozoa (base of formation not seen)	30

In the vicinity of Franklin the laminated and cross-bedded massive limestones of the Bigby increase in thickness to 80 feet but diminish northward, eastward, and southeastward until at Nashville, as noted in the general section elsewhere, the thickness is only 22 feet.

East of Nashville, in the section near Hermitage station, the Bigby although still maintaining its granular, laminated phosphatic character is only 30 feet thick. Northeast of Nashville the Bigby soon disappears, and the Cannon limestone is found resting upon the Hermitage, as shown in the various sections given under these two formations.

East of Bethesda, in the southeast corner of the Franklin quadrangle, this thinning of the Bigby and its final extinction can be followed in successive exposures to a point where the typical overlying basal dove beds of the Cannon limestone are seen to rest immediately upon the underlying sandy Hermitage strata.

In Rutherford County, except in a few places on the northwest edge where it overlaps from the west, the Bigby is reported by Galloway as absent. As shown in our general sections, the formation is absent from all of central Tennessee east of the western third of the Basin. In the southern part of the State the western edge of the Basin still shows a considerable thickness of the Bigby; at Pulaski and southward the formation is at least 60 feet thick. Southwest of Pulaski at Iron City, near the Alabama line, this limestone is present in wells, Miser reporting a probable total thickness of 90 feet.

The Bigby has been identified in central Kentucky by several authors, but in the opinion of the writer the strata so correlated are phosphatic layers well up in the equivalent of the Cannon formation. These Kentucky strata are the lower Paris beds called the Benson bed.

From the above distribution it seems evident that the Bigby did not cover the whole of the Nashville Dome but overlapped it from the west.

At least four well-marked phosphatic zones, distinguished from each other by their relative position, their fossils, and their lithologic characters, may be recognized in the Bigby and overlying Catheys. These zones have been described in some detail by Hayes and Ulrich in the Columbia folio, where it is shown that zones 1 and 2 form the main phosphate of the Mount Pleasant region and are indeed often mined as a single bed. Above them is zone 3 in the Catheys, characterized by an abundance of the branching stony bryozoan, the so-called "star coral" *Constellaria*, in the unleached rock. Zone 4 when unleached is a fine-grained laminated rock about 6 feet thick, underlying the Stromatocerium bed of the Catheys formation. The phosphate derived from this bed is soft and shalelike, but the presence of a large percentage of fine sand in the product makes this zone the least valuable of the four.

The fossils of the Bigby limestone are usually so fragmentary that it is difficult to make out a complete faunal list. Especially prominent in the rock are large species of straight cephalopods with conspicuous siphuncles, examples of which can be seen in many of the Nashville buildings, especially in the blocks forming the walls of the Capitol. A partial list of these fossils follows:

Fauna of Bigby limestone

Calcareous algae: *Solenopora compacta* Billings.

Sponges: *Hindia sphaeroidalis* Duncan var.

Bryozoa: *Eridotrypa briareus* Nicholson, *Constellaria teres* Ulrich and Bassler, and various undetermined species.

Brachiopods: *Rhynchotrema increbescens* Hall, *Hebertella frankfortensis* Foerste, *Lingulops norwoodi* James, *Dalmanella cfr. bassleri*, *Rafinesquina alternata* Conrad.

Cephalopods: *Actinoceras cuvieri* Troost (*A. capitolinum* Safford) and undetermined species of *Orthoceras* and *Cyrtoceras*.

Gastropods: *Cyclora minuta* Hall and the associated dwarf forms *C. pulcella* and *Microceras inornatum* Hall, *Cyrtolites retrorsus* Ulrich, *Hormotoma gracilis* Hall, *Archinacella patelliformis* Hall, *Lophospira oweni* Ulrich var., *Bellerophon clausus* Ulrich, var., *Bellerophon clausus* Ulrich, *Bucania* sp.

Pelecypods: *Ctenodonta obliqua* Hall, *C. subrotunda* Ulrich, *Lyrodesma* sp., *Byssonychia intermedius* Meek and Worthen, and *Clidophorus fabula* Hall.

CANNON LIMESTONE

While mapping the Woodbury quadrangle in the summer of 1908, Dr. E. O. Ulrich and the writer found that here all the Trenton strata above the Hermitage formation formed a unit of massive gray limestone interspersed with massive dove strata and some nodular and earthy layers. This was quite different from any of the formations of the Columbia quadrangle, the only area in central Tennessee which had been studied in detail. For use in mapping, the provisional name of Cannon limestone was given to this formation, although it was then believed that these strata contained representatives of the Bigby limestone and the Catheys formation, much changed in appearance from their type area of outcrop on the west. The name was published without definition in correlation tables included by Dr. Ulrich in his Revision of the Paleozoic Systems[7]. Later Galloway in his work on the Geology of Rutherford County recognized and mapped the Cannon formation as a distinct limestone unit between the Bigby and Leipers formations, stating, however, that it includes undifferentiated Bigby, Flanagan, Perryville, and Cynthiana strata, all of which would doubtless eventually be recognized in central Tennessee.

The present work on the Franklin quadrangle and neighboring areas has shown that the Bigby limestone thins out to a feather edge in the southeastern part of this quadrangle, and that farther east the Catheys limestone, which immediately overlies the Bigby in the Columbia quadrangle, becomes separated from it by a gradually increasing thickness of massive dove, blue and gray limestone that lithologically and faunally agrees exactly with the greater part of the Cannon formation in its type area. As the formation beneath it increases, the Catheys formation on the contrary, while maintaining its usual rock and fossil characters, decreases in thickness. In the Woodbury quadrangle the thin remnant of the Catheys formation was at first considered to be a part of the Cannon limestone, but as up to the present time the Cannon has neither been defined nor have sections of it been given in detail, the authors of the name prefer to exclude the Catheys portion, restricting the term Cannon to the formation of massive gray and dove limestone with occasional intermediate nodular and granular layers that occupies the interval between the Bigby limestone and the Catheys formation. Other names—Ward limestone, Dove limestone, and Cyrtodonta bed—have been applied to small members of this formation, but as they are not geographic terms it seems undesirable to recognize any of them in place of Cannon.

The recognition of the Cannon limestone as a distinct formation in the Central Basin is another example of the enlarging of the geologic column that has come about in recent years through the interpolation of additional geologic formations discovered in detailed stratigraphic studies over wide areas. Even the detailed work necessary for the preparation of the Columbia folio did not cause Hayes and Ulrich to suspect the presence of this new formation, for the good reason that the typical Bigby limestone is followed by the Catheys formation throughout the area mapped by them. The Dove and Ward limestones of the Nashville area seemed to be accounted for by their belief that the Bigby limestone lost more and more of its granular structure and phosphatic

[7] Geol. Soc. America Bull., vol. 22, No. 3, pp. 281-680, 1917.

content northward and northeastward until it was finally replaced by the massive dove and gray limestone now referred to the Cannon. Actual tracing of the strata and study of the contained fossils show that this is not the fact, because there are wide areas where a considerable thickness of Cannon limestone with its characteristic dove layers at the base occurs immediately above the full thickness of the typical Bigby limestone.

It should be noted that many geologists still believe that such a formation as the coarsely granular, phosphatic Bigby limestone with a fauna peculiar to itself changes laterally into the totally different rock types of the Cannon formation with quite distinct fossils, in other words, the Bigby and Cannon represent one and the same formation. The supposition of overlapping formations due to oscillation in the level of the ancient sea can only be proved by correlation of actual sections taken from place to place. So we have introduced a number of sections of the Cannon limestone, not only because of their stratigraphic interest but also because of the valuable phosphate deposits and building stone in the formation.

Type section—In Cannon County, the type area, the Cannon limestone with a thickness of 200 feet or more is fairly well exposed on many of the hillsides. It is usually overlain by the Chattanooga shale, thus making uncertain how much of the upper part may have been lost by pre-Mississippian erosion. The outcrop on the high hill in the northwest corner of the county, 1.5 miles east of Milton, has been selected as typical, because it preserves a representation of the overlying Catheys and the underlying Hermitage formations and thus gives definite upper and lower boundaries. The section here, as studied by Dr. Ulrich and the writer is as follows.

Section on hill at Cannon-Rutherford County boundary, 1.5 miles east of Milton, Tennessee

	Feet
Mississippian:	
Fort Payne chert overlying Chattanooga black shale.	
Ordovician:	
Catheys formation.	
Thin-bedded, blue, granular limestone weathering cobbly. Contains *Cyclonema varicosum*, *Hebertella sinuata*, *Platystrophia*, *Constellaria emaciata*, *C. teres*, *Orthorhynchula linneyi*, etc.	40
Cannon limestone	
Rather even bedded, impure limestone with mollusca	17
Argillaceous limestone with ostracoda (*Leperditia*)	15
Massive, granular limestone containing gastropods (*Lophospira*) and cephalopods	10
Massive, gray, argillaceous limestone containing large ostracods and a species of *Tetradium* with tubes arranged in small meshes (*T. ulrichi* n. sp.)	20
Gray, argillaceous limestone layers with *Isochilina ampla* and a species of *Tetradium* having single tubes	1

	Feet
Argillaceous limestone filled with *Stromatocerium pustulosum* and *Tetradium columnare*	25
Gray argillaceous limestone with mollusca and ostracoda (*Isochilina ampla*) abundant in lower part and *Tetradium fibratum* in upper	15
Massive, dark-blue, fine-grained limestone in 3 to 12 inch beds alternating with gray argillaceous limestone, much of the latter full of ostracoda. Fifty feet above base the *Cyrtodonta* bed occurs	70
Hermitage formation	
Granular, crinoidal, slightly phosphatic limestone	3
Sandy, argillaceous beds with limy layers crowded with bryozoa near the top and having the *Modiolodon oviformis* bed at the base	25

A considerable increase in thickness is shown in the section on the hill across East Fork, just northwest of Woodbury, where the Cannon limestone, although poorly exposed, extends from an altitude of 760 to that of 1,060 feet and exhibits the Hermitage below and the Chattanooga shale above. This would form an excellent type section were the strata better exposed.

The edge of the Highland Rim east of Woodbury exposes the Cannon limestone as follows: Massive, yellow to gray, argillaceous limestone 50 feet thick forms the upper beds, followed by the Chattanooga shale, the two formations being separated by a well-marked undulating unconformity. Next beneath the upper 50 feet is 100 feet of mottled, argillaceous, massive limestone, some layers with the typical gastropods; below this is 50 feet of similar strata with occasional dove beds.

Sections showing distribution of the Cannon limestone.—Reference to the section at Columbia, Tennessee, typical for the Columbia quadrangle in general, indicates that the *Constellaria emaciata* bed of the Catheys formation immediately follows the coarsely crystalline, gray Bigby limestone, which here is 33 feet thick. The same arrangement of strata exists in the southwest corner of the Franklin quadrangle, where 70 feet of typical Bigby limestone is succeeded by the *Constellaria emaciata* and *Stromatocerium pustulosum* beds of the Catheys formation. A few miles northeast a thin layer of the dove limestone forming the base of the Cannon formation appears and with a few feet of overlying granular strata referred to the Ward limestone intervenes between the Bigby and Catheys. Still farther east and northeast these two divisions of the Cannon thicken, until at the railroad cut northeast of Thompsons station, which is just west of the Columbia pike, the following section is clearly shown.

Section in cut on Louisville & Nashville Railroad half a mile northeast of Thompsons station, Tennessee

	Feet
Catheys formation	
Nodular, argillaceous limestone with *Constellaria emaciata* beds at the base (to top of hill)	80

	Feet
Cannon limestone	
Granular, blue, massive limestone with *Rhynchotrema increbescens* and other fossils of the Ward division	20
One layer of massive dove limestone thinning to extinction southwestwardly....	1
Bigby limestone	
Typical gray, massive, coarsely granular, semiphosphatic limestone (to bottom of cut).	

Continuing northeastward the intervening dove and blue limestones containing the Cannon fauna thicken rapidly, the dove limestone increasing to a thickness of 37 feet at the Rhodes quarry of the Franklin Lime Company 1½ miles southwest of Franklin. The Bigby and Catheys limestones retain their usual thickness, and the strata overlying the dove beds in the Cannon still average 20 feet in thickness. The details of this formation, copied from the general section on page 26 are as follows:

Section of Cannon limestone at Rhodes quarry, 1½ miles southwest of Franklin, Tennessee

	Feet
Catheys formation	
Nodular, clayey limestone at base containing *Cyclonema varicosum, Orthorhyncula linneyi*, etc.	
Cannon limestone	
Gray to blue, massive, laminated, semi-phosphatic limestone filled with *Rafinesquina alternata*	10
Clayey limestone made up of comminuted fossils, among which were recognized *Orthorhynchula linneyi, Platystrophia, Hebertella frankfortensis* var., bryozoa and various species of cyclorid shells	5
Finely crystalline to argillaceous, blue to gray limestone in beds 4 to 12 inches thick, weathering cobbly and containing small ostracoda, gastropods, and *Solenopora compacta*	5
Massive, pure, dove limestone with small *Scolithus* markings (*S. columbina*) many of the tubes filled with green iron silicate	15
Massive, fine-grained, sub-granular, gray limestone speckled with grains of green iron silicate	2
Blue to gray, massive, granular limestone with a 15-inch dove layer in the middle containing the characteristic elongate gastropod *Hormotoma columbina*	7
Massive dove limestone in beds 6 to 30 inches thick, pierced by small Scolithus tubes	12
Gray to flesh-colored coarsely crystalline limestone full of *Cyrtodonta grandis*...	1.5
Bigby limestone (at base of quarry).	

The following section just south of Franklin, extending from the top of Battlefield Hill down to the Columbia pike displays the details of certain zones not well shown elsewhere in the vicinity of Franklin.

Section at Battlefield Hill, just south of Franklin, Tennessee

	Feet
Cannon limestone	
Massive dove limestone in four layers, pierced by small *Scolithus* tubes (*S. columbina*) and containing *Leperditia tumidula* and species of *Isochilina* (to top of hill)	8
Dark-gray to blue, irregularly bedded, argillaceous limestone crowded with	

	Feet
Tetradium fibratum. Massive on fresh exposure but weathering irregularly and cobbly. *Orthorhynchula linneyi* is present	4
Pure dove limestone in three beds separated by an inch or two of shale. Small *Scolithus* tubes as well as a few gastropods present	5
Irregularly bedded, gray to brown, argillaceous to subcrystalline limestone filled with *Tetradium fibratum*, with impure dove beds at the top	7
Coarsely crystalline and porous ashen-gray to flesh-colored massive limestone containing many *Cyrtodonta grandis*	1.5
Bigby limestone.	
Typical thick-bedded, coarsely granular, phosphatic limestone to bottom of hill, not well exposed.	

On the way to Nashville the section seen where the Hillsboro pike crosses the Harpeth River illustrates not only the divisions of the Cannon limestone but also all the formations up to the Mississippian. This section occurs in one of the Silurian embayments, thus exhibiting the Fernvale formation. It commences at the water's edge under the bridge across Harpeth River and continues half a mile northeast to the top of the hill, 920 feet high. The Bigby limestone is well exposed in the river bank, and the dove and other layers of the Cannon limestone may be seen at the level of the road. There are excellent exposures of the Catheys formation, containing many fossils, on the hill west of the pike, the higher formations being seen only on the hills east of the pike.

Section on Harpeth River 5 miles northwest of Franklin, Tennessee

	Feet
Mississippian:	
Chattanooga black shale and overlying formations present starting at 845 feet, but outcrops absent to top of hill.	
Silurian:	
Fernvale formation	
Covered shale, probably Fernvale (Mannie)	10
Massive, coarsely crystalline limestone in beds 6 to 12 inches thick, the lower strata being dark red, the middle strata pink, and the upper gray and blue with green mottling	30
Ordovician:	
Cincinnatian:	
Leipers formation	
Thin-bedded, nodular, blue, clayey limestone with occasional intervening layers of shale. Fossils numerous, *Platystrophia ponderosa* particularly abundant in the lower part and the typical bryozoa and other Leipers fossils numerous in the higher beds	40
Mohawkian:	
Catheys formation	
Massive, fine-grained, argillaceous limestone giving a fetid odor upon fracture	30
Blue to dark-colored, clayey limestone weathering cobbly	35
Massive, granular, slightly phosphatic limestone	40
Thin-bedded, blue and gray, semicrystalline limestone and interbedded shale layers crowded with *Constellaria emaciata* and associated fossils	20

	Feet
Cannon limestone	
Blue to gray coarsely crystalline limestone, in beds 3 to 6 inches thick, weathering laminated and slightly phosphatic	20
Massive, crystalline, slightly phosphatic, blue-gray limestone with intervening shaly beds crowded with *Rhynchotrema increbescens*	10
Massive, brown-speckled, blue limestone in several layers, the upper layer 3 feet thick	6
Massive dove limestone in two layers, both with *Scolithus* borings (*S. columbina*)	2
Argillaceous gray to semi-dove limestone with *Leperditia*	2
Bigby limestone	
Typical massive, gray, phosphatic Bigby limestone exposed from the level of the road to the water's edge.	

Near Nashville the formation although still thin, indicating the nearness of the shore line on the west, shows considerable variation within a short distance. The thickness of 37 feet shown in the St. Cloud Hill section, given on a later page, increases to 67 feet in the following section. The lower part of this section, ending with the Bigby limestone, has been given in the general section at Nashville on a preceding page. Along the Tennessee Central Railroad the Cannon outcrops show slight variations from those in the exposure on St. Cloud Hill, which supplied the rest of the general section. Both sections are repeated below for reference, as these particular strata have been referred to by a number of authors. The lowest beds of the section are seen in the old quarry just behind the old City Hospital, formerly the Blind Asylum.

Section of Cannon limestone and associated formations along the Tennessee Central Railroad, Nashville, Tennessee

	Feet
Catheys formation	
Shaly beds and massive layers separated by thin shale bands, to top of formation.	
Shaly limestone crowded with large colonies of *Stromatocerium pustulosum* and *Columnaria alveolata*	4
Sub-granular limestone, massive when fresh, filled with *Constellaria teres*, *C. emaciata* and other bryozoa	3.5
Cannon limestone	
Rough crystalline limstone in one layer with uneven, ironstained upper surface. Fossils mainly *Rafinesquina alternata*	1.2
Shaly layer crowded with bryozoa	0.2
Irregularly bedded granular limestone with earthy seams containing bryozoa as in bed below. Two feet below the top occur *Rhynchotrema* (narrow species), *R. increbescens*, and *Hebertella frankfortensis*	10
Blue crystalline limestone and shale alternating in beds from 1 to 5 inches thick, all highly fossiliferous. Bryozoa (*Heterotrypa*) common; mollusca (*Vanuxemia*) in lower half	12.5
Crystalline limestone in thin beds with few shale partings. *Eridotrypa briareus*, etc., occur	4
Fine-grained, sparingly fossiliferous limestone with the top distinctly marked by an iron-stained layer	5.5
Limestone like bed above but less pure and less cobbly; fossils few	5.5

	Feet
Fine-grained, argillaceous limestone weathering cobbly with iron-stained layer in the middle. Massive bryozoa, *Rhynchotrema increbescens* and *Hebertella frankfortensis* not uncommon	7
Rather pure dove limestone changing into impure layers laterally and containing many ostracodes, particularly *Leperditia appressa*, and *Isochilina saffordi*. (False dove bed)	0.2
Massive, flesh-colored to ashen-gray, porous limestone with lenses of shells that silicify on weathering (Cyrtodonta bed)	10
Sub-granular blue limestone with chert nodules (Ward)	25
Pure, dove-colored limestone weathering into thin layers above and crowded with *Tetradium laxum* (True dove limestone—upper bed)	1.5
Impure argillaceous dark-gray limestone containing the gastropod *Hormotoma columbina* and at the top a layer of *Tetradium fibratum*	4
Massive pure dove limestone penetrated by markings of *Scolithus columbina*. Uppermost three inches filled with *Leperditia* species and *L. columbina*. An impure green shaly bed 2 ½ feet from the base (True dove limestone—lower bed)	6
Bigby limestone	
Massive, coarsely granular, laminated and cross-bedded, semi-phosphatic, grayish limestone in beds 1 to 6 feet thick, composed mainly of comminuted fossils	22

Even in still shorter distances the variations are considerable, for in places near Nashville, the Cyrtodonta bed between the true and false dove beds is represented by the following strata, which around Nashville have received the name of "Ward limestone."

Section of "Ward limestone" in vicinity of Nashville, Tennessee

	Feet
Massive, granular, fossiliferous limestone (upper part of *Cyrtodonta* bed)	2
Regularly laminated, blue limestone with few fossils	4
Subgranular, irregularly laminated limestone	10
Granular even-bedded limestone the upper 2 feet of which are fossiliferous and more crystalline. Six feet from the top occurs the hemispheric bryozoan bed. The upper 4 feet passes laterally into the lower part of the *Cyrtodonta* bed	14

In the St. Cloud Hill section at Nashville the pure dove beds are absent, the fine-grained limestone with numerous mollusca being most conspicuous.

Section of Cannon limestone on St. Cloud Hill, Nashville, Tennessee

	Feet
Catheys formation	
Thin-bedded, clayey limestone with *Constellaria emaciata* fauna at base.	
Cannon limestone	
Massive, crystalline limestone weathering into red, clayey débris; contains *Vanuxemia hayniana, Platystrophia elegantula-triplicata, Hindia parva, Rhynchotrema increbescens* and *Columnaria alveolata*	6
Shaly limestone with *Eridotrypa briareus* and other bryozoa	1
Massive, irregularly laminated, subgranular, gray limestone with few fossils, weathering into impure phosphate	6

	Feet
Fine-grained, argillaceous, massive limestone weathering into clay having siliceous fossils, particularly *Saccospongia danvillensis* and *Lophospira medialis*	1.5
Argillaceous, shaly limestone weathering cobbly	1.5
Massive, fine grained, argillaceous limestone yielding silicified fossils upon weathering, especially ramose bryozoa, *Saccospongia danvillensis, Strophomena vicina, Oxydiscus subacutus, Lophospira medialis, Hindia parva, Bellerophon troosti, Hebertella frankfortensis,* and *Rhynchotrema increbescens*	2
Crystalline, bluish, massive limestone containing *Hebertella frankfortensis.* Top plated with large *Stromatocerium pustulosum*	4
Fine-grained, bluish-gray to semi-dove, massive limestone weathering into porous chert and red clay; contains many silicified fossils, among which are *Saccospongia danvillensis, Tetradium columnare, Hindia parva, Zygospira recurvirostris, Hebertella frankfortensis, Rhynchotrema increbescens, Platystrophia amoena, Ctenodonta hartsvillensis, Byssonychia* sp., *Cyrtolites retrorsus, Bucania nashvillensis, Oxydiscus cristatus, Bellerophon troosti, B. clausus, Lophospira medialis, L. sumnerensis, Liospira,* and *Orthoceras*	15
Bigby limestone	
Massive, laminated and cross bedded, gray phosphatic limestone weathering into phosphate (exposed in railroad cut)	16

The foregoing sections illustrate the characters of the Cannon limestone along the west side of the Basin. Nearer the center of the Basin the following section, measured on the hill near Hermitage station, between Stones Creek and the Lebanon-Nashville and Central pikes, shows the changes that occur and illustrates particularly the increase in thickness of the Cannon limestone and the diminution and final extinction of the Bigby.

Section of Ordovician formations near Hermitage station, Tennessee

	Feet
Cannon limestone	
Blue, granular limestone weathered into phosphate	6
Dove limestone with *Leperditia* and *Camarocladia*	3
Shaly limestone with *Hebertella frankfortensis, Rhynchotrema,* and *Strophomena*	4
Massive, fine-grained, gray limestone with *Leperditia* and small ostracoda	2
Shaly limestone, mainly covered	5.5
Massive dove limestone	9
Clayey limestone crowded with *Tetradium fibratum*	1.5
Blue-gray, granular, subcrystalline limestone	3.6
Fine-grained dove limestone	2
Fine-grained gray limestone with ostracoda	6
Blue-gray, granular, slightly phosphatic limestone	2
Massive dove limestone	3
Fine-grained gray limestone with ostracoda	1.5
Fine-grained to subcrystalline, drab-gray limestone containing gastropods, *Oxydiscus,* etc., in abundance	2.6
Dove limestone	2
Bigby limestone	
Laminated, subgranular to granular, phosphatic limestone	30
Hermitage formation	
Siliceous, blue, fine-grained limestone weathering into sandy phosphate.	

The following section commences about a mile and a half west of Harvey Knob, where the argillaceous, flaggy limestone and shale of the Hermitage formation are exposed, and continues eastward through a typical development of the Bigby limestone up Harvey Knob through the Cannon and Catheys formations, all well exposed, to an altitude of 1,090 feet, where the Black shale is reached. In contrast to the few feet developed along the west edge of the Franklin quadrangle, less than 10 miles away, the Cannon limestone has increased here to almost 200 feet, but owing to the dip of the strata, which follows in part the slope of the hill, the determination of all its divisions is difficult.

Section at Harvey Knob, 5 miles east of Franklin, Williamson County, Tennessee

	Feet
Mississippian:	
Chattanooga black shale (10 feet) at elevation of 1,090 feet, followed by Ridgetop shale and Fort Payne chert to the top of the hill.	
Ordovician:	
Catheys formation	
Thin-bedded, nodular, clayey, fossiliferous limestone and yellow shale with many ramose bryozoa, *Tetradium fibratum*, *Orthorhynchula linneyi*, etc..	20
Heavy-bedded, fine-grained, compact, argillaceous limestone, giving a fetid odor upon fracture. Fossils, mainly gastropods and cephalopods, abundant, but usually seen only as cross sections in the rock...........	35
Nodular blue limestone weathering cobbly...........................	25
Massive, gray and blue-speckled, granular, semiphosphatic limestone, in places weathering into thin laminae...............................	50
Thin-bedded, blue, granular limestone interbedded with yellow shale. *Constellaria emaciata* and associated fossils very abundant at the base..	25
Cannon limestone	
Dull-gray to brown, fine-grained limestone with some blue, granular beds, occasionally cross-bedded and semiphosphatic, weathering into chert and yielding silicified examples of *Columnaria alveolata*, *Stromatocerium pustulosum*, and many gastropods................................	20
Typical dove limestone in 1 to 2 foot layers..........................	6
Massive, brown-speckled, granular limestone..........................	20
Dove and mottled dull-gray, massive limestone........................	15
Nodular argillaceous and gray massive limestone with certain layers containing many colonies of *Tetradium fibratum*.......................	20
Fine-grained, impure, gray limestone with *Columnaria alveolata* and gastropods abundant..	45
Massive, brown to gray, argillaceous limestone yielding chert and silicified fossils upon weathering..	30
Dove limestone in one layer..	2
Gray, fine-grained limestone weathering into yellow platy chert...........	20
Pure dove and impure gray limestone in beds 6 to 18 inches thick.........	10
Bigby limestone	
Massive, gray and blue, coarsely crystalline laminated cross-bedded, limestone with phosphatic streaks...................................	40
Hermitage formation	
Blue shales and thin, flaggy, argillaceous limestone......................	40+

Although a similar succession is shown near Peytonsville, about 10 miles southeast of Franklin, 5 miles south of this point, near Bethesda, the Bigby limestone has thinned out to nothing.

Section along road and up hill 1½ miles northwest of Peytonsville, Williamson County, Tennessee

	Feet
Mississippian:	
Chattanooga black shale, Ridgetop shale, and Fort Payne chert (mainly covered).	
Ordovician:	
Catheys formation	
Massive, fine-grained to argillaceous, fetid limestone in upper part, bluish granular and cobbly limestone with *Cyclonema varicosum* and *Stromatocerium pustulosum* in the middle, and strata crowded with *Constellaria teres* and *C. emaciata* at the base	70
Cannon limestone	
Fine-grained dark-blue limestone in layers 3 to 6 inches thick	5
Blue, crystalline limestone in 2 to 6 inch beds with *Columnaria alveolata* and *Stromatocerium pustulosum*	25
Massive, coarsely crystalline, blue and pink, semi-phosphatic limestone with many hemispheric bryozoa in the basal bed	30
Massive gray, argillaceous, irregular limestone crowded with *Tetradium fibratum*	6
Typical massive dove limestone in layers 1½ to 2½ feet thick, showing on weathered surface specimens of the gastropod *Hormotoma columbina*	20
Bigby limestone	
Massive, laminated, phosphatic, gray limestone	30
Hermitage formation	
Unfossiliferous clayey and sandy shale with sandstone beds at top	80

The absence of the Bigby limestone is to be noted in the following section, although 2 miles north coarsely crystalline, phosphatic limestone 2 feet thick, which can be traced westward into the typical Bigby, appears between the Hermitage and the Cannon.

Section on hill 1.6 miles east of Bethesda, Williamson County, Tennessee

	Feet
Mississippian:	
Chattanooga black shale forming upper 30 feet of hill (1,050-1,080).	
Ordovician:	
Catheys formation	
Massive, fetid limestone in upper part, nodular cobbly layers beneath, with thin-bedded strata containing many bryozoa at base	100
Cannon limestone	
Compact, gray-blue limestone in thin even beds	10
Laminated, coarsely crystalline, semiphosphatic, gray-blue limestone crowded with bryozoa	10
Yellow shales and thin, nodular limestone strata yielding many *Rhynchotrema increbescens* and *Hebertella frankfortensis*	6
Massive, coarsely crystalline, laminated, phosphatic limestone, pink, gray, and blue, crowded with hemispheric to rounded bryozoa 1 to 3 inches in diameter (*Cyphotrypa*)	2

	Feet
Thin-bedded clayey limestone and yellow shales with many fossils, particularly *Rhynchotrema increbescens*, *Hormotoma bowdeni*, bryozoa, *Strophomena vicina*, and *Rafinesquina alternata*, weathering free	6
Blue to gray, massive, laminated, granular limestone weathering into phosphate that analyzes 80 per cent of lime phosphate	25
Knotty, irregular, blue limestone	5
Crystalline blue limestone with many examples of *Solenopora compacta*	1
Massive, fine-grained, gray limestone containing *Tetradium laxum* and *Cyrtodonta*	4
Irregular, argillaceous, gray limestone containing *Tetradium fibratum*	6
Massive dove limestone pierced by the small tubes of *Scolithus columbina* and containing the gastropod *Hormotoma columbina*	25
Hermitage formation	
Arenaceous, blue to gray, unfossiliferous limestone weathering into brown sandstone layers 1 to 3 inches thick	20
Thin-bedded, argillaceous, blue limestone and interbedded blue shale with few fossils	60

Still farther east the following section, exposed near the boundary line between Williamson and Rutherford Counties, is interesting for the increase in thickness of the formation but with the characteristic dove beds containing *Hormotoma columbina* at the base.

Section 1 mile south of Allisona, Tennessee

	Feet
Catheys formation	
Irregular, knotty, argillaceous limestone at base with *Constellaria emaciata* fauna.	
Cannon limestone	
Gray-blue, granular limestone with *Goniophora* at the top and *Solenopora* (variety with concentric base) at the bottom	10
Massive, coarsely crystalline, brown-speckled, blue limestone with the Cyrtodonta bed developed near the top. *Hebertella frankfortensis* (fine lined), *Lophospira sumnerensis* and other gastropods well developed	35
Argillaceous, brown limestone yielding abundant chert. Gastropods occur at the top, and *Dinorthis ulrichi* and *Strophomena vicina* are abundant in the lower part	8
Irregularly bedded, grayish, fine-grained limestone yielding many *Rhynchotrema increbescens*	2.5
Shaly layers with a 10-inch impure dove limestone in the middle	2
Subgranular, fine-grained, massive limestone with clay seams and chert nodules. *Hebertella frankfortensis* abundant	5
Massive dove limestone in six or seven layers with the upper half thinner bedded than the lower. Small *Scolithus* (*S. columbina*) markings present throughout, and the lower part contains a *Tetradium* reef. The ostracoda *Leperditia* sp. and *L. columbina* not uncommon	17
Massive, grayish-blue, granular limestone crowded with valves of *Cyrtodonta grandis*	3
Massive dove limestone with *Tetradium laxum*	2
Fine-grained, dark-blue, granular limestone showing many gastropods on the surface	2
Stratum of dove limestone	1
Cross-bedded, fine-grained limestone with edgewise conglomerate developed in upper half	6

	Feet
Massive, pure dove limestone containing the large gastropod, *Hormotoma columbina*. Basal part shaly but lowest layers full of chert and gastropods..	13
Hermitage formation	
Massive, laminated, sandy limestone with a few layers exhibiting *Dalmanella fertilis;* weathers into sand, sandy blocks, and impure sandy phosphate...	20
Dark-blue unfossiliferous strata (to bottom of railroad cut)...................	5

A few miles east of Columbia the Cannon has developed 37 feet of strata with the usual dove limestone layer at the base. The section at this locality follows:

Section along Bear Creek pike on the west side of Loftin Hill, 8 miles east of Columbia, Tennessee

	Feet
Mississippian:	
Fort Payne chert.	
Chattanooga black shale..	5
Ordovician:	
Leipers formation	
Nodular, earthy shale and shaly, blue, impure limestone with *Platystrophia ponderosa*, etc..	50
Catheys formation	
Shaly and argillaceous to subgranular limestone with subcrystalline limestone and shale crowded with *Constellaria emaciata* at the base..........	28
Cannon limestone	
Laminar, grano-crystalline limestone weathering into thin platy phosphate.	10
White and grayish oolite crowded with fossils, particularly gastropods, *Lophospira sumnerensis, Bucania, Oxydiscus*, etc.....................	10
Grano-crystalline, phosphatic limestone..............................	9
Dove limestone..	8
Bigby limestone	
Gray, subcrystalline limestone..	2+

South of the Columbia quadrangle the Cannon limestone reappears in the northern part of Giles County and increases in thickness to about 90 feet in the vicinity of Pulaski.

Section of Cannon limestone near Pulaski, Tennessee

	Feet
Catheys limestone	
Blue, granular, massive and shaly limestone, much of it weathering cobbly, with the *Constellaria emaciata* beds at the base..............................	32.5
Cannon limestone	
Covered interval with much platy chert, derived probably from blue to gray massive limestone..	25
Blue shale crowded with fossils, particularly *Eridotrypa briareus* and other bryozoa, sponges, gastropods (*Lophospira saffordi, L. medialis*, etc.), *Platystrophia* and other brachiopods, *Enopleura punctata*, etc.............	15
Covered interval	5
Granular, blue limestone full of *Solenopora compacta*..........................	5
Massive, granular, semiphosphatic, gray-blue, speckled limestone............	15

	Feet
Thin-bedded fossiliferous clayey limestone and shale with abundant *Rhynchotrema increbescens*, massive bryozoa, etc	8
Massive, gray-brown, speckled, granular limestone laminated and cross-bedded, resembling the Bigby	15
Dove limestone layers filled with *Scolithus* markings	1
Bigby limestone	
Massive, laminated and cross-bedded, coarsely crystalline, blue and gray phosphatic limestone	60

The southernmost part of the Central Basin in Tennessee shows essentially the same section as at Pulaski, differing only in the decreased thickness of the Cannon limestone.

Section on road from Aspen Hill to Prospect, along hill 2 miles southeast of Lester, Giles County, Tennessee

	Feet
Rest of section to top of hill obscured by cover of Fort Payne chert. Leipers formation and Chattanooga shale probably present.	
Catheys formation	
Thin-bedded argillaceous limestone full of *Constellaria* and other bryozoa at base, above which are more massive layers with *Stromatocerium pustulosum.*	
Cannon limestone	
Thin-bedded, laminated, semiphosphatic limestone with an occasional layer containing the *Lophospira sumnerensis* gastropod fauna	20
Gray argillaceous limestone layers 6 to 12 inches thick at top, massive beds of dove limestone in lower part	25
Dove limestone layers filled with *Scolithus*	1
Bigby limestone	
Massive, laminated and cross-bedded, coarsely crystalline, blue and gray phosphatic limestone with large cephalopods at top	60
Hermitage formation	
Massive, laminated, phosphatic limestone at top with many zones filled with *Dalmanella fertilis*	25+

Farther east, in Lincoln County, a part of the Cannon limestone exposed at and near the stone bridge at Fayetteville, shows details as represented in the following section.

Section of Cannon limestone at Fayetteville, Tennessee

	Feet
Massive clayey limestone with several beds of blue, granular and crystalline strata. Fossils few	16
Covered but with chert residue	6
Limestone similar to underlying bed but less laminar and with chert nodules. Fossils few but *Saccospongia danvillensis* present	8
Massive, laminated, clayey limestone, solid in the quarry but breaking up into thin plates under the weather	6
Light-colored limestone becoming clayey in upper half, crowded with *Hebertella*, *Rafinesquina*, and *Rhynchotrema increbescens*	6
Bluish, dark-gray, fine-grained limestone with *Leperditia*, *Hormotoma salteri*, *Oxydiscus subacutus*, and *Tetradium apertum*	4.5
Dove limestone with *Scolithus* markings	1
Clayey, white, slightly arenaceous limestone	2
Dove limestone with *Scolithus*	5.5
Dove-colored shaly limestone	2.5

The succession of Ordovician rocks in the northern part of Giles County is best shown at Clear Creek near Deray.

Section at Clear Creek, 2 miles west of Deray, Giles County, Tennessee

	Feet
Catheys formation	
Covered to top of hill, which is capped by Fort Payne débris.	
Gray-blue, argillaceous to subgranular limestone in 6-inch beds separated by shale; contains an abundance of *Constellaria emaciata* and associated fossils..	12
Thin-bedded, gray-blue, argillaceous limestone and clay shale weathering cobbly. *Constellaria emaciata* abundant..........	12
Cannon limestone	
Light-pink to dove-colored, massive limestone with large pelecypods..........	3
Massive, subgranular to crystalline, slightly phosphatic limestone weathering rough and pitted. *Rhynchotrema increbescens* and gastropods abundant....	22
Irregular, thin-bedded, grayish, speckled, phosphatic limestone with many large *Solenopora*..........	6
Thin-bedded, blue, clayey, fossiliferous limestones..........	6
Thin-bedded, argillaceous, gray-blue limestone with abundant fossils, particularly *Rhynchotrema increbescens*..........	6
Irregularly bedded limestone in 2 to 3 inch layers ranging from gray, argillaceous to coarsely crystalline, weathering nodular; crowded with a hemispheric species of *Hemiphragma* and *Eridotrypa briareus*..........	18
Bigby limestone	
Gray, fine to medium grained, crystalline, slightly phosphatic, limestone in one bed, weathering rounded..........	4
Massive, cross-bedded, coarsely crystalline, phosphatic limestone yielding thin plates and flakes of phosphate on weathered surfaces..........	45
Hermitage formation	
Thin-bedded, bluish-gray, siliceous, clayey limestone giving impure phosphatic, sandy beds upon weathering. *Dalmanella fertilis* rare..........	50
Thin-bedded, argillaceous and arenaceous limestone weathering into slightly phosphatic sandstone..........	20
Carter limestone	
Massive dove and dolomitic limestone.	

Sections northeast of Nashville.—North and northeast of Nashville, in the range of counties along the north edge of the Basin, the Cannon limestone becomes increasingly fossiliferous. Some of the beds, especially those weathering into siliceous débris, being a mass of mollusca. The following section extends from Dry Creek to the north end of the railroad cut along Cumberland River, a distance of about a mile.

Section of Cannon and Catheys formations, at Edgefield Junction, Tennessee

	Feet
Catheys formation (upper beds not shown).	
Light-colored, nodular, shaly limestone crowded with fossils, particularly *Orthorhynchula linneyi* and *Hebertella sinuata*, *Tetradium fibratum* and *Cyclonema varicosum*..........	6
Granular limestone in many beds, with *Heterotrypa* and *Rhinidictya*..........	6
Clayey, bluish, limestone and shale with few fossils, mainly *Stromatocerium pustulosum*..........	40

	Feet
Cannon limestone	
Thin-bedded, light-colored, nodular, shaly limestone with large masses of *Columnaria alveolata*, *Tetradium apertum*, *Oxydiscus cristatus*, and bryozoa	2
Bluish, heavy-bedded, subcrystalline, nodular limestone	14
Covered area but probably nodular limestone	15
Thin-bedded and heavy-bedded, bluish, nodular limestone, lower half fossiliferous with *Rhynchotrema increbescens* and *Cyrtolites retrorsus* and upper half giving rise to impure phosphate	12
Massive dove limestone, the upper layer especially filled with *Scolithus* markings	5.6
Gray to blue, grano-crystalline limestone without ostracoda	13
Blue and dove, fine-grained limestone with many ostracoda (*Leperditia*, etc.)	14
Laminar, fine-grained, clayey limestone, light-colored below and dark-blue above	4
Nodular, fine-grained, dark-gray limestone with *Tetradium fibratum* and many *Leperditia*	3

Many exposures along the roads and on the hillsides in Trousdale County, particularly in the vicinity of Hartsville, give opportunity for a more detailed study of the individual beds of the formation, especially of the characteristic molluscan faunas that weather out of the limestone in a silicified condition. The section of the Cannon portion of this area is repeated below with the faunas listed in more detail.

Section of Cannon limestone near Hartsville, Tennessee (west and north)

	Feet
Catheys formation	
Nodular, shaly, blue, crystalline and fine grained, argillaceous limestone with *Cyclonema varicosum* and bryozoa at the base.	
Cannon limestone	
Fine-grained, dirty-gray limestone weathering into silicified gastropods and bryozoa; *Lophospira bowdeni* abundant in upper part, also *Eridotrypa briareus*, *Columnaria alveolata*, *Saccospongia danvillensis*, *S. laxata*, *Oxydiscus subacuta*, *Lophospira saffordi*, *Bellerophon troosti*, etc	10
Irregularly bedded, blue, crystalline limestone with a few shale layers containing *Eridotrypa briareus*	4
Granular, brown-speckled limestone weathering into impure phosphate	5.5
Massive dove and crystalline limestone, the latter with abundant bryozoa and gastropods particularly *Lophospira sumnerensis* and *L. saffordi*	6
Fine-grained, massive limestone with *Lophospira saffordi*, *L. sumnerensis*, and many other gastropods	8
Dove-colored shaly limestone in thin layers, the lower beds with green specks and containing a few ostracoda	4.5
Fine-grained gray limestone full of gastropods	4
Dove limestone without *Scolithus* markings	1.5
Dark-gray limestone with ostracoda (*Leperditia*)	1
Massive dove limestone with small *Scolithus* markings	2
Covered, but the siliceous débris that results from weathering contains gastropods, particularly *Lophospira sumnerensis* and *Hebertella frankfortensis*	3
Sublaminar, impure limestone with *Stromatocerium* and *Tetradium;* also crinoid stems 0.25 to 0.37 inch in diameter	5

	Feet
Grayish to dove-colored limestone partly even bedded and partly nodular, weathering rapidly and exhibiting many fossils in the débris, particularly large *Stromatocerium* in the lower part. *Vanuxemia hayniana* in several layers, and *Lophospira sumnerensis, Tetradium columnare, Rhynchotrema increbescens,* and *Hebertella frankfortensis* in the upper part	17
Nodular limestone with few recognizable fossils but containing many large examples of *Tetradium laxum*	13
Fine-grained, even-bedded limestone in 2 to 20 inch layers, disintegrating rapidly on exposure and liberating many silicified gastropods, sponges, and pelecypods	13
Fine-grained, mostly crystalline limestone, the upper 2 to 4 feet filled with masses of *Tetradium columnare*	9
Hermitage formation	
Shale below and hard clayey layers above containing *Tetradium minus.* The lower foot or two crowded with massive and convoluted bryozoa (*Amplexopora cerebrum*)	6.5
More or less granular, impure, phosphatic limestone with many *Rafinesquina alternata* in upper part	15
Sandy shales with *Dalmanella fertilis, Prasopora patera,* etc. (Base not seen.)	22+

The details of the Cannon limestone are well shown in the section exposed at the hill on the Hartsville-Carthage pike 4.5 miles east of Hartsville.

Section of Cannon limestone 4.5 miles east of Hartsville, Tennessee

	Feet
Cannon limestone (to top of hill).	
Laminated, light-gray to blue, subgranular limestone with several layers crowded with *Rafinesquina*	22
Clayey limestone crowded with gastropods (*Lophospira bowdeni,* etc.) and *Modiolopsis*	8
Blue nodular limestone with fossils at several horizons	24
Laminar blue limestone becoming crystalline in upper part	12
Nodular, shaly limestone with solid ramose bryozoa and *Rafinesquina*	9
Blue limestone with gastropods, *Columnaria, Stromatocerium,* and pelecypods weathering out siliceous	6
Somewhat laminated, finely crystalline, light-blue limestone	6
Shale and shaly limestone with bryozoa and *Rafinesquina*	3
Laminated, granular, slightly phosphatic limestone	2
Irregularly bedded, dark-gray limestone yielding many silicified fossils upon weathering (*Eridotrypa briareus, Columnaria, Stromatocerium,* and *Lophospira saffordi*)	6
Light-colored, massive limestone giving many gastropods (*Lophospira saffordi,* etc.) upon weathering	11
Argillaceous limestone with bryozoa (*Hebertella, Tetradium laxum*), and at the top ostracoda (*Leperditia,* etc.)	4
Dark-gray limestone with abundant gastropods and large masses of *Stromatocerium pustulosum*	4
Clayey, somewhat nodular limestone with bryozoa and *Hebertella* abundant	6.5
Dark-gray limestone; weathering frees many gastropods	3
Dove limestone with *Scolithus columbina*	2
Light-gray limestone having large crinoid stems and many *Rhynchotrema increbescens*	5
Massive, dark-gray limestone with a few gastropods	10

	Feet
Nodular limestone without fossils	7
Dark-gray, massive, argillaceous limestone yielding on weathering many silicified gastropods and *Tetradium laxum* and having the peculiar hydrozoon *Cryptophragmus arbusculus*	12
Hermitage formation	
Sandy shales with few fossils	20

The stratigraphic relationship of the Lower Trenton formations is well shown in the section exposed 3½ miles south of Alexandria in easternmost Wilson County. Here the dove layers with *Scolithus* of the lower Cannon limestone are not developed, but the horizon is well marked by the characteristic fossil *Cryptophragmus arbusculus*. The Hermitage in this region is more shaly than usual.

Section 3½ miles south of Alexandria, Tennessee

	Feet
Cannon limestone	
Massive, nodular limestone (higher beds covered)	9
Even-bedded, gray limestone with layers having the branching hydrozoon *Cryptophragmus arbusculus*	8
Nodular limestone with *Tetradium fibratum* abundant	9
Hermitage formation	
Nodular, clayey limestone with *Tetradium minus* and *Rhynchotrema increbescens*	7
Shaly limestone becoming sandy toward the top; a layer at the base contains many *Cyrtolites retrorsus*	15
Sandy shale (to base of exposure)	5

The following two sections in Smith County show that in this area the dove limestones are not well developed, although the characteristic gastropod faunas are present in the rocks as elsewhere.

Geologic section at Monoville post office, 4 miles northwest of Carthage, Tennessee

	Feet
Catheys formation	
Argillaceous limestone and shale not well exposed. *Cyclonema varicosum* and other characteristic fossils present	40
Cannon limestone	
Nodular limestone	16
Clayey limestone with *Vanuxemia* and *Cyrtodonta* as well as *Lophospira sumnerensis* and other gastropods	24
Argillaceous limestone with many gastropods and pelecypods; bryozoa and the brachiopod *Hebertella* abundant	20
Heavy-bedded limestone with *Stromatocerium pustulosum*	6
Rough-bedded limestone with gastropods	11
Even-bedded limestone with crinoid-column layer at base	11
More or less massive limestone with *Vanuxemia hayniana* and other large pelecypods in the middle third	40
Shale and more or less nodular, gray, fine-grained limestone with a few bryozoa and *Tetradium* in the upper half and *Tetradium fibratum* and *Columnaria alveolata* in the lower	6

	Feet
Laminated, sandy limestone forming an introductory deposit of reworked material	5
Hermitage formation	
Shale and nodular limestone full of *Dalmanella fertilis*, bryozoa, and *Lichenaria globularis*	12

Section along hill on Hartsville-Carthage pike just north of Carthage, Tennessee

	Feet
Catheys formation (base only shown).	
Nodular, argillaceous limestone crowded with bryozoa (*Constellaria emaciata*, *C. teres*, *Eridotrypa mutabilis*, *Monticulipora* n. sp. etc.), *Zygospira recurvirostris*, *Rafinesquina alternata*, *Hebertella sinuata*, etc	8
Cannon limestone	
Fine-grained, argillaceous limestone with many gastropods, ostracoda, *Vanuxemia* and *Modiolopsis*, and large masses of *Tetradium columnare* at bottom	6
Clayey, nodular limestone having few bryozoa (*Eridotrypa briareus*), *Cyrtodonta*, *Stromatocerium*, and *Rafinesquina*	10
Massive limestone with *Rhynchotrema* and the gastropods *Bellerophon troosti*, *B. clausus*, *Cyrtolites*, *Lophospira*, and large, broad *Bucania* as well as many silicified bryozoa and *Tetradium columnare*	10
More even bedded limestone. A thin, shaly layer with a 20-inch bed in middle and an 18 to 20 inch bed at top, the latter full of *Tetradium laxum*	10
Somewhat nodular limestone with *Hormotoma salteri*, *Bellerophon troosti*, *Lophospira sumnerensis*, *Rhynchotrema increbescens*, *Saccospongia danvillensis*, and *Rhinidictya*	7
Fine-grained limestone with abundant mollusca, *Tetradium*, and two beds of *Hebertella* and *Rhynchotrema increbescens*	8
Even-bedded limestone with the basal beds containing the hydrozoan *Cryptophragmus arbusculus* (lower beds not well exposed)	18

Distribution and lithologic divisions.—Examination of the various sections just presented and of the general sections on preceding pages shows that the Cannon limestone does not appear in outcrops west of the Central Basin but commences as a thin formation of dove and nodular layers overlapping the Bigby limestone and overlain by the Catheys formation in areas surrounding the Columbia region. It increases in thickness northeast, east, and southeast until in the type area of outcrop, around Woodbury in Cannon County, it is more than 300 feet thick. It is the predominating Ordovician formation of the eastern side of the Basin. Passing under cover of the Highland Rim and Cumberland Plateau, where it is exposed in the Sequatchie Valley with a thickness of 175 feet, it crops out on the west side of the Appalachian Valley, but farther east it disappears. It likewise disappears north of Kentucky but is well developed along the southern edge of the Central Basin. Evidently its sea of deposition invaded this area from the Gulf of Mexico region. It is not the equivalent of the Bigby in places where the latter is absent, because its basal dove layers with thin characteristic fossils can be traced over wide areas, overlapping the underlying formations.

Further reference to the sections shows that in general six or more distinct types of rock make up the formation. Along the eastern side of the Basin in the typical area of outcrop a considerable part of it is made up of a fine-grained, dull-gray, impure limestone with massive dove layers near the base. Here the Cannon is the predominant limestone formation and outcrops, especially on the slope to the Highland Rim, are abundant. Its charactertistics in this area, where the thickness is shown to be as much as 250 feet, have been given in the Snows Hill, Woodbury, and Normandy portions of the general geologic sections. Throughout the Hollow Springs quadrangle the thickness in many places exceeds this figure, at some localities reaching 300 feet. Dove layers are so common among the lower beds of the formation in the western half of the Basin that the terms true and false dove beds were instituted by earlier workers. These dove layers are usually pierced with *Scolithus* tubes or contain large ostracods and the characteristic elongate gastropod, *Hormotoma columbina*. Their surface, in many places divided into the regular polygons formed by shrinkage cracks or sun cracks, indicates that these rocks are of lagoon or tidal-flat origin. Above the dove beds there is usually granular, blue, some of it brown-speckled, limestone, weathering phosphatic, and light-gray to blue, argillaceous to subcrystalline limestone, some of the layers of which are crowded with large and small ostracods, particularly *Isochilina ampla* and *Leperditia tumidula*.

The nodular limestones in the formation are most often noted on the west side of the Basin, and in the vicinity of Nashville such beds associated with the dove limestone have received the special name of Ward limestone. These layers have most frequently an abundance of *Tetradium*. Throughout the Basin the formation contains massive fine-grained to coarse, granular limestone filled with fossils particularly mollusca, which by weathering are changed to siliceous pseudomorphs left free in the soil. These limestones occur at intervals throughout the formation and contain essentially the same fauna at each horizon, namely the *Lophospira sumnerensis* fauna, named from a characteristic gastropod. Lastly at several horizons there are locally gray to blue, laminated, semiphosphatic limestones, which at places weather into a phosphate of a grade high enough for mining.

The basal dove limestones of the Cannon are so conspicuous in most sections of the formation that as noted before they have received special mention from students of Tennessee stratigraphy. These limestones are composed of compact fine-grained, brittle, dove-colored, rather pure limestone, which breaks with a conchoidal fracture and contains stringers or tubes like worm borings, most of them filled with calcite but some with glauconite. These tubes resemble the supposed worm tubes of *Scolithus* in other formations and because of their special characters have here received the name *Scolithus columbina*. The dove beds of the Nashville area, where they have long furnished excellent building stone, are separated into a lower true-dove bed and an upper false-dove bed by a massive porous limestone filled with the bivalve *Cyrtodonta*.

The *Cyrtodonta* bed, as shown in the railroad cut along the Cumberland River at Nashville, is a massive, flesh-colored to ashen-gray, porous limestone crowded with pelecypods (*Cyrtodonta* and *Vanuxemia*), gastropods, etc. Where in the reef form the shells occur in lenses which tend to silicify. The *Cyrtodonta* bed passes laterally into beds, many of which are dovelike, also into crystalline, dark-blue, limestone indistinguishable from the usual blue limestone. This change within short distances has been noted in the Nashville section, given on a previous page.

The dark-blue, coarsely crystalline limestone lying immediately above the true and below the false dove limestone was designated the Ward limestone by Jones in 1892. As shown in the preceding sections, this same interval in other places is occupied by the Cyrtodonta bed, which changes laterally into the Ward limestone within short distances.

The upper, false-dove bed, containing many ostracods (*Leperditia*, etc.), is a rather pure dove limestone, which changes laterally into impure layers but does not replace the *Cyrtodonta* bed, as stated by some authors. Instead this dove bed thickens and thins, and lies upon the Cyrtodonta bed, the contact being undulating. In the vicinity of Nashville this bed ranges from 2 to 5 feet in thickness and makes a good horizon marker for the region. East of this area, however, more than one dove bed occurs above the basal one, so that it is impossible to distinguish this particular upper dove bed. Again in some sections the basal dove bed is absent, and a 3 to 5 foot bed of coarsely granular gray limestone full of *Cyrtodonta grandis* introduces the Cannon.

Above the typical basal dove and Cyrtodonta beds of the Cannon, as shown especially in the section a mile south of Allisona, are argillaceous brown limestones with gastropods and the brachiopods *Dinorthis ulrichi* and *Strophomena vicina*. The latter two species occur in Kentucky for the first time in the Benson member of the Flanagan limestone, which may represent the base of the Cannon in that State. The Benson member, however, has been taken to be of Bigby age by Ulrich who regards the presence of the two fossils mentioned in the Tennessee Cannon strata as a recurrence of the Bigby fauna.

The conspicuous fossils in these different types of strata are noted in the sections, but much detailed work is still necessary upon the various faunas. The *Lophospira sumnerensis* fauna noted above, repeated in so many of the various layers, has, however, been fairly well described, and so a more or less complete list can be given as follows:

Fauna of the Cannon limestone

Calcareous algae: *Solenopora compacta* Billings.

Sponges: *Saccospongia danvillensis* Ulrich, *S. massalis* n. sp., *S. laxata* n. sp., *Hindia parva* Ulrich.

Hydrozoa: *Cryptophragmus arbusculus* n. sp., *Stromatocerium pustulosum* Safford.

Corals: *Tetradium fibratum* Safford, *T. columnare* Hall, *T. saffordi* n. sp., *T. ulrichi* n. sp., *T. laxum* n. sp., *Columnaria alveolata* Goldfuss.

Cystids: *Enopleura punctata* n. sp.

Bryozoa: *Eridotrypa briareus* Nicholson; various undetermined species.

Brachiopods: *Dinorthis ulrichi* Foerste, *Hebertella frankfortensis* var., *Orthorhynchula linneyi* (James), *Platystrophia globosa* McEwan, *P. elongata* McEwan, *P. elongata triplicata* McEwan, *P. amoena* McEwan, *Zygospira recurvirostris* Hall, *Rhynchotrema increbescens* Hall, *Rafinesquina alternata* Conrad var., *Strophomena vicina* Foerste.

Gastropods: *Bucania lindsleyi* Safford, *B. peracuta* Ulrich, *B. nashvillensis* Ulrich, *B. rugatina* Ulrich, *Bellerophon clausus* Ulrich, *B. troosti* D'Orbigny, *Cyclora minuta* Hall, and associated dwarfed species, *Eotomaria elevata* Ulrich, *Hormotoma salteri* Ulrich, *H. columbina* n. sp., *Carinaropsis cunulae* Hall, *Cyrtolites subplanus* Ulrich, *C. retrorsus* Ulrich, *Lophospira conoidea* Ulrich, *L. humilis* Ulrich, *L. producta* Ulrich, *L. saffordi* Ulrich, *L. bowdeni* Safford, *L. sumnerensis* Safford, *L. ulrichi* n. sp., *L. medialis* Ulrich, *L. medialis burginensis* Ulrich, *L. elevata* Ulrich, *Oxydiscus cristatus* Safford, *O. subacutus* Ulrich, *Holopea rotunda* Ulrich.

Pelecypoda: *Cyrtodonta saffordi* Hall, *Cyrtodonta grandis* Ulrich, *C. grandis intermedia* Ulrich, *Vanuxemia hayniana* Safford, *Byssonychia*, *Vanuxemia gibbosa* var., *Ctenodonta hartsvillensis* Safford.

Cephalopods: *Orthoceras* and other, undetermined forms.

Ostracoda: *Isochilina ampla* Ulrich, *I. saffordi* Ulrich, *Leperditia columbina* n. sp., *L. tumidula* Ulrich, *L. appressa* Ulrich.

Vermes: *Scolithus columbina* n. sp.

CATHEYS FORMATION

Over a large part of the Central Basin knotty, earthy and fine-grained, argillaceous limestone and shale of Trenton age, for the most part highly fossiliferous, and easily distinguished from the preceding formations by the lithologic character alone, succeed the massive dove and blue to gray strata of the Cannon limestone. These strata have been named the Catheys formation by Hayes and Ulrich from Catheys Creek, a tributary of Duck River in Maury County. The formation shows considerable variation in thickness from 100 feet or more, the maximum, but erosion of the upper beds has reduced its thickness at some places to a small fraction of the maximum and indeed here and there has removed the formation entirely. As the section along Catheys Creek, although essentially the same as the one at Columbia, does not show the details so well, the section below taken at the latter place is given as typical for the formation. This section, condensed from the one given in more detail on a preceding page, is as follows:

Section of Catheys formation at Columbia, Tennessee

	Feet
Catheys formation	
Unevenly-bedded, subgranular, blue to dark, argillaceous limestone weathering cavernous in the upper part and giving a fetid odor upon breaking........	34
Massive, fine-grained, clayey limestone with many mollusca in the upper part and subcrystalline to crinoidal limestone with bryozoa and *Solenopora* in the lower part........	29
Nodular, blue, clayey limestone with a layer at the base and one above the middle containing many large examples of *Stromatocerium pustulosum*....	18
Finely granular, laminated phosphatic limestone........	12
Blue granular limestone and yellow shale crowded with *Constellaria emaciata*, *C. teres*, and other bryozoa........	8
Bigby limestone	
Gray to blue granular limestone crowded with *Rafinesquina*.	

Hayes and Ulrich, although recognizing the underlying *Constellaria emaciata* beds as a part of the formation elsewhere, considered the *Stromatocerium pustulosum* bed as the base of the Catheys at this place. The shaly beds with various species of *Constellaria* and other bryozoa so abundantly represented form the most widespread member of the formation and almost invariably introduce the Catheys fauna and lithology, unless it be wanting, in which case some higher bed, usually that with *Stromatocerium pustulosum*, forms the base.

The section exposed along the bluff of Big Bigby Creek at the bridge carrying the Mount Pleasant-Hampshire pike gives the details of the Catheys formation in this area, although neither the top nor the bottom is exposed. Here as elsewhere in this region the *S. pustulosum* and succeeding beds are composed largely of clayey limestone with abundant fossils.

Section of Catheys formation along Big Bigby Creek at crossing of Mount Pleasant-Hampshire pike, Maury County, Tennessee

	Feet
Catheys formation	
Blue limestone bed with gastropods and *Columnaria alveolata* (top of formation just above in a gently sloping area)........	2
Clayey blue limestone with a smooth species of *Cyclonema* and a massive convoluted *Escharopora*........	1
Covered slope with surface showing many small fragments of brown chert....	2
Clayey limestone, the upper part especially filled with *Tetradium fibratum*, *Stromatocerium pustulosum*, gastropods, *Cyrtodonta* and other pelecypods..	10
Impure limestone weathering into yellow siliceous nodules and plates of chert..	3
Clayey limestone with fragments of *Isotelus;* ostracoda and a layer of *Ctenodonta* also present........	7
Shaly nodular limestone with *Cyclonema varicosum*, large *Homotrypa*, and other bryozoa........	12
Limestone similar to above but crowded with *Rafinesquina*........	3
Subcrystalline limestone with large *Cyclonema varicosum*, small *Platystrophia*, *Hebertella sinuata* var., *Columnaria alveolata*, and *Stromatocerium pustulosum*	5
Nodular limestone with bryozoa and *Rafinesquina* (to level of creek)........	10

A slightly greater thickness is exposed at Franklin, but as shown in the section below, copied from the general section on a previous page, the *Constellaria* beds are preceded by 20 feet of coarsely granular and clayey limestone, composed mainly of crinoidal fragments but containing *Cyclonema varicosum* and other Catheys fossils.

Section of Catheys formation at Rhodes Quarry, 1½ miles southwest of Franklin, Tennessee

	Feet
Mississippian:	
Chattanooga black shale	
Black carbonaceous shale, covered but represented by flakes in the soil....	10
Ordovician:	
Mohawkian (Trenton):	
Catheys formation	
Massive argillaceous limestone weathering irregularly cavernous with a few interbedded layers of yellow shale full of ramose bryozoa, *Constellaria emaciata*, *Homotrypa*, etc., and the brachiopods *Rafinesquina alternata* and *Platystrophia precursor*..........	20
Argillaceous to fine-grained, dark-blue to gray, massive, fetid limestone with the trilobites *Platylichas* sp. and *Acidaspis rebecca* and the ostracoda, *Isochilina saffordi* and *Leperditia pondi;* many cross sections of gastropods and cephalopods, which do not silicify upon weathering and are difficult to break out of the rock, are present..	25
Fine-grained argillaceous limestone and blue, crystalline, knotty limestone in beds 1 to 4 inches thick, Many layers weather cobbly and others full of holes. Fossils abundant, particularly *Rafinesquina alternata*, *Hebertella sinuata*, and *Cyclonema varicosum*..........	30
Massive, blue to gray, speckled, granular, semiphosphatic limestone with abundant bryozoa in the lower beds....................	10
Thin clayey limestone and yellow shale with a few 4 to 6 inch interbedded blue crystalline layers, crowded with *Constellaria emaciata* and its accompanying fauna..............................	10
Coarsely granular, gray-blue, massive limestone with brown specks, one bed 3 feet thick containing many examples of *Cyclonema varicosum* but most of the layers composed of crinoidal fragments..	15
Nodular clayey limestone with *Solenopora compacta*, *Eridotrypa briareus*, *Cyclonema varicosum*, *Orthorhynchula linneyi*, *Columnaria alveolata*, *Rafinesquina alternata*, and *Hebertella sinuata* abundant..........	5
Cannon limestone	
Gray to blue, massive, laminated, semi-phosphatic limestone full of *Rafinesquina alternata*..........	10

Five miles northwest of Franklin the section although of greater thickness is normal, as indicated below.

Section on north edge of Franklin quadrangle, about 5 miles northwest of Franklin, Tennessee

	Feet
Mississippian:	
Chattanooga black shale, Ridgetop, and Fort Payne formations (covered) to top of hill.	
Silurian (Richmond group):	
Fernvale formation	
Massive, coarsely crystalline limestone in beds 6 to 12 inches thick, the lower part being dark red, the middle strata pink, and the upper gray and blue with green mottling	30
Ordovician:	
Leipers formation	
Thin-bedded, blue, shaly limestone with abundant fossils particularly bryozoa and *Platystrophia ponderosa*	40
Catheys formation	
Massive, argillaceous limestone, giving a fetid odor upon breaking	30
Blue to gray limestone in thin beds, weathering cobbly	35
Massive, granular, semiphosphatic limestone	40
Shaly limestone and shale full of bryozoa, *Constellaria emaciata*, etc	20
Cannon limestone	
Dove and gray limestone.	

In the vicinity of Nashville the Catheys can be studied to excellent advantage, as the various divisions are well exposed usually in their maximum thicknesses at many places. The following section is condensed from the detailed one given on a former page.

Section of Catheys formation at Nashville, Tennessee, and vicinity

	Feet
Catheys formation	
Massive, fine-grained, dark, argillaceous limestone weathering into beds 3 to 4 inches thick; emits fetid odor when broken; *Cyclonema varicosum*, large *Leperditia* (*L. pondi*), *Tetradium fibratum*, *Platystrophia praecursor*, etc., among the fossils	26
Laminar, subgranular to granular, gray limestone with some fine-grained, argillaceous strata. A layer crowded with *Stromatocerium pustulosum* at the top	25
Massive, fine-grained, argillaceous limestone with many layers containing large and small ostracoda (*Leperditia*, *Isochilina*, and *Saffordella muralis*)	19
Thin-bedded shaly limestone, weathering cobbly, with some of the layers crowded with *Constellaria emaciata*, *C. teres*, and *Homotrypa centralis*	7
Cannon limestone	
Massive, crystalline limestone, weathering into red clay and siliceous débris.	

Along the northern edge of the Central Basin as far as Hartsville, as shown in the general section for Trousdale County, the Catheys occurs in normal thickness and development, with the shaly *Constellaria emaciata* beds at the base and the fine-grained, argillaceous limestone at the top. Its thickness diminishes eastward and southeastward until just south and southeast of the northeast corner of Rutherford County the formation disappears entirely, and it is not encountered along the east side of the Basin again. Forty feet of the thin-bedded, blue, Catheys limestone, weathering cobbly, with *Cyclonema varicosum*, *Orthorhynchula linneyi*, *Platystrophia*, and *Constellaria emaciata*, is shown above the Cannon limestone in the section at the high hill 1½ miles east of Milton, on the northeast edge of Rutherford County. East of this place the section at Snows Hill, 4 miles east of Liberty, Dekalb County, published long ago by Safford gives the following development of Catheys.

Catheys formation at Snows Hill, 4 miles east of Liberty, Dekalb County, Tennessee

	Feet
Mississippian:	
Chattanooga black shale.	
Ordovician. Mohawkian (Trenton):	
Catheys formation	
Thin-bedded argillaceous and blue crystalline limestone with abundant fossils particularly *Hebertella sinuata*, *Orthorhynchula linneyi*, *Holopea nashvillensis*, *Byssonychia*, and *Rafinesquina alternata* in the upper half..	42
Clayey and thin-bedded blue limestone with *Constellaria emaciata* and other bryozoa (partly covered)	25
Cannon limestone.	

South of Snows Hill along the Highland Rim escarpment the Catheys rapidly thins out to extinction, and along this line in both the Woodbury and Hollow Springs quadrangles as well as farther south it is unknown. The succeeding and closely related Leipers formation has a similar distribution, appearing for the last time along the eastern part of the Basin in the northeast corner of the Woodbury quadrangle.

Southwest of the type area of the Catheys in the vicinity of Columbia, on the way to Mount Pleasant, the formation is represented by the *Constellaria emaciata* bed, 10 feet thick, followed by 25 feet of blue limestone with *Stromatocerium pustulosum* very abundant in the upper part, and this in turn by 53 feet of subcrystalline to shaly limestone much of it crowded with fossils. The formation continues southward into Alabama, where it disappears under cover of the higher rocks. A considerable decrease of thickness in this direction is shown in the following section taken at Pulaski, although the *Constellaria emaciata* beds are still present.

Section of Catheys formation at Pulaski, Tennessee

	Feet
Catheys formation	
Top bed dirty-gray to dove-colored argillaceous limestone, pierced by *Scolithus* tubes 0.3 inch in diameter	7
Heavy-bedded, fine-grained, bluish limestone weathering cobbly, with *Hebertella* in abundance	10
Massive subgranular, blue-gray limestone crowded with colonies of *Tetradium columnare*	4
Massive, fine-grained limestone weathering laminated	5.5
Blue limestone weathering cobbly	2
Granular blue and shaly limestone full of ramose bryozoa, particularly *Constellaria emaciata* and *C. fischeri*	4
Cannon limestone.	

Eight miles east of Columbia the result of one of the rapid changes in thickness that develop in places is shown in the Loftin Hill section given on another page. Here only 27 feet is developed, the *Constellaria emaciata* and *Stromatocerium pustulosum* beds being present but the upper division of fine-grained argillaceous limestone being entirely absent. This is probably due to erosion during Early Cincinnatian time, when the Eden shale and associated formations not present in the Central Basin were deposited elsewhere.

The various sections in Williamson County southeast and east of Franklin, quoted elsewhere in this report, show the general sequence and thickness as at Franklin. Exposures in southwestern Rutherford County near the extreme southeast corner of Williamson County still show a considerable thickness for the formation.

Section of Catheys formation, 1 mile south of Allisona, southwest corner of Rutherford County, Tennessee

	Feet
Trenton (Catheys formation)	
Covered but scattered boulders show presence of granular, blue and dark, argillaceous limestone with trilobite remains near the base	40
Granular, unfossiliferous, blue limestone weathering into chert	30
Blue, granular, massive limestone with abundant fossils particularly *Columnaria alveolata*, *Hebertella sinuata*, *Peronopora*, *Platystrophia*, *Constellaria*, *Lophospira bowdeni*, and *Heterotrypa parvulipora*. Near the base is an argillaceous bed, 10 inches thick, filled with ostracoda and at the bottom a pothole layer with depressions 1 to 3 inches wide	10
Irregular, knotty, blue, argillaceous limestone with many brachiopod shells, *Rafinesquina alternata* and *Hebertella sinuata; Constellaria emaciata* and *Stromatocerium pustulosum* occur 10 inches from the top	30

West of the Central Basin the Catheys formation has not been noted either in the Wells Creek Basin or in the outcrops along the Tennessee River Valley of West Tennessee, older rocks being exposed at the surface in each area. East of the Central Basin the upfold forming the Sequatchie Valley shows a thickness of 300 feet of limestone assigned to the Catheys, and in the western part of the Appalachian Valley the characteristic lithology and fossils of the formation have been noted along a considerable stretch of country. North of the Central Basin the Catheys crops out in Kentucky, where it is represented by the Greendale member of the Cynthiana formation. The Bromley, Gratz, and Rogers Gap members of the Cynthiana formation do not appear to be developed in Tennessee.

From the foregoing sections it will be noted that shaly beds crowded with fossils particularly bryozoa of the genus *Constellaria* introduce the Catheys formation, and that these are followed in many places by coarsely granular, blue and gray, speckled, semiphosphatic limestone without any conspicuous fossils. Above these comes the widespread

Stromatocerium pustulosum bed in places 25 feet thick, in which this hydrozoon although not restricted to this division is a conspicuous fossil. Then occurs the fine-grained clayey limestone weathering cobbly, which is usually developed to a greater thickness than any other member, and thus makes the cobbly weathering an apparent feature of the Catheys as a whole. The Catheys is usually terminated by massive, fine-grained, clayey limestone giving a fetid odor upon fracture and containing a fauna mainly of ostracoda, large and small, which can be broken out of the rock in great perfection. Large fossils occur in these layers, but as they do not silicify upon weathering and are difficult to break out of the rock they are not conspicuous. In each of these divisions a shelly limestone or clay layer, in places crowded with fossils, particularly ramose stony bryozoa, may occur, but these five divisions well maintain their identity over a large part of the Catheys area of outcrop. These divisions with approximate thickness may be listed under the following names for reference.

Divisions of the Catheys formation

	Feet
5. *Leperditia* beds. Fine-grained, massive, clayey limestone giving a fetid odor on breaking. Trilobites and large ostracoda abundant	35
4. Cobbly beds. Argillaceous fossiliferous limestone weathering into rounded fragments	35
3. *Stromatocerium pustulosum* bed. Nodular, blue, clayey limestone with many large colonies of the fossil named	20
2. Phosphatic bed. Coarsely granular, gray-blue massive limestone with brown specks, weathering into phosphate	40
1. *Constellaria emaciata* bed. Shaly limestone and blue to yellow shale crowded with bryozoa, particularly *C. emaciata*	20

Constellaria emaciata bed.—The shale and shaly limestone at the base of the Catheys invariably crowded with the "star coral", the bryozoan *Constellaria*, form one of the best horizon markers in the Central Basin. The beds are wide spread and easily recognized by both lithology and fossil content. Moreover, they serve for the discrimination of the boundary between two formations that would be separated with difficulty otherwise. Their overlap on different parts of the Cannon and in places on lower formations is an indication of the geologic history and distinctness of the Catheys as a separate formation.

The faunal list of this bed at the base of the Catheys, printed below, shows much similarity to that of the overlying Leipers, a point to be discussed later. This list follows:

Fauna of Constellaria emaciata bed

Plants: (Calcareous alga) *Solenopora compacta* Billings.
Sponges: *Hindia sphaeroidalis* Duncan var.
Hydrozoa: *Dermatostroma cavernosum* Parks.
Corals: *Columnaria alveolata* Goldfuss, *Tetradium fibratum* Safford.

Bryozoa: *Amplexopora cylindracea* Ulrich and Bassler, *Bythopora* cfr. *gracilis*, *Constellaria emaciata* Ulrich and Bassler, *C. fischeri* Ulrich, *C. teres* Ulrich and Bassler, *Corynotrypa delicatula* James, *Crepipora simulans* Ulrich, *Eridotrypa briareus* (Nicholson), *E. mutabilis* Ulrich, *Escharopora* cfr. *falciformis*, *E.* cfr. *pavonia*, *Hallopora* cfr. *rugosa*, *Heterotrypa parvulipora* Ulrich and Bassler, *Heterotrypa* cfr. *solitaria*, *Homotrypa centralis* n. sp., *Nicholsonella* cfr. *vaupeli*, *Peronopora milleri* Nickles, *Prasopora nodosa* Ulrich, undetermined species of *Batostoma*, *Ceramoporella*, *Coeloclema*, *Dekayella*, *Heterotrypa*, *Homotrypella*, and *Monticulipora*.

Brachiopods: *Crania laelia* Hall, *C. scabiosa* Hall, *Hebertella sinuata* Hall var., *Orthorhynchula linneyi* (James), *Platystrophia amoena robusta* McEwan, *P. colbiensis* and var. *mutata* Foerste, *P. precursor* Foerste and varieties *angusta*, *latiformis*, and *profunda* McEwan, *Zygospira recurvirostris* Hall.

Pelecypods: Various unidentified species.

Gastropods: *Cyclonema varicosum* Hall and undetermined species of *Bellerophon*, *Bucania*, and *Lophospira*.

Cephalopods: *Billingsites? williamsportensis* Foerste, *Orthoceras* sp.

Trilobites: *Calymene* sp.

Ostracoda: *Ctenobolbina*, etc., undetermined.

Phosphatic bed.—Between the well-marked basal *Constellaria emaciata* bed and the equally conspicuous *Stromatocerium pustulosum* bed is in many places as much as 40 feet of coarsely granular, massive limestone, phosphatic enough to weather into good phosphate under the right conditions. Fossils although present are not well preserved in this division.

The phosphatic beds are replaced in some areas by fine-grained argillaceous strata crowded with large and small ostracoda, among which are the interesting small species *Drepanella* and *Saffordella muralis* and the large forms *Leperditia pondi* and *Isochilina apicalis*.

Stromatocerium pustulosum bed.—This division of the Catheys is almost as wide spread as the basal *Constellaria emaciata* bed, and indeed it has been used as the lower boundary in the Columbia folio. Similar limestones with *S. pustulosum* in equal abundance, however, occur in the Cannon limestone, so that the bed can not be relied upon alone in distinguishing the Catheys. The fauna of the Catheys *S. pustulosum* bed, although containing many of the usual Upper Trenton species, is especially characterized by the massive corals and coral-like organisms belonging to the genera *Columnaria*, *Tetradium*, and *Stromatocerium*. This assemblage of fossils reappears in the Leipers, adding to the difficulty of separating these two formations.

Fauna of Stromatocerium pustulosum bed

Plants: (Calcareous alga) *Solenopora compacta* Billings.

Sponges: *Zittelella* sp.

Corals: *Columnaria alveolata* Goldfuss, *Tetradium columnare* Hall, *T. fibratum* Safford.

Hydrozoa: *Stromatocerium pustulosum* Safford (large and very abundant).

Brachiopods: *Hebertella frankfortensis* Foerste, *H. sinuata* Hall, var., *Orthorhynchula linneyi* James.

Gastropods: *Bucania frankfortensis* Ulrich, *B. lindsleyi* Safford, *Cyclonema varicosum*

Hall, *Cyclora minuta* Hall, and associated dwarf forms, *Holopea* sp., *Lophospira bowdeni* Safford, *Oxydiscus cristatus* Safford.

Cephalopods: Unidentified species of *Cyrtoceras*, *Ormoceras*, and *Orthoceras*.

Bryozoa: *Constellaria*, *Homotrypa*, and other unstudied bryozoa.

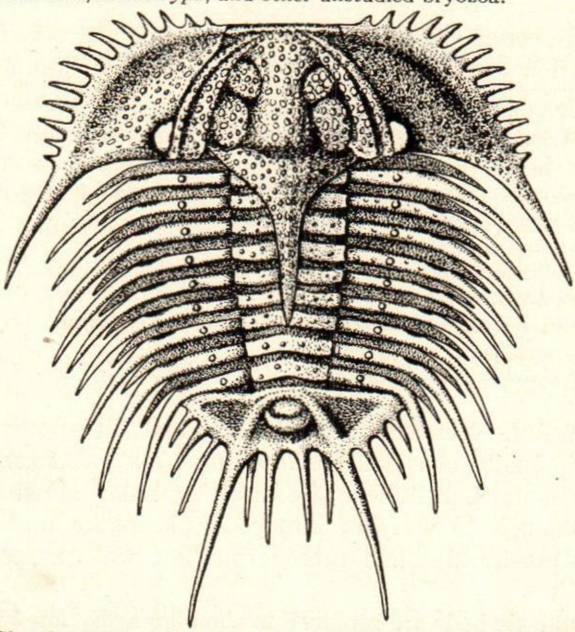


Figure 3. Sketch, natural size, of *Acidaspis rebecca*, n. sp., (Ulrich and Bassler). Upper Catheys, 1½ miles southwest of Franklin, Tenn.

The Upper Catheys: Cobbly and Leperditia beds.—The cobbly beds and massive clayey limestones with large ostracoda and trilobites, forming the upper half of the Catheys, contain an extensive fauna that has not been worked out in detail, although the species listed below are known to occur here. The beds with trilobites and large ostracoda have a wide distribution and serve as a good horizon marker. In these beds the fragments of the beautiful new trilobite *Acidaspis rebecca* (Figure 3) are not uncommon.

Fauna of Upper Catheys

Calcareous alga: *Solenopora compacta* Billings.

Corals: *Columnaria alveolata* Goldfuss, *Tetradium fibratum* Safford.

Starfishes: *Mesopaleaster antiquus* Troost.

Bryozoa: Various species of *Bythopora*, *Constellaria*, *Crepipora*, *Eridotrypa*, *Escharopora*, *Heterotrypa*, *Homotrypa*, and *Dekayella* similar to those in the basal bed.

Brachiopods: *Hebertella frankfortensis* Foerste var., *Orthorhynchula linneyi* (James), *Platystrophia precursor* Foerste, *Rafinesquina alternata* (Conrad).

Gastropods: *Bucania frankfortensis* Ulrich, *B. singularis* Ulrich, *Conularia gattingeri* Safford, *Cyclonema varicosum* Hall, *Crytolites retrorsus* Ulrich and Scofield var., *Holopea nashvillensis* Ulrich, *Lophospira abnormis* Ulrich, *L. bowdeni* (Safford), *L. saffordi* Ulrich, *Oxydiscus cristatus* Safford, *Schizolopha textilis* Ulrich.

Pelecypods: *Byssonychia* cfr. *radiata*, *Caritodens* (*Pterinea*) sp., *Colpomya constricta* Ulrich, *Cyrtodonta crassa* Ulrich, *Modiodesma kentonense* Ulrich.

Cephalopods: *Cyrtoceras massiense* Safford, *Cyrtoceras saffordi* Miller, *Wetherbyoceras* (*Cyrtoceras*) cfr. *vallandighami* Miller.

Ostracoda: *Ceratopsis intermedia* Ulrich, and other small ostracoda, *Isochilina nelsoni* n. sp., *I. saffordi* Ulrich, *Leperditia pondi* n. sp. *L. tumidula* Ulrich.
Trilobites: *Acidaspis rebecca* n. sp., Ulrich and Bassler, *Ceraurus* sp., *Platylichas* sp.

From an inspection of the foregoing lists it will be noted that the Catheys formation embraces two faunules. The first faunule consists largely of bryozoa, brachiopods, and various mollusca, found in the basal beds and repeated in the upper half, all quite similar to those found again in the Leipers. Careful study shows that these apparently identical species are seldom exactly the same although always closely related. Such faunas can be best separated by the unlike species in them. The second faunule consists of massive corals and bryozoa belonging to the genera *Stromatocerium*, *Tetradium*, and *Columnaria*. These conspicuous fossils are best developed in the lower half of the Catheys but reappear in a zone well up in the Leipers formation. As the latter formation in Tennessee rests on the Catheys, separation of these two appearances is difficult, but in Ohio more than 250 feet of Eden shale, not counting an equal amount of shale detected only in deep wells, separate the Catheys and the equivalent of the Leipers.

The Catheys and Leipers well illustrate the principle brought out by Ulrich that the time interval between two superposed formations may, in spite of their closely similar faunas, be very great. There are no conglomerates or other clastic deposits of importance at the contact of these two, and, as noted before, the similarity of the faunas makes their distinction very difficult. The physical evidence of the unconformity between the two is, however, the unquestionable landward overlap of the Leipers. This is shown in that the most western exposures of the formation contain a number of distinguishable beds in its lower part, which are entirely absent at Nashville, and that at some places such as along the south flank the Leipers is represented by only the uppermost member, the *Platystrophia* bed.

CINCINNATIAN SERIES

Cincinnatian strata (Utica, Eden, and Maysville) are absent on the south and east sides of the Nashville Dome, but along the west and north sides the Maysville is represented by the Leipers formation of Hayes and Ulrich. The Eden is unknown along the Cincinnatian axis south of Central Kentucky. Crustal movements occurred in Cincinnatian time, which caused elevation of the region of the southern States but left a way open for the Utica invasion of the northeastern region, reaching probably as far south as Cincinnati.

In middle Tennessee the emergence at the close of the Trenton continued all through the Utica and Eden stages, so that submergence in Maysville time resulted in the deposition of the Leipers formation upon the Upper Trenton Catheys formation. There is no conglomerate or other evidence of unconformity other than overlaps that can be traced in the Leipers.

LEIPERS FORMATION

The Leipers formation, the only representative of the Cincinnatian group in Central Tennessee, was named by Hayes and Ulrich in the Columbia folio (U. S. Geological Survey Folio 95, 1903) from Leipers Fork of West Harpeth River in Williamson County, along which fair exposures may be studied. The authors define the formation in the type area, the east half of the Columbia quadrangle, as a "knotty, earthy limestone at the top, with similar but more shaly and highly fossiliferous beds below." Lithologically the Leipers is so similar to the Catheys formation that when, as is usual, it follows the latter, the separation of the two without the aid of fossils becomes quite difficult. However, the presence of the robust brachiopod *Platystrophia ponderosa* in the Leipers is sufficient for its recognition. This similarity of the two formations caused Safford to consider them a single unit when he proposed the term College Hill limestone in his Geology of Tennessee. Now with the recognition of the upper part of the College Hill as of Maysville (Cincinnatian) age and the lower part as Trenton (Mohawkian) with an unconformity between them representing time during which thick sediments of Utica and Eden shales were deposited on the northeast, the term has no standing as a definite stratigraphic unit. The type area of outcrop along Leipers Creek shows the following section:

Geologic section along Leipers Creek, 2½ to 3 miles north of Water Valley, Tennessee

	Feet
Mississippian:	
Chattanooga black shale	
Typical black shale with 4 inches of kidney concretions at top	5.3
Conglomeratic blue phosphate	0.3
Ferruginous yellow shale	1.3
Silurian:	
Richmond group:	
Fernvale limestone	
Gray to white, massive, crystalline limestone with characteristic fossils	8
Ordovician:	
Maysville group:	
Leipers formation	
Granular, semiphosphatic to earthy, nodular limestone more coherent in the lower half. Rather unfossiliferous but *Solenopora compacta*, *Platystrophia ponderosa* and *Rafinesquina ponderosa* occur with *Amplexopora columbiana* and other bryozoa in the lower half	21
Earthy nodular limestone like the above but beds more shaly and fossils more abundant; contains one or more layers full of *Bellerophon*	36.5

Trenton group:	Feet
Catheys formation	
Brownish-white crystalline limestone	2.5
Rough, crystalline, crinoidal limestone and soft shale, upper half with many bryozoa, *Stromatocerium pustulosum* and *Tetradium fibratum*	19
Crystalline to nodular limestone with many *Rafinesquina* in upper part	15
Granocrystalline limestone (to bed of creek)	10

Excellent exposures of the lower part of the formation are shown at Columbia, but a more detailed section can be seen at Loftin Hill 8 miles east.

Section along Bear Creek pike on western side of Loftin Hill, 8 miles east of Columbia, Tennessee

Mississippian:	Feet
Fort Payne chert.	
Chattanooga black shale	5
Ordovician:	
Cincinnatian (Maysville):	
Leipers formation	
Nodular, earthy, calcareous shale with *Platystrophia ponderosa*	13
Shaly, blue limestone crowded with bryozoa	4.5
Impure limestone with large *Platystrophia ponderosa* and *Strophomena planoconvexa*	7
Shaly limestone, not well shown, full of *Tetradium fibratum*, mollusca, and *Platystrophia ponderosa*	7
Grayish-blue limestone with no recognizable fossils, the upper layer cavernous on its upper face	10
Blue limestone with *Bucania*, *Heberte!la sinuata*, and *Platystrophia ponderosa*	8
Mohawkian (Trenton):	
Catheys formation	
Laminated granular, shaly, subcrystalline and clayey limestone with *Constellaria* beds at base	21

Study of many sections during the mapping of the Columbia quadrangle by Dr. Ulrich led to the publication of the following general section for the eastern part of the area.

General section of Leipers formation, eastern part of Columbia quadrangle, Tennessee

	Feet
8. Earthy blue limestone weathering knotty, but appearing solid in fresh exposures, with more or less waterworn valves of *Platystrophia ponderosa* as the only common fossil	0-10
7. Thin bed of soft, calcareous, light-blue shale, seldom exposed, containing *Bythopora gracilis* a slender, smooth, solid, branching bryozoan	0-4
6. Widely distributed earthy limestone and calcareous shales with *Orthorhynchula linneyi* and *Tetradium fibratum*, much resembling similar beds in the Catheys with the same fossils	7
5. Knotty, impure, blue and gray limestone and shales crowded with fossils, particularly stony bryozoa. *Amplexopora columbiana*, *Homotrypella nodosa*	

	Feet
and *Strophomena planoconvexa* characteristic of this zone. Well exposed at excavations for Columbia reservoir and at Fort Negley, Nashville	5-12
4. Granular crystalline, occasionally arenaceous, grayish limestone, slightly phosphatic and with few fossils	40
3. Thin-bedded, shaly, very fossiliferous layers with *Platystrophia laticosta* var., *Hindia* one-half to one inch in diameter and several species of undescribed bryozoa	6-14
2. More or less coarsely crystalline speckled limestone with *Ctenodonta* a large branching *Escharopora* and ramose bryozoa, *Bythopora*	20
1. Shales and thin limestone with a species of *Bucania* or *Salpingostoma*	10

A section north of Gallatin, given in more detail on a later page, shows the several divisions of the Leipers as developed on the north side of the Nashville dome.

Leipers section on north side of ridge 3 to 4 miles north of Gallatin, Tennessee

Leipers formation	Feet
Shaly limestone crowded with *Platystrophia ponderosa*	12
Phosphatic, fossiliferous limestone weathering to phosphate. The upper beds are more cellular than the lower, the original rock being more crystalline (source of the Gallatin phosphate)	36
Shale and thin-bedded blue limestone crowded with *Rafinesquina ponderosa* and with *Constellaria florida* and other bryozoa	15
Shaly limestone with large specimens of *Strophomena planoconvexa*	15
Unfossiliferous shale (to base of creek)	7

The sections given above show much similarity in the divisions of the formation, the main differences being that the basal beds are missing by lack of deposition and the top members are absent from some, probably because of erosion. The thickness therefore differs widely, ranging from nothing to over 100 feet. South of Columbia the same conditions hold for, as shown in the general section on a preceding page, similar divisions exist in the 58 feet occurring at Mount Pleasant and the 45 feet at Pulaski. Eastward, however, the Leipers pinches out, for throughout Rutherford County the Chattanooga shale rests upon the Catheys or older formations and in Coffee and Cannon Counties usually upon the Cannon limestone. Starting in the southwest corner of DeKalb County, the Leipers reappears and continues well developed to the northeast, north, and northwest.

The Leipers therefore overlaps the Nashville Dome from the south, west, and north but was not deposited along the central and most of the eastern parts. At some places within this area of deposition it is locally absent owing to erosion. However, in the Sequatchie Valley on the east over 235 feet of argillaceous limestone with the characteristic fossils of the formation occur, indicating that the central and eastern part of the Nashville Dome was an island during Leipers time.

West of Columbia the outcrops along Swan Creek and Duck River show the formation changed to a rather unfossiliferous, uniform, granular oolitic or granular crystalline limestone with the more granular portions laminated and highly phosphatic. These strata, which are 60 to 90 feet thick, replace the eight beds of the general section on the east and give rise by leaching to the important light-brown phosphate rock of the area. Most of this thickness belongs to the lower four beds of the general section and in many places bed 4 alone is represented.

As noted by Hayes and Ulrich, the absence of the upper beds, indicating elevation and erosion, which began in Upper Leipers time and continued until the Mississippian, occurs in the same areas that have the best development of the Chattanooga blue phosphate.

As the Leipers has not been noted in the Wells Creek basin nor known to crop out in the Tennessee River Valley on the west, the old shore line along which the phosphatic limestone of Swan Creek and Duck River were deposited must have existed not far west of this area.

In the Central Basin the Leipers usually crops out along the hillsides, where it gives a rubbly soil with steep slopes. In the areas on the west it forms an excellent soil in the larger tracts along the stream valleys.

Certain layers of the Leipers formation are crowded with fossils, particularly those making up bed 5 of the general section. Excellent collections from this bed at Nashville have yielded the following species:

Fauna of Leipers formation at Fort Negley, Nashville, Tennessee

Sponges: *Dystactospongia insolens* Miller, *Hindia sphaeroidalis* Duncan, var.

Hydrozoa: *Dermatostroma scabra* (James), *Stromatocerium huronensis australe* Parks.

Corals: *Tetradium fibratum* Safford.

Brachiopoda: *Crania laelia* Hall, *C. scabiosa* Hall, *Hebertella sinuata* (Hall), *Orthorhynchula linneyi* (James), *Platystrophia laticosta* (Meek), *P. ponderosa* Foerste, *Rafinesquina ponderosa* Ulrich, *Strophomena planoconvexa* Hall, *S. sinuata* James, *Zygospira modesta* Say.

Bryozoa: *Amplexopora ampla* Ulrich and Bassler, *A. columbiana* Ulrich and Bassler, *A. filiasa* (D'Orbigny), *Atactoporella mundula* Ulrich, *Bythopora gracilis* (Nicholson), *Ceramoporella ohioensis* (Nicholson), *C. whitei* (James), *Constellaria florida* Ulrich, *Corynotrypa delicatula* (Ulrich), *C. inflata* (Gall), *Crepipora simulans* Ulrich, *Escharopora falciformis* (Nicholson), *E. pavonia* (D'Orbigny), *Hallopora dalei* (Edwards and Haime), *Heterotrypa frondosa* (D'Orbigny), *H. solitaria* Ulrich, *H. subpulchella* (Nicholson), *Homotrypa flabellaris* Ulrich, *Homotrypella nodosa* Ulrich and Bassler, *Monticulipora cincinnatiensis* (James) var., *M. mammulata* (D'Orbigny), *M. molesta* Nicholson, *Peronopora compressa* Ulrich, *P. decipiens* (Rominger), *Petigopora gregaria* Ulrich, *P. petechialis* (Nicholson), *Phylloporina clathrata* (Miller and Dyer), *Proboscina auloporoides* (Nicholson), *P. frondosa* (Nicholson), *Stomatopora arachnoidea* Hall.

Crinoidea: *Glyptocrinus decadactylus* Hall, *G. subglobosus* Meek.

Cystoidea: *Agelacrinus cincinnatiensis* (Roemer), *Streptaster vorticellatus* (Hall).

Gastropoda: *Bellerophon capax* Ulrich, *Cyclonema mediale* Ulrich, *Cyclora minuta* Hall and associated small species, *Cyrtolites ornatus* Conrad, *Lophospira bowdeni* Safford, *L. tropidophora* (Meek).

Cephalopoda: *Wetherbyoceras* (*Cyrtoceras*) *vallandighami* Miller, *Cyrtoceras convidale* Wetherby.

Pelecypoda: *Byssonychia radiata* (Hall), *Ctenodonta pectunculoides* (Hall), *Modiolopsis modiolaris* (Conrad), *M. truncatus* Hall, *Pterinea cincinnatiensis* Miller and Faber, *P. demissa* Conrad.

Vermes: *Cornulites minor* Nicholson.
Trilobita: *Amphilichas halli* (Foerste), *Calymene meeki* Foerste, *Ceraurus milleranus* Miller and Gurley, *Proteus parviusculus* Hall, *Pterygometopus carleyi* (Meek).

Tilting of Nashville dome.—East and west tilting of the Nashville dome is clearly indicated by the distribution of the various Ordovician formations. The Murfreesboro, Pierce, and Ridley divisions crop out only in the central part of the dome and give no surface evidence as to their lateral distribution. The succeeding Lebanon limestone, judging from sections on the east and west sides, is well developed on all sides except possibly the northwest. No Lebanon deposits have been determined in the next uplift northwest, the Wells Creek Basin, where Black River limestone immediately succeeds the Wells cherty limestone of the Canadian. Tilting commences with early Black River time, for the Carters limestone is present only on the west side, whereas the Lowville, overlapping the Carters on the west, is the only Black River formation on the east, north, and south. The Kimmswick limestone at the top of the Black River is found only locally on the southwest margin if present at all. It is possible that the earliest Trenton formation of Kentucky, the Curdsville, reaches northern Tennessee, but this is still unproved. At any rate the Hermitage formation next in order is widespread over the entire dome. Following it is the Bigby limestone, limited to the west and southwest sides and thinning to extinction toward the northeast. The Cannon limestone, on the contrary, is absent along the southwest side, but starting at the east edge of the Columbia quadrangle it gradually increases in thickness eastward until several hundred feet of dove and gray limestone occur along the north and east sides of the dome. The Catheys formation, terminating the Trenton, has a more general distribution over the dome, although it is absent throughout the Hollow Springs quadrangle and southward along the east side.

The Cincinnatian division of the Ordovician, represented by the Leipers formation of early Maysville age, is absent along most of the eastern side although well developed throughout the northern and the western and southern parts of the dome. The early Cincinnatian Eden shales, well developed in Ohio and Kentucky and in the Appalachian Valley, were never deposited in central Tennessee.

SILURIAN SYSTEM

Rocks of Silurian age are seldom encountered in the Central Basin, because at the end of the Leipers division of the Ordovician the area was uplifted above sea level, where it remained except locally until the beginning of Mississippian time. Thus no marine deposits of Silurian or Devonian age of notable extent can, as a rule, be expected, and the early Mississippian Chattanooga black shale is found usually resting upon the Ordovician or older strata. The exceptions noted are local occurrences of Silurian and Devonian strata formed along the sea margin of the Nashville dome and now exposed by erosion or like the Fernvale formation deposited in narrow embayments occurring on the north, west, and south flanks of the dome. In spite of this limited occurrence, eight distinct formations have been noted along the edges of the Basin. The following table gives the classification of these formations with their thickness and type of rock. They all occur along the northwest and west edges of the Basin.

Silurian formations of the Central Basin

	Feet
Cayugan series:	
Decatur limestone (West Tennessee only).	
Niagaran series:	
Lockport group:	
Lobelville formation. Blue shale and massive limestone crowded with corals	35
Lego limestone. Massive, light-gray, crystalline limestone with a few bands of green shale	45
Waldron shale. Green clay shale with a few limestone layers, in places crowded with fossils	10
Laurel limestone. Massive gray limestone with pink specks	30
Clinton group:	
Osgood formation. Green and red shale below, changing upward to argillaceous limestone. Entire examples and plates of *Holocystites* present	15
Medinan series:	
Alexandrian group:	
Brassfield limestone. Massive, blue-gray, crystalline limestone with bands of nodular and platy chert. The corals *Halysites*, *Heliolites*, and *Favosites* not uncommon	30
Richmond group:	
Fernvale formation. Massive pink to red coarsely crystalline limestone and soft green to chocolate-colored shale	75
Arnheim formation. Cherty blue argillaceous limestone and light-colored shale with abundant fossils	35

RICHMOND GROUP

The age of the several formations belonging to the Richmond group has been under active discussion during the past decade or longer, but all the writer's observations convince him that their assignment to the Silurian is correct. Only two formations of Richmond age occur in the Central Basin area, the Arnheim and the Fernvale.

ARNHEIM FORMATION

At various places along the north and west sides of the Nashville dome the massive, reddish, crystalline limestone of the Fernvale formation is separated from the shaly, blue limestone of the Leipers by a variable thickness of fossiliferous, blue, nodular limestone and shale containing early varieties of *Rhynchotrema dentatum*, *Leptaena richmondensis*, and *Dinorthis carleyi*, fossils that characterize the Arnheim formation in southwestern Ohio. This formation, originally called the Warren formation by Nickles from its outcrops in Warren County, Ohio, and placed at the top of the Maysville group of the Ordovician, is now recognized as the basal member of the early Silurian Richmond group because of its fossils and for diastrophic reasons. In Ohio the Arnheim usually succeeds the uppermost Mount Auburn division of the Maysville group; in Tennessee it rests by overlap upon rocks of various ages, usually the Leipers of early Maysville age in the Central Basin and in West Tennessee along the Tennessee River the Hermitage division at the base of the Trenton.

In Ohio and Kentucky east of the Cincinnati axis the lower part of the Arnheim, consisting of cross-bedded and in places wave-marked blue limestone, named the Sunset member from Sunset, Kentucky, by Foerste, is comparatively unfossiliferous, and its transition to the upper fossiliferous Oregonia member, so designated from Oregonia, Ohio, is somewhat abrupt. This upper member contains the fossils mentioned above as characteristic of the Arnheim. West of the Cincinnati axis the differences between the two members are not so distinct, but each member can be recognized. In each area the upper part at least is composed mainly of limestone rubble, uneven, argillaceous, thin-bedded limestone readily weathering into irregular, rounded fragments, with much shale.

The following sections give the details of the Arnheim as developed in the northern part of the Central Basin.

Section of Arnheim formation along Long Hollow pike, about 8 miles northeast of Goodlettsville, Tennessee

	Feet
Silurian (Richmond group):	
Fernvale limestone	
Massive, salmon-colored to reddish, coarsely crystalline limestone	10+
Arnheim formation	
Argillaceous to impure phosphatic limestone and shale weathering into a brownish-red clay and brown phosphate with chert; *Streptelasma rusticum* and *Rhynchotrema capax* abundant, *Sowerbyella* (*Plectambonites*) *clarksvillensis* and *Columnaria alveolata* less common	25
Thin-bedded, unfossiliferous gray shale separated by a few thin limestone bands, crowded with *Sowerbyella* (*Plectambonites*)	20
Blue fossiliferous shale with *Streptelasma rusticum* and *Rhynchotrema dentatum* var. *arnheimensis* abundant	8
Nodular limestone and blue shale with *Platystrophia ponderosa*, *Rhynchotrema dentatum* var. *arnheimensis*, *Dinorthis carleyi*, and *Dalmanella jugosa*	6
Shaly blue limestone with *Platystrophia cypha*, *Leptaena richmondensis* var. *precursor*, *Platystrophia ponderosa*, etc	1
Ordovician (Cincinnatian):	
Leipers formation.	
Shaly blue limestone with *Platystrophia ponderosa*, *Orthorhynchula linneyi*, *Rafinesquina ponderosa*, and many Leipers bryozoa	25+

The north side of the ridge 3 to 4 miles north of Gallatin shows 30 feet of thin-bedded limestone and shale, in which the usual fauna of the Arnheim is accompanied by considerable numbers of the sponges *Heterospongia subramosa* and several species of *Dystactospongia*. This section is given under the discussion of the Fernvale formation.

At Whites Creek post office, in Davidson County, 23 feet of strata with this fauna occurs between the Leipers and Fernvale. This section follows:

Section at Whites Creek post office, Davidson County, Tennessee

	Feet
Mississippian:	
Chattanooga black shale	30-40
Silurian:	
Niagaran and Medinan:	
Whitish crinoidal limestone of Niagaran age in upper two-thirds and nodular gray limestone of Brassfield (Medinan) below	45
Richmond group:	
Fernvale limestone	
Gray to white massive limestone with bryozoa	20
Laminar, rusty, subcrystalline, crinoidal limestone in lower part and more-crystalline massive, light-colored limestone in upper 6 feet	29
Arnheim formation	
Subcrystalline, gray to blue limestone with yellow clay layers. *Rhynchotrema capax*, *R. dentatum* var. *arnheimensis*, *Dinorthis subquadrata*, *Sowerbyella* (*Plectambonites*) *clarksvillensis*, and *Strophomena concordensis* observed	6
Covered, but yellow clays at top with bryozoa and *Streptelasma rusticum*	11
Shaly limestone with *Rafinesquina* and *Platystrophia ponderosa*	6
Ordovician (Cincinnatian):	
Leipers formation	
Shaly limestone with *Platystrophia ponderosa*	4
Gray to blue granular and clayey limestone with ramose bryozoa. A layer or two at the top weathers into phosphate	14
Nodular limestone and shale crowded with bryozoa particularly *Constellaria florida* (to base of exposure)	15

Along the west side of the Nashville dome strata with *Rhynchotrema dentatum arnheimensis* and other Arnheim fossils occur at Newsom southwest of Nashville, at a locality 5 miles southwest of Franklin, and at other localities where the formation is developed in the embayments associated with the Fernvale formation. They appear also at Clifton, on the Tennessee River 85 miles southwest of Nashville, where *Dinorthis carleyi*, *Rhynchotrema dentatum arnheimensis*, and their associates occur in cherty gray limestone up to 3 feet thick following the equivalent of the Hermitage formation. East of the several areas mentioned in Tennessee the formation is unknown, so it is undoubtedly limited to embayments on the west flank of the dome. Limestones of Arnheim age weathering into phosphate crop out in the Swan Creek valley. These beds, having *Rhynchotrema dentatum*, were called the Swan Creek limestone by Dr. Foerste, who, however, has dropped this name in favor of Arnheim.

Although still not studied in detail, the fauna of the Arnheim is expressed in the following list of species found in the lower beds at localities north of Nashville.

Fauna of lower beds of Arnheim formation in northern Tennessee

Corals: *Streptelasma rusticum* Billings, *Protarea richmondensis* Foerste, *Columnaria alveolata* Goldfuss.

Sponges: *Heterospongia subramosa* Ulrich, several species of *Dystatospongia*, and *Hindia sphaeroidalis* Duncan.

Bryozoa: *Rhombotrypa quadrata* Rominger and various unstudied species.

Brachiopods: *Platystrophia ponderosa* Foerste, *P. cypha* (James), *P. cypha conradi* Foerste, *P. cypha arcta* McEwan, *P. cypha tumida* McEwan, *Sowerbyella* (*Plectambonites*) *clarksvillensis* Foerste, *Strophomena concordensis* Foerste, *S. planumbona* (Hall), *S. subtenta* Hall, *Hebertella sinuata* Hall, *H. insculpta* (Hall), *Rafinesquina alternata* Conrad, *Dalmanella jugosa* James, *Dinorthis subquadrata* Hall, *D. carleyi* Hall, *Leptaena richmondensis precursor* Foerste, *Rhynchotrema capax* Conrad, *R. dentatum arnheimensis* Foerste.

Gastropods: *Cyclonema fluctuatum* James, *Lophospira bowdeni* var.

At the time of printing the Franklin geologic map it was believed by the writer that the occurrence of such typical Waynesville species as *Strophomena planumbona*, *Streptelasma rusticum*, and *Rhombotrypa quadrata* in the rocks now called Arnheim indicated their Waynesville age. They were accordingly assigned to this formation with a question and a note suggesting Arnheim age, but since then these same species have been noted in the Arnheim of Ohio.

The Arnheim affords good proof as to the differential movements that went on in the Mississippi Valley in late Ordovician and early Silurian times. As indicated above the formation is known locally in northern and western Tennessee and occurs farther north on the flanks of the Cincinnati dome. Like the Leipers its fauna indicates a Gulf of Mexico origin, many of the species being modified descendants of those in the Leipers, and a number of typical early Silurian Richmond types are also introduced. In Tennessee the Arnheim is followed by the Fernvale limestone, which is present in several States on the west and northwest where the Arnheim is unknown. Both formations contain large numbers of species with so few in common that it is impossible that both had the same origin. The absence of all the higher Cincinnatian rocks in Tennessee indicates a long period of emergence before the basal Silurian Arnheim strata were deposited.

After the Arnheim was laid down, tilting of the continent northward must have occurred, for the following Fernvale formation has faunal elements of the far north.

FERNVALE FORMATION

The name Fernvale formation was proposed in 1903 by Hayes and Ulrich in the Columbia folio for the soft chocolate-colored and green shales with associated coarsely crystalline, much of it flesh colored and green speckled limestone of Richmond group age, which succeed the Arnheim formation or older strata.

In the same year Foerste[1] proposed the names Leipers Creek limestone and Mannie shales for Richmond formations in the valley of the Tennessee River covering the same time interval as the Fernvale. As these are only depositional phases of the Fernvale, Dr. Foerste has long ago expressed the wish that his names should not conflict with the term Fernvale.

The name Fernvale is derived from Fernvale Springs on South Harpeth Creek in the southwestern part of Williamson County, where the formation forms the basal rocks of the valley. The section here is not complete; indeed, for reasons given below the Fernvale varies considerably in its lithology from place to place. Field work has shown that in Tennessee the Fernvale strata were deposited in embayments or baylike indentations along the western half of the Nashville dome. At the head of these shallow troughs and along their borders the formation is thin and consists largely of shale, but elsewhere the succession is usually limestone below followed by shale, although at some places the entire formation is limestone. Much of the limestone is so highly charged with iron that it has a vermilion color and weathers into the dyestone or hematite that has been mined in the past.

The Fernvale is unknown in the Ohio region and in the Appalachian Valley, but west of the Cincinnati anticline the formation has been recognized at so many places that it is now known to be widely spread over the Mississippi Valley and farther west. Northward from Tennessee it crops out in northern Illinois, where its fossils have been collected in great abundance at Wilmington. Westward it crops out along the eastern and southern flanks of the Ozark uplift of southern Missouri, and south of this area it occurs in northern Arkansas and in the Arbuckle region of south central Oklahoma. Apparently the same zone occurs in Western Texas and New Mexico and on the east side of the Rocky Mountains, but the absence of the bryozoa throughout these western areas makes the exact correlation doubtful. However, the geographic distribution of undoubted Fernvale strata is sufficiently large to show that one of the wide submergences of the continent occurred at this time.

In Tennessee the boundaries of the baylike indentations to which the Fernvale is restricted have been determined accurately only in the Columbia and Franklin quadrangles, but their general distribution is fairly well known. On the north one of these bays ends near Gallatin,

[1] Foerste, A. F., The Cincinnati group in western Tennessee between the Tennessee River and the Central Basin: Jour. Geology, vol. 11, No. 1, pp. 29-45.

and probably divisions of the same area of sedimentation account for the Fernvale outcrops north and west of Nashville and for a narrow area ending north of Franklin. The indentations in the central third of the western flank of the dome are indicated in the Columbia and Franklin folios. For some miles south of Columbia the Fernvale is absent, and then broad areas of deposition, first seen along the Tennessee River at Clifton, may be followed by many exposures eastward across the Waynesboro quadrangle, ending in the development of the formation from Pulaski east as far as Kelso in Lincoln County.

The lithologic nature and characteristic development of the Fernvale in one of these areas are well shown in a section exposed along the hill 2 miles southwest of Southall and about half a mile west of the Carter Creek pike. The thicknesses here happen to be about the average and fossils are abundant, so that the section might be considered as typical.

Section on south side of hill 2 miles southwest of Southall, Williamson County, Tennessee

	Feet
Mississippian:	
Fort Payne chert	
Massive dull-drab limestone giving rise to abundance of chert (to top of hill).	
Ridgetop shale	
Light-green shale with 2-inch bed of kidney phosphatic nodules at base....	2
Chattanooga shale	
Black fissile shale, some of the layers crowded with conodonts. The Hardin sandstone at the base represented by a sandy phosphate bed 4 inches thick	13
Silurian:	
Osgood limestone	
Massive, light-gray, compact limestone with *Halysites catenularia*, *Favosites favosus*, *Hallopora magnopora*, etc..................................	10
Fernvale formation	
Soft yellow shale with *Rhynchotrema capax manniense*, *Dinorthis proavita*, *Rhombotrypa quadrata*, and other characteristic species................	13
Coarsely crystalline, massive, reddish limestone with *Rhynchotrema capax* var., and other fossils..	15
Arnheim formation	
Blue nodular limestone with *Rhynchotrema capax*, *Dinorthis carleyi*, *Platystrophia ponderosa*, etc.....................................	4
Ordovician (Cincinnatian):	
Leipers formation	
Knotty earthy and shaly limestone.	

The Fernvale embayments on the north and northwest sides of the Central Basin show an unusually thick development of pink to red limestone, and it is in this region that important dyestone deposits of Fernvale age were mined. In the Gallatin, Sumner County, section given below the limestone reaches a thickness of 56 feet with sandstone and shale forming the upper member. In Davidson County the section at White's Creek, given under the discussion of the Arnheim formation, shows 49 feet of limestone and no shale. These two localities were probably some distance from the shore of the old bay.

Section on north side of ridge 3 to 4 miles north of Gallatin, Tennessee

	Feet
Mississippian:	
Chattanooga black shale and overlying formations, covered.	
Silurian:	
Niagaran group:	
Siliceous limestone above with whitish beds below. *Favosites favosus* and other Niagaran corals present	20
Richmond group:	
Fernvale formation	
Sandstone above with casts of tuberculated bryozoa, lower half covered	15
Massive granular gray to pink limestone with brachiopods and bryozoa of Fernvale type	26
Covered but probably limestone. Surface strewn with blocks and plates of light-colored chert	35
Arnheim formation	
Shaly limestone with bryozoa, *Ctenodonta cingulata*, etc	6
Thin-bedded limestone and shale with many fossils weathering out silicified. *Heterospongia subramosa*, *Dystactospongia*, *Cyclonema fluctuatum*, and *Platystrophia ponderosa* abundant	24
Ordovician (Cincinnatian):	
Leipers formation	
Shaly limestone full of *Platystrophia ponderosa*	12
Phosphatic, fossiliferous limestone weathering to phosphate. The upper beds more cellular than the lower, the original rock having been more crystalline	36
Shale and thin-bedded blue limestone crowded with *Rafinesquina ponderosa*, and *Constellaria florida* with other bryozoa	15
Shaly limestone with large specimens of *Strophomena planoconvexa*	15
Unfossiliferous slate (to bed of creek)	7

The section southeast of Southall, Williamson County, given above as typical for the formation, expresses one phase of development on the west side of the Basin, for in other parts of this general embayment only limestone is developed, as shown in the Leipers Creek section given under the discussion of the Leipers formation.

The embayment reaching across the western part of the State, showing outcrops first at Clifton and extending to the marble quarries near Kelso, Lincoln County, affords many interesting exposures where the fauna is represented by well-preserved fossils. Sections of three of these exposures are reproduced below. In the region between the Central Basin and the Tennessee River in West Tennessee the formation ranges from 20 to 40 feet in thickness and consists of the Leipers Creek limestone below and the Mannie shale above of nearly equal thickness. At this distance from the head of the old bays the limestone is light gray, cross-bedded, and coarsely crystalline with scattered grains of phosphate. Some of the clays derived from the weathering of this rock are rich enough in phosphate to be a possible future source of supply. The overlying strata are soft and usually green. Bryozoa and brachiopods are unusually abundant in the lower shales of the following section near Pulaski.

Section along Pulaski-Brick Church pike at milepost 3 miles northeast of Pulaski, Tennessee

	Feet
Mississippian:	
Fort Payne chert.	
Chattanooga shale	6
Silurian (Richmondian):	
Fernvale formation	
Covered interval but almost certainly shale and soft light-yellow shale containing *Rhynchotrema capax manniensis, Dinorthis proavita*, and other brachiopods	30
Soft blue and yellow shale with several bands of more-calcareous material holding many *Rhombotrypa quadrata* and other characteristic bryozoa	5
Coarsely crystalline, pink and white massive limestone with *Rhynchotrema capax*, etc. (to bottom of valley)	15

Essentially the same sequence but with diminished thicknesses occurs in the next section southeast.

Section along road, three-quarters of a mile west of Bryson, Giles County, Tennessee

	Feet
Mississippian:	
Fort Payne chert to top of hill.	
Silurian:	
Fernvale formation	
Yellow, blue, and green shale with *Dinorthis proavita, Rhynchotrema capax, Rhombotrypa quadrata*, and other Fernvale fossils	15
Massive, coarsely crystalline pink and flesh-colored limestone, weathering into rounded masses or giving rise to porous hematite	5
Ordovician:	
Leipers formation	
Coarsely crystalline blue limestone weathering nodular, with many *Platystrophia ponderosa*	5
Clayey limestone with usual Leipers fossils (to base of section).	

Quarrying near Kelso in central Lincoln County shows the Fernvale to consist entirely of flesh-colored crystalline limestone of such nature that it can be used as a marble.

Section at marble quarry 3 miles southeast of Kelso, Linco'n County, Tennessee

	Feet
Mississippian:	
Fort Payne limestone	
Light-blue, massive dull limestone weathering into typical chert with a 1-foot bed of green shale (Maury) containing a layer of kidney concretions at the base.	
Chattanooga shale	
Black fissile shale with 6 inches of sandy, phosphatic blue shale bearing conodonts, representing the Hardin sandstone, at the base	6.5

	Feet
Silurian:	
Fernvale formation	
Massive flesh colored, coarsely crystalline limestone in beds 1 to 5 feet thick, containing many fossils especially fragmentary bryozoa	25
Ordovician:	
Leipers formation	
Dark-blue argillaceous limestone with *Platystrophia ponderosa*, etc.	

Stratigraphic relations.—The widespread submergence of the continent in Fernvale time, with the formation overlapping strata of many different ages in areas west of Tennessee, is indicated in the Central Basin area by the shallow troughs of deposition, which overlapped parts of the western flank of the Nashville dome. These troughs, less extensively developed, were present in the earliest Silurian, Arnheim, time, although the areal extent of the Arnheim is not so well known as that of the Fernvale. The Nashville dome was then wider, at least its western edge was farther west, for the greater part of the Fernvale embayments now lie west of the Central Basin. Thus in the Columbia quadrangle the outlines of these shallow troughs of Fernvale deposition can be made out in the valleys of various creeks of the Highland Rim area. As pointed out by Hayes and Ulrich these creeks still follow the ancient depression in a general way. Similar troughs, following the same general lines, sometimes received the post-Fernvale Silurian deposits, but just as often the next formation was the widespread, early Mississippian Chattanooga shale. Thus in southern Williamson County the Fernvale rests upon the Leipers and is followed by the Chattanooga shale. In the next area of outcrop on the north it occurs in a trough used also by the Arnheim and Osgood limestones, for here (2 miles southwest of Southall) the succession is Leipers, Arnheim, Fernvale, Osgood, and Chattanooga shale. Still farther north, in the northwest corner of the Franklin quadrangle, the arrangement is Leipers, Fernvale, and Chattanooga, whereas at Newsom, southwest of Nashville, the full succession of Leipers, Arnheim, Fernvale, Osgood, Waldron and higher formations is present.

Up to the end of Leipers time the Ordovician formations had spread over the whole dome or formed broad areas on its side. Warping at the beginning of the Silurian produced shallow depressions, which when submergence set in were occupied first by the Arnheim, then by the Fernvale, and finally by higher Silurian formations. In the latter times the same embayments were used, although a few new embayments are known to have developed.

Economic features.—The development of the Fernvale in narrow troughlike areas, although restricting its distribution, has caused a concentration of certain minerals in its strata, which give it economic value. These have already been briefly mentioned. The highly crystalline limestones, many of a pleasing color, are developed to such a thickness in some areas as to make them of value as building stone. In certain parts of northern and also of southern Tennessee the streams pouring into the old bays of deposition were so charged with iron compounds that a brilliant red or vermilion color was imparted to the strata, which on weathering gave rise to the dyestone deposits already mentioned. Phosphatic granules form a part of the Fernvale limestone in the Waynesboro quadrangle area, and weathering of the limestone leaves the phosphate scattered throughout the resulting clays. Although these clays produce excellent soils, they do not analyze high enough in calcium phosphate to make the recovery of this material worth while at present.

Fauna of the Fernvale.—Whether its thickness is a few inches or the maximum the formation contains its characteristic fossils with little change from the lowest to the highest beds. The fauna of the Fernvale is quite uniform throughout its occurrence in Tennessee not only from place to place but also throughout the formation. The massive limestone portion contains many fossils, but aside from noting the characteristic *Rhynchotrema capax* and some typical bryozoa these have not been listed. The upper, shaly portion in places contains fossils in greater profusion, although elsewhere specimens are not so common. The fauna thus arrived with the beginning of deposition and continued little changed until the seas of the time retreated. The Fernvale fauna is undoubtedly of Arctic origin, as a representation of it occurs in the same or closely allied formations northward to Alaska and Greenland, whereas southward both the formation and the fauna cease in the baylike areas outlined before. The following fauna has been noted in the shales.

Fauna of Fernvale (Mannie) shales in central Tennessee

Brachiopods: *Crania laelia* Hall, *Dalmanella tersa* Sardeson, *Dinorthis proavita* Winchell and Schuchert, *D. subquadrata* (Hall), *Hebertella insculpta* (Hall), *H. sinuata* Hall, *Leptaena unicostata* Meek and Worthen, *Lingulops cliftonensis* Foerste, *Platystrophia acutilirata* (Conrad) var., *Rafinesquina alternata* Conrad, *Rhynchotrema manniense* Foerste, *R. perlamellosum* Whitfield, *Sowerbyella (Plectambonites) saxea* Sardeson, *Strophomena odessae* n. sp., *S. planodorsata* Winchell and Schuchert, *Zygospira recurvirostris* Hall var.

Bryozoa: *Anaphragma mirabile* Ulrich and Bassler, *Anolotichia ponderosa* Ulrich, *Constellaria polystomella* Nicholson, *Corynotrypa turgida* Ulrich, *Crepipora hemispherica* Ulrich, *Dicranopora fragilis* (Billings), *Diplotrypa dubia* Ulrich, *Favositella epidermata* Ulrich, *Goniotrypa bilateralis* Ulrich, *Lioclemella bifurcata* new species, *Pachydictya grandis* Ulrich, *Peronopora decipiens* Rominger, *Ptilotrypa obliquata* Ulrich, *Rhombotrypa quadrata* Rominger.

Gastropoda: *Cyclonema bilix* Conrad, *Cyclora minuta* Hall, and associated dwarfed species.

Crinoidea: Beadlike crinoid columns characteristic of Fernvale.

POST-RICHMOND SILURIAN STRATA

Strata of post-Richmond Silurian age appear only in a small area in one of the four quadrangles here considered, the Franklin quadrangle, where they occur by overlap upon the Central Basin from one of the bays of deposition plotted on the Columbia map. Here even-bedded, compact, light-gray or bluish limestone 10 feet in thickness contains fossils referable to the Osgood limestone of the Niagaran group. The relationship to the underlying Fernvale formation and the overlying Chattanooga shale is shown in the section 2 miles southwest of Southall, given under the discussion of the Fernvale formation. Other Niagaran and earlier Silurian formations crop out around the north edge of the Basin and are mentioned in several sections of that area. Devonian limestones also occur in a few places along the north and west edges but like the Niagaran they do not enter into the present discussion. Various articles by Foerste and one by Pate and Bassler give details regarding these formations. The following sections, the second kindly furnished me by Dr. Erwin R. Pohl of Vanderbilt University, show the characteristics of these formations on the north and west sides of the Basin.

Geologic section from Goodletts to Bakers station, Tennessee

	Feet
Mississippian (Chattanooga black shale).	
Silurian:	
Waldron formation	
Yellowish-gray dolomite (3 feet) above and green sandy shale (3 feet) below, sparingly fossiliferous but containing *Atrypa newsomensis*, *Hallopora elegantula*, *Caryocrinus*, *Camarotoechia*, etc.	6
Laurel limestone	
Massive pinkish, crystalline limestone	35+
Osgood limestone	
Argillaceous and subcrystalline gray limestone and shale	25
Brassfield limestone	
Finely crystalline gray limestone with layers of gray flint	8
Fernvale formation	
Massive, coarsely crystalline, pink limestone	10
Arnheim formation	
Cherty, blue argillaceous limestone and shale weathering into a red soil, with many fossils, particularly *Rhynchotrema capax*, *Streptelasma rusticum*, and *Cyclonema fluctuatum*	15
Light-colored shales and thin-bedded limestone, some layers crowded with *Sowerbyella* (*Plectambonites*)	10
Shaly blue limestone with many *Rhynchotrema dentatum arnheimensis*	8
Ordovician:	
Leipers formation	
Thin-bedded, phosphatic limestone with *Orthorhynchula linneyi*, etc. A bed full of *Rafinesquina ponderosa* at the top	15
Yellow shale and thin blue limestone having *Platystrophia ponderosa* and *Rafinesquina ponderosa*	10
Thin bedded blue limestone and shale with many fossils	30
Blue and yellow shales and a few thin blue limestones with few fossils	10

The following section is well exposed in a broad dome through which Tennessee Highway No. 1 cuts.

Geologic section on Memphis to Bristol highway, 14 to 15 miles west of Nashville and 1½ miles northwest of Newsom, Tennessee

	Feet
Mississippian:	
Rosewood shale, New Providence shale and Ridgetop shale exposed to top of hill.	
Chattanooga shale	
Black, thinly fissile, bituminous shale with Mississippian conodonts, grading downward into sandstone below	20
Hardin member	
Brown phosphatic sandstone carrying silicified fossils of various Silurian and Ordovician formations	0.5-1
Devonian:	
Jeffersonville limestone	
Massive, white, coarsely crystalline, crinoidal limestone with sand lenses, an irregular band up to 4 feet thick of coarse, saccharoidal sandstone in places at top. Fauna composed of *Leptaena rhomboidalis*, *Stropheodonta perplana* and *S. demissa?*, *Hadrophyllum orbignyi*, *Proetus crassimarginatus*, and many other Jeffersonville species	15
Silurian:	
Niagaran:	
Lobelville formation	
Massive, coarse oolite with *Uncinulus stricklandi*	8
Grey, rubbly, argillaceous limestone and green shale with characteristic Lobelville corals, etc	25
Lego limestone	
Light-grey, crystalline, crinoidal limestone in regular, thick beds parted in upper portion by 1 to 2 inch bands of barren green shale	43
Waldron shale	
Covered interval, but green clay, limestone lenticles, and typical Waldron fossils present	10
Laurel limestone	
Grey, massive, thick-bedded, crystalline, crinoidal limestone with pink specks, carrying a few straight cephalopods	27
Osgood formation	
Greenish and red shale, with *Calymene* and ostracods below, becoming more calcareous and crinoidal above. Upper half an argillaceous, crinoidal limestone with ¼ to ½ inch columnals, and plates of *Holocystites*	13
Medinan:	
Brassfield formation	
Fossiliferous, blue-grey, massive, finely crystalline limestone in regular thin and thick beds 6 inches to 2 feet thick, carrying considerable nodular and banded white to light-grey chert. *Halysites catenulatus* and var., *Favosites favosus*, *Heliolites interstinctus*, *Dalmanella* and encrusting bryozoa	27
Massive single bed of compact, blue-grey, finely crystalline limestone (calcareous sandstone) pronouncedly cross-bedded on etched surface	1-2½
Richmondian:	
Fernvale formation	
Grey to green shale with thin, nodular limestone lenses carrying	

	Feet
Fernvale fossils. Upper surface irregularly truncated by slight angular unconformity	1-5
Rather barren, pinkish and greenish, massive, crystalline, crinoidal limestone in irregular thick beds with thin shale partings (to base of section)	9

DEVONIAN SYSTEM

As mentioned on a previous page the Nashville Dome was a land area during Devonian time, so that strata of this age in central Tennessee were deposited in the surrounding sea and thus today occur only locally along the margin of the Dome. No Devonian strata were discovered in the four quadrangles forming the subject of this report so that a discussion of this system is not included herein. In northern Tennessee the lower part of the Black shale is separated from the upper by a well-marked unconformity and, moreover, contains Devonian fossils. This Devonian part of the shale does not apparently extend southward over the Nashville Dome to any great distance.

MISSISSIPPIAN SYSTEM

The Mississippian (Lower Carboniferous or Subcarboniferous) rocks of Tennessee were early divided by Professor Safford into a lower, "Siliceous group" and an upper, "Mountain or Pentremital limestone," the Black Shale member at that time being considered to be of Devonian age. Although Dr. Troost was the originator of the term "siliceous strata," making use of it in his reports, Safford was the first to describe the strata. In his article The Silurian Basin of Middle Tennessee, with Notices of the Strata surrounding it (American Journal of Science, series 2, vol. 12, 1851, pp. 352-361), Safford divides all the Paleozoic rocks of the State that underlie the Pentremital limestone into five sections. The name Siliceous Group was applied to the uppermost section, the other four consisting of the limestones and shale now referred to the Ordovician, Silurian, and Devonian. The Siliceous Group included all the strata between the Black shale and the Pentremital limestone or in terms of today formations of the Lower Mississippian. He subdivided the Siliceous group into two members, the lower or true siliceous beds consisting of a light-blue, fine-grained, siliceous, rather unfossiliferous limestone weathering into a light-yellow to gray or brown soil strewn with chert fragments, and the upper member, the cherty limestone proper, differing from the lower member "in being a true limestone affording a brick red soil, in the character of its interbedded (flint) masses, and in being much more fossiliferous". A species of *Lithostrotion* was noted as a characteristic fossil of the upper member.

In 1856 Safford again described these strata but gave little additional information concerning the rocks. Later, in 1869 in his classic work the Geology of Tennessee, he gave an excellent description of the Siliceous group, naming the divisions the "Lower or Protean bed" and the "Lithostrotion Coral bed."

The Lithostrotion bed is characterized everywhere by *L. canadense* and in this volume is correlated with the St. Louis limestone. The lower or Protean member is said to be "in general equivalent to the divisions of the Lower Carboniferous limestone lying below the St. Louis limestone. It is perhaps more especially the equivalent of the Keokuk limestone, it contains, however, some Burlington forms". Some of the lower Siliceous fossils listed by Safford are Keokuk species elsewhere, and as shown in the Table of Geological equivalents (by A. Winchell) on page 364 of the Geology of Tennessee the lower Siliceous was correlated with the Keokuk.

In the Resources of Tennessee, 1874, Safford and Killebrew use the term "Barren group" instead of Protean bed for these strata, and later in their text book The Elements of the Geology of Tennessee, 1900, they abandon both the names Siliceous group and Barren group and substitute for them St. Louis limestone and Tullahoma limestone, introducing the new term Maury green shale for the basal member of the series in Maury County.

The next work upon the subject in so far as it relates to Tennessee is by Hayes and Ulrich (U. S. Geological Survey, Columbia folio, Tennessee, No. 95, 1903) who adopt the names Tullahoma formation and St. Louis limestone but include the Maury green shale with the Chattanooga black shale. In the Tullahoma formation they describe a lower calcareous shale member and state that it is absent in many places. This shale, which contains many ostracoda indicative of early Mississippian age, was separated by Bassler, in 1911, as the Ridgetop shale of the Kinderhookian. In their correlation table Hayes and Ulrich make the Tullahoma the equivalent of the Kinderhook, Burlington, and Keokuk of the generalized time scale.

The above notes include all of the more important references to the lower or Protean member of the Siliceous group in Tennessee, but the terms Tullahoma and Fort Payne have also been frequently employed in the discussion of the geology of neighboring States. The Fort Payne chert, a term proposed by Hayes for practically the same division in the southern Appalachian Valley, was also used by him in the McMinnville folio, covering a part of the eastern rim of the Central Basin.

The Fort Payne chert, as found on exposures of the formation in the eastern rim of the Central Basin, seems to agree with the Tullahoma of Safford and Killebrew, except that the section of Tullahoma includes Warsaw in addition to Keokuk strata. Moreover Safford and Killebrew used the name Tullahoma also for the beds between the Maury green shale and the St. Louis limestone along the western edge of the Basin thus including the Kinderhook and New Providence shales, which are there locally developed beneath the cherty bed. Hayes and Ulrich adopted the term in the latter sense in the Columbia folio. The typical Fort Payne embraces cherty limestone of Keokuk age only and is so employed in the present work.

The Mountain or Pentremital limestone was described in some detail by Safford in his Geology of Tennessee, in which he published several extended sections, differentiating the several lithologic units but not giving them separate names. He did show the equivalence of the Mountain limestone to the Chester group of Illinois and gave a list of its characteristic fossils.

This limestone with its included shale and sandstone form, for the most part, the base of the Cumberland Plateau, where its subdivisions can be studied in detail. Charles Butts in his Geology and Oil Possibilities of the Northern part of Overton County, Tennessee, and of Adjoining parts of Clay, Pickett, and Fentress Counties (Tennessee Geological Survey, Bull. 24, 1919), has distinguished the several formations of the Mountain limestone and correlated them with named divisions in Kentucky and Illinois.

A composite section of all the Mississippian formations of Tennessee is as follows:

Composite section of Mississippian formations of Tennessee

	Feet
Pennsylvanian System:	
Lee group:	
Coarse, thick-bedded sandstone, 30-200 feet thick, locally conglomeratic (Rock Castle sandstone) at top, with 140 feet of thin sandstone and sandy shale containing thin coal beds (Vandever shale) below.	
Mississippian System:	
Chester group:	
Pennington shale	
Red and green shale with thin limestone and sandstone layers......	200
Glen Dean limestone	
Argillaceous gray limestone at top, blue crystalline, fossiliferous limestone in middle, and thick-bedded bluish limestone with abundant geodes at bottom..................................	140
Hardinsburg sandstone. Shale and soft sandstone......................	0-40
Golconda shale. Soft green and red shale............................	0-30
Cypress sandstone. Moderately hard, medium thick bedded sandstone....	0-75
Monte Sana limestone	
Gasper oolite. Gray oolitic limestone with some gray, glassy-textured, brittle limestone..............................	100-140
Fredonia oolite. Gray oolitic limestone much like the succeeding Gasper oolite but separated from it by a few feet of earthy shale and limestone..	100-140

	Feet
Meramec group:	
St. Louis limestone	
Dark-blue fine-grained limestone weathering into abundant solid, yellow, blocky and rounded chert and containing many *Lithostrotion canadense*	120-140
Warsaw formation	
Sandy, fragmental, cross-bedded limestone with shale at base and Garretts Mill sandstone at top	100
Osage group:	
Fort Payne formation	
Massive argillaceous limestone weathering into solid, brittle, blocky chert (typical Fort Payne) and siliceous shale (Rosewood phase)	200-275
New Providence shale	
Bluish clay shale with occasional crinoidal limestone layers, a lens of limestone in the middle part	0-200
Kinderhook group:	
Ridgetop shale	
Gray-blue shale weathering gray	0-240
Maury shale	
Green shale composed of greensand grains with layer of kidney phosphate nodules at the base. Represents the introductory layer of post-Chattanoogan time	0-5
Chattanooga group:	
Chattanooga shale	
Black, fissile, carbonaceous shale with the introductory member, the Hardin sandstone, at the base, the latter here and there replaced by blue phosphate	0-35

CHATTANOOGA SHALE

Lying unconformably upon the older rocks of the Central Basin is the "Black Shale" of Safford (Geology of Tennessee, 1869, p. 331), which because of its widespread distribution and distinctive lithologic character is perhaps the best-known formation of Tennessee. The geographic name Chattanooga shale, taken from the Tennessee city, was given to the formation by C. W. Hayes (Geol. Soc. America, Bull. II, 1890, p. 142), who, like most other geologists, believed this formation to be the southern extension of the Devonian black shales of New York. The Devonian age of the Chattanooga shale was long ago questioned by Ulrich, whose experience in the study of the stratigraphy and paleontology of the typical Devonian black shales in New York and of overlying similar black shales of Mississippian age in Ohio led him to the conclusion that all the Tennessee black shales are of Mississippian age. (The Chattanooga Series with Special Reference to the Ohio Shale Problem. American Journal of Science, 4th ser., vol. 34, pp. 157-183, 1912.) The stratigraphic evidence on this question was supported by a study of the fossils particularly the conodonts, microscopic organisms like fish teeth, which abound in most black shales of late Paleozoic age.

Dr. Ulrich and the writer found that of more than 50 species from the black shales of Alabama and Tennessee not one was identical with an equally large number of species from the Devonian black shales of New York, although many of them are identical with those found in the Mississippian shales of northern Ohio. In spite of this direct evidence many geologists and geological organizations still continued to regard the formation as of Devonian age.

There thus arose the "Black shale problem," which was of such interest and geologic importance that Mr. Nelson detailed Joel H. Swartz to correlate the black shales throughout Tennessee and to trace them into their northern equivalents. Professor Swartz, after extensive field work and study of the faunas collected[1], agreed in every respect with Dr. Ulrich's conclusions. He found that the typical Chattanooga shale of east Tennessee could be divided into three parts: (1) An upper black shale, the Big Stone Gap member, (2) a middle pure to sandy gray shale, the Olinger member, and (3) a lower very sandy black shale, the Cumberland Gap member. The Olinger or middle member contains a typical Mississippian fauna, so that its age and that of the overlying Big Stone Gap member are thus determined. As the upper part of the Cumberland Gap member interfingers with the Olinger member, it too must be of this age. The entire Chattanooga shale, therefore, with the possible exception of the lower part of the Cumberland Gap member, is of undoubted Mississippian age.

In general the Chattanooga shale is a nearly black, highly fissile, rather tough, slaty, bituminous shale, known usually because of its slaty character as the Black slate. On fresh surfaces it has a distinct petroliferous odor, and scattered through much of it are crystals of pyrite. In the Appalachian Valley region it commences south of Birmingham, Alabama, as a feather edge and increases in thickness northeastward to Cumberland Gap, on the boundary of Virginia, Kentucky, and Tennessee, where by overlap a combined thickness of 500 feet occurs, and farther north at Big Stone Gap, Virginia, it reaches 1,100 feet. Throughout most of this latter region it overlies the uppermost Chemung sandstones and shales of the Devonian. Extending westward across Kentucky and Tennessee it crops out in Arkansas, Missouri, and Oklahoma, and northward it reaches into Illinois, Indiana, Ohio, and Michigan. In its western extension it maintains its character of a thin shale of Mississippian age, but in the northern States it overlaps older black shales, which combined with it in Indiana and Kentucky are known as the New Albany shale and in Ohio as the Ohio shale.

Mather in 1920 from a study of the black shale in northern Tennessee[2] came to the conclusion that here the lower part of the shales are of

[1] Swartz, Joel H., The age of the Chattanooga shale of Tennessee: Am. Jour. Sci., 5th ser., vol. 7, pp. 24-30 (1924).

[2] Oil and Gas Resources of the Northeastern part of Sumner County, Tennessee: Tenn. Geol. Survey Bull. 24, pt. 2-B.

Devonian age and the upper, early Mississippian. As in Kentucky a well-marked unconformity is the dividing line between these two members.

The Chattanooga shale is one of the guide formations over a considerable part of the Central Basin in determining geologic structure. It crops out almost continuously in more or less uniform thickness along the lower or middle slopes of the surrounding Highland Rim escarpment, and even though its outcrops may be obscured by débris from the overlying rocks, loose particles of the shale can be found as "float" whenever the proper horizon is reached. In the Central Basin proper erosion has removed, together with the younger formations, most of the black shale, but it is preserved in the higher hills and in the ridges and rows of hills extending into the Basin from the Highland Rim. This shale is so rich in bituminous matter that pieces of it will burn when thrown into a fire. This property of the shale led many persons to believe that coal was to be found with it, and consequently many futile attempts were made to find coal here. It is interesting to note that in one of his early reports Troost pointed out the uselessness of such operations.

The lithology of the Chattanooga shale is so similar throughout the Central Basin that in most of the stratigraphic sections given in this volume it is described as a single unit without accompanying details. The outcrops along the Louisville & Nashville Railroad at Bakers station, Tennessee, show its character in more detail than most exposures. Here, as indicated in the Bakers-Ridgetop section given under the discussion of the Ridgetop formation, the Chattanooga shale is 19 feet thick with the lower 9 feet of softer, less fissile material than the upper half, which is of the typical black-slate nature. Here also the basal conglomeratic layer, called the Hardin sandstone farther south, is 2 inches thick and contains silicified Ordovician and early Silurian fossils. The excellent exposures, as indicated in plate 43, also show the typical Chattanooga shale passing upward without a break into the Ridgetop shale, the upper beds of the former being black shales 1 foot thick, with phosphatic nodules similar to those in the overlying green Maury shale, which usually introduces the first post-Chattanooga Mississippian formation. In places the Chattanooga shale is absent, owing either to erosion before the higher Mississippian formations were laid down or to nondeposition.

The shale has usually been described as consisting of three members; first, a sandstone or phosphatic layer at the bottom; second, the typical black shale constituting the main body of the formation, and third, at the top, a thin stratum of greenish shale with earthy sandstone. The last division, which received the designation Maury green shale from Professor Safford, is now excluded from the formation because it forms the introductory member of whatever division succeeds the Black shale.

In Hardin County, Tennessee, the basal sandy layers, which here reach a maximum thickness of 12 feet, were distinguished by Safford as the Hardin sandstone. Usually the thickness is much less, and in many parts of the Basin there is only an inch or two of sandstone representing the initial deposit of the Mississippian upon the old land surface. Silicified fossils of various Ordovician and early Silurian ages washed from the old lands into the encroaching sea of the Mississippian make up most of its fauna, as for example the characteristic Leipers brachiopod *Platystrophia ponderosa* and the Arnheim gastropod, *Cyclonema fluctuatum*. This sandstone is also well developed in Wayne and Perry Counties where, as in Hardin County, it is almost everywhere slightly phosphatic and in places has a shaly structure. At other places in the Central Basin this sandstone is replaced by a gray, black or bluish-black, bedded phosphate deposit, composed of small rounded grains of an amber color and with a polished surface. As shown on plate 29, many of these rounded grains are the casts of minute gastropod shells of Ordovician species, which, as they formed a part of the older rocks, were eroded away when the Central Basin was a land surface during Upper Silurian and Devonian times and deposited as the basal formation of the Chattanooga shale. At other places this phosphate bed grades laterally into coarse sandstone or conglomerate containing smaller amounts of phosphate. Thus in different parts of the Basin the introductory beds of the Chattanooga shale are represented by either the Hardin sandstone, or a conglomerate, or a blue-black phosphate, all being different phases of deposition, the differences being due to the source of the material. The Hardin sandstone and the rocks correlated with it represent, therefore, a true basal deposit of a widely transgressing formation—its age, moreover, varying according to the stage of the overlap.

The fossils of the lower member of the Chattanooga formation have been mentioned briefly under the Hardin sandstone where it was indicated that these are simply specimens weathered from older rocks. With these, however, occur fossils of early Mississippian time, particularly fragmentary water-worn bones of large fishes, and in the sandy and phosphatic shale members great numbers of teeth, jaws, and plates of an extinct group of animals called conodonts. Plate 26 gives magnified views of various species of these conodonts, which are supposed to be related to the myxinoid fishes of today. In the black shale proper certain thin layers are crowded with *Lingula*, *Orbiculoidea* and with the same conodont faunas as in the Hardin sandstone. In some localities plant remains are very abundant in the black shales. These consist of rounded spores flattened out in the rocks and are so rich in organic matter that they are supposed to be the source of the oil that can be distilled from the shale.

Although the widespread distribution and rather uniform thickness and character of the black shale in central Tennessee has been commented upon, in places the formation shows great variation in the development of its members. This formation is of great interest in recording geologic phenomena and the history of early Mississippian time. Because of its apparent uniformity, the main body of the black shale has not been studied so carefully as the lower members, but future work may show it to be equally interesting. The section at Bakers station, which has been mentioned before, is repeated below for comparison with sections following. The features of this section are the basal sandstone layers, the two-fold divisions of the shale proper, and the imperceptible passage of typical Chattanooga black shale into the green Ridgetop shale.

Section of Chattanooga shale at Bakers, Tennessee

	Feet
Mississippian:	
Ridgetop shale	
Blue-green to gray-green shales	50
Green shale with phosphatic nodules (Maury green shale)	0.5-1
Green shale passing downward gradually into black shale	0.25-0.33
Chattanooga shale	
Black shale with phosphatic nodules as above	1
Black fissile shale with six inches of coarse sandstone at base	9
Black shale, softer and less fissile than that in bed above	9
Sandy conglomerate with Ordovician and early Silurian silicified fossils (Hardin sandstone member)	0.2
Silurian (Waldron formation):	
Yellowish-gray dolomite (3 feet) and green sandy shale (3 feet)	6

The classic locality at Whites Creek Springs exposes the smaller divisions of the main body of the shale to more advantage. This section is as follows:

Section of Chattanooga shale at White's Creek Springs, Tennessee

	Feet
Maury green shale. Represented by thin bed of widely scattered kidney phosphate nodules.	
Chattanooga black shale	
Fissile black shale	14
Thin, slightly phosphatic sandstone band (2 to 4 inches)	0.3
Black shale softer but more fissile than shale below	1.5
More or less phosphatic sandy shale	0.1
Black shale poorly fissile but weathering into large blocks. Small *Lingula* abundant in places	6.5
Basal sandstone	0.25
Niagaran limestone and shale.	

The above sections exhibit the shale as developed along the north edge of the Basin. In Barren County, Kentucky, north of this area, the black shales consist of a lower division of shale and sandstone 10 feet thick and an upper division, 30 or more feet thick, of dense, black, fissile clay shale. The lower division contains calcareous sandstone layers from a fraction of an inch to a foot thick interbedded with very soft, intensely black, finely fissile shale having the characteristic Genesee shale fossils *Schizobolus truncatus* and *Lingula spatulata*. The upper part contains *Lingula melie* and *Orbiculoidea newberryi* of early Mississippian age. The Devonian shales overlapping southward from their great development in New York and Ohio have thus apparently reached this far south.

The following three sections in Hickman and Maury Counties in the region of blue phosphate development give an idea of variations in this part of the geologic column.

Section along Morgan Branch, 2 miles north of Totty's Bend, Duck River, Hickman County, Tennessee

	Feet
Mississippian:	
Fort Payne chert	
Usual siliceous limestone weathering into chert. A bed of yellow clay at the base.	
Maury shale	
Green shale with the upper part having a layer of kidney phosphatic nodules	0.5
Chattanooga shale	
Black fissile shale	5
Sandy beds with clay seams, crowded with conodonts, *Cycloras*, and fish remains	0.5
Blue-gray phosphate composed of Cycloras and fragmentary fossils, regularly bedded and splitting into thin layers	1
Ordovician (Cincinnatian):	
Leipers formation	
Phosphatic limestone and brown phosphate	50+

West of Mount Pleasant the black shale is absent entirely, being represented only by the phosphatic beds.

Section on hill 4 miles west of Mount Pleasant, Tennessee

	Feet
Mississippian:	
Ridgetop shale. Blue-gray shale.	
Maury green shale with kidney phosphate bed	0.5
Chattanooga shale. Represented only by a blue to black phosphate bed with a thin phosphatic shale at the base	1.5
Silurian:	
Niagaran limestone with *Favosites favosus*	0.2
Ordovician:	
Leipers formation. Phosphatic limestone with *Platystrophia ponderosa* and *Rafinesquina alternata*.	

A similar arrangement of the strata is shown at Gordonsburg.

Section at Gordonsburg, Tennessee

	Feet
Fort Payne chert (to top of hill).	
Ridgetop shale	
Light-blue shale with several layers crowded with the characteristic ostracoda and other small fossils.	
Maury green shale with kidney phosphate	0.2
Chattanooga shale. Represented only by dark-gray to blue phosphate beds with occasional silicified boulders of Leipers formation	5+
Leipers formation	
Granular phosphatic limestone, where exposed usually weathered into brown phosphate, surface of topmost layer uneven (to bottom of section).	

Farther south on the west side of the Basin a section near Franklin shows 10 feet of black shale, with the Hardin sandstone absent, followed by 20 feet of Ridgetop with the green Maury shale and the kidney phosphate bed at the base. The next section, 2 miles southwest of Southall, Williamson County, shows the Silurian Osgood limestone followed by a sandy phosphate bed of the Chattanooga, here 4 inches thick, and this by 13 feet of black fissile shale, some of the layers of which are crowded with conodonts. Above this is a 2-inch bed of the phosphatic nodules followed by 2 feet of the light-green Ridgetop shale.

The Leipers Creek section, 3 miles north of Water Valley, Tennessee, shows 1.6 feet of ferruginous yellow shale and conglomeratic blue phosphate followed by 5 feet of the typical black shale and 4 inches of the phosphatic concretions, resting upon the Fernvale limestone.

At Loftin Hill, 8 miles east of Columbia, a bed of black shale 5 feet thick, which rests upon the Leipers, is immediately followed by the Fort Payne chert.

In the vicinity of Pulaski 6 feet of black shale rests on top of the Fernvale and is followed by the Fort Payne chert. The sequence of early Mississippian strata on the south side of the Basin is well exhibited near Kelso. Here the marble quarry, 3 miles southeast of Kelso, Lincoln County, shows 6 feet of shale with 6 inches of sandy phosphatic blue shale at the base, the Chattanooga shale here resting upon the Fernvale limestone. At this place the green Maury shale, 1 foot thick, containing a layer of kidney concretions, introduces the Fort Payne limestone.

Along the east side of the Basin the shale maintains a rather uniform development and thickness. In Cannon County, as shown in our Woodbury section, only the black fissile shale is developed, usually to a thickness of 35 feet, with the Hardin sandstone phase and the overlying phosphatic nodular layer absent. The shale rests upon the Cannon limestone and is followed by 8 feet of Maury green shale, which here is the initial deposit of the Fort Payne chert. Farther north, in Dekalb

County, the conditions are essentially the same except that there the shale rests upon the Catheys formation.

Four and one-half to five miles north of Tullahoma 22 feet of black shale is in close contact with the underlying Cannon limestone, and here, as elsewhere in this region, no basal sandstone is developed.

In one part of the eastern Central Basin Ralph Lusk has noted an unusual thickness and occurrence of the shale. This exceptional locality is in the valley of Rush Fork near its junction with Flynn's Creek, 5 miles south of Gainesboro, where the shale was found to exceed 149 feet in thickness with continuous outcrops of 75 to 90 feet at several places in the vicinity. Here the shale occupies an irregular depression in a limestone conglomerate that is at the same elevation as the Cannon, Catheys, and Leipers strata of the area. Elsewhere in the region the shale rests upon the Leipers limestone and has its usual thickness of about 20 feet. On three sides of this area the dips suggest that the region may be another example of crypto-volcanic structure such as that described by Bucher for Adams County, Ohio.

Another interesting area of the shale is found in Coffee County 2 miles southeast of Beech Grove, where, in a small circular region of sink holes, the shale and Fort Payne chert outcrop at angles of 40°—far below their normal position in the hills. Evidently the Mississippian rocks have here dropped down at an angle around the edges of a sink hole.

MAURY GREEN SHALE

Green shale ranging from several inches to several feet in thickness, usually with a layer of calcium phosphate concretions near its base, and locally containing glauconite grains of iron and potassium silicate, which gives its green color, succeeds the Chattanooga shale at many places in the Central Basin and East Tennessee. This bed is so well developed in Maury County that it has been named the Maury green shale by Safford and Killebrew and described by them as a distinct division at the base of the Tullahoma (Fort Payne) formation. The bed is, however, present in many places irrespective of the age of the rocks following it, so that it doubtless represents the introductory stage of the succeeding formation no matter what that may be. This shale, composed of a material like bentonite, is of especial interest because of its contained nodules made up of 50 to 65 per cent of calcium phosphate. Although the percentage of phosphate is too small for present-day mining the nodules may have an economic value in the future. These nodules, ranging in size and form from marbles to kidney and gourd shaped objects a foot long, can be relied upon in mapping even though they do not appear at every outcrop. Where all the other rocks are covered, the occurrence of a layer of phosphatic nodules on a hill slope clearly marks the top of the Chattanooga shale. Specimens of *Lingula* may be found in some of the concretions, but other fossils are not known in this shale. The varying thickness, its relationship to other Mississippian formations, and other characteristics of the Maury green shale are shown in the sections given on following pages.

RIDGETOP SHALE

Grayish-green to pale-blue shale ranging from a feather edge to 30 feet in thickness were mentioned as forming in many places the lowest member of the Tullahoma formation by Hayes and Ulrich in their Columbia folio, when also they noted the characteristic fossils of the shale —various undescribed species of ostracoda. In 1911 the present writer in a discussion of The Waverlyan Period of Tennessee (Proceedings U. S. National Museum, vol. 41, pp. 209-224) separated these strata as the Ridgetop shale and published as a type section the one exposed along the Louisville & Nashville Railroad between Bakers and Ridgetop. More recent study of this section has shown that the upper 30 feet of the supposed Ridgetop held the bryozoan fauna of the New Providence shale so that the following revision is necessary.

Geologic section along Louisville & Nashville Railroad from Bakers station to Ridgetop, Tennessee

	Feet
Mississippian:	
Warsaw limestone	
Massive granular limestone weathering into characteristic soft chert and red soil	70
Fort Payne (Rosewood phase)	
Gray to light-blue siliceous and argillaceous limestone becoming quite shaly in the middle third. Geodes not uncommon but little chert developed. Basal beds deposited over eroded edge of underlying strata	120
New Providence shale	
Blue calcareous shale with occasional thin argillaceous limestone bands with characteristic bryozoa of the New Providence. At the base, sandy layers 2 feet thick with corals (*Beaumontia americana*, *Favosites*, *Zaphrentis*, *Monilopora*, *Striatopora*, etc	30
Ridgetop shale	
Gray-green shale becoming calcareous toward the top	12
Blue-green to gray-green soft shale with a 6-inch glauconite band at both the top and bottom	4
Gray-green siliceous shale	10
Siliceous limestone with conchoidal fracture weathering yellow and containing ostracoda	1-2
Calcareous green and finely sandy gray-green shale with a few geodes in the upper half and ostracods in several layers	20
Yellow platy chert with fossils, *Chonetes ornatus*, *Rhipidomella diminutiva*, *Cyrtina burlingtonensis*, *Cladochonus*, *Trachypora*, etc	1-1.3

	Feet
Green shale with phosphatic nodules	0.5-1.0
Green shale passing gradually downward into black shale	0.25-0.33
Chattanooga shale	
Black shale with phosphatic nodules as above	1
Fissile black shale	9
Brown to black coarse sandstone	0.5
Black shale, soft and not as fissile as bed above. A 2-inch sandy conglomerate with Ordovician and Richmond silicified fossils at the base, representing the Hardin sandstone	9
Silurian:	
Waldron formation	
Yellowish-gray dolomite (3 feet) and green sandy shale (3 feet)	6

Detailed mapping in the quadrangles of middle Tennessee so far published and reconnaissance work elsewhere show that the Ridgetop shale, like the Niagaran and Richmond formations, was deposited in embayments of the Nashville Dome, these, however, being of greater extent than those of the older strata. These embayments were limited apparently to the northern and western sides of the Basin, as no evidence of the Ridgetop was found in mapping the Woodbury and Hollow Springs quadrangles of the eastern side nor in sections noted along the southern edge. The Lillydale quadrangle gives good evidence of a broad embayment with its western side plainly outlined by the feather edge of the formation in the western fourth of the quadrangle. The thickness of this shale increases eastward until a total of 200 feet is reached in the eastern part of the quadrangle. In the type area in northern Davidson County the typical section just quoted gives less than the average thickness, for east of Ridgetop the formation increases to at least 200 feet. The changing thickness of the formation in this embayment may be noted in the sections of the area given under the discussion of the New Providence.

Another embayment of Ridgetop deposition lies north of Duck River and extends east to Franklin and vicinity, where a thickness of 20 feet is usually registered. South of Duck River on the western part of the Rim the Ridgetop is not developed north of the region of Gordonsburg, where for a few miles north and south and extending as far east as Mount Pleasant, a thickness reaching 30 feet in places is developed. Farther south in the vicinity of Pulaski and east to the eastern edge of the Basin the formation has not been noted by the writer, and as stated above it is not present along the eastern part of the Rim until the region just south of the Lillydale quadrangle is reached.

Various species of *Spirifer*, *Productus*, *Brachythyris*, *Spiriferella*, and other large shells occur at several zones in the Ridgetop, but these are in course of study and can not be listed definitely at present. The most characteristic fossils of the formation as determined so far, are the microscopic bivalve crustacea, the ostracoda, which literally crowd some of the layers. In weathering these fossils assume a red color, and many of the small slivers of shale are spotted with their tiny carapaces.

A considerable number of species has been noted in the Ridgetop, and the following examples, figured on plate 27, have been selected to represent the fauna.

Ostracoda of the Ridgetop shale

Aechmina longicornis n. sp., *Allostraca fimbriata* n. sp., *Barychilina lineata* n. sp., *Beyrichiopsis pulchra* n. sp., *B. modesta* n. sp., *Bursulella? tennesseensis* n. sp., *Ctenobolbina loculata* Ulrich, *Mauryella mammillata* Ulrich and Bassler, *Paracythere cornuta* n. sp., *P. granopunctata* n. sp.

Although no exact correlation of the Ridgetop shale with the standard Mississippi Valley section has yet been possible, it is significant that one of the above ostracods, *Ctenobolbina loculata* Ulrich, is found also in the shale at the base of the Louisiana limestone near Louisiana, Mo. The inclusion of the Ridgetop in the Kinderhookian therefore seems warranted.

NEW PROVIDENCE FORMATION

The wealth of crinoids in the rocks outcropping around Whites Creek Springs, 12 miles north of Nashville, in Davidson County, has long made it a classic locality for the paleontologist. Safford in his Geology of Tennessee referred to this area as a good representative of his Lower or Protean member of the Lower Carboniferous and in listing the fossils stated that most of the species listed that occurred outside of Tennessee were Keokuk forms. It thus came about that all fossils from Whites Creek above the Black shale were labelled "Keokuk," a procedure that caused much confusion particularly in the study of the crinoids. This led Dr. Frank Springer to make a special study of the crinoid forms of Whites Creek and other noted early Mississippian localities and in 1910 to request the author to study the stratigraphic section at this Tennessee locality. These combined studies resulted in two papers, The Crinoid Fauna of the Knobstone Formation by Frank Springer (Proceedings U. S. National Museum, vol. 41, pp. 175-208, 1911) and The Waverlyan Period of Tennessee by R. S. Bassler (Proceedings U. S. National Museum, vol. 41, pp. 209-224, 1911), which presented evidence of the occurrence of another Lower Mississippian formation between the Black shale and the typical Keokuk, hitherto not recognized in Tennessee. This formation was found to be the equivalent of the New Providence formation, so named by Borden in 1874 (Indiana Dept. Geology and Natural History, Fifth Ann. Rept., p. 161) from New Providence, Clarke County, Indiana, where it included the lower 80 to 120 feet of the Knobstone group.

In his 1911 paper the writer published the geologic section at Whites Creek Springs, but a restudy of the locality in 1923 showed that he was in error in attributing the lower 40 feet of shale under the New Providence crinoidal limestone to the Ridgetop. It seemed improbable to him in 1911 that the Ridgetop shale, so well developed at Ridgetop just a few miles northeast of Whites Creek, should not be represented at all at the latter place, but experience since then has shown many examples of such rapid changes in the thickness and distribution. The writer's present idea of the Whites Creek section is as follows:

Geologic section of Mississippian rocks at Whites Creek Springs, Tennessee

	Feet
Warsaw limestone	
Massive and thin-bedded limestone weathering into chert, and sandy shale (to top of hill)	40
Fort Payne (Rosewood phase)	
Massive gray argillaceous limestone and gray siliceous to calcareous shale weathering light brown, with a few massive argillaceous limestones near the base, containing the crinoid fauna of this classic area. Fossils rare, crinoidal remains being most common; among the species are *Agaricocrinus americanus*, *A. nodulosus*, *Dorycrinus gouldi*, and *Lobocrinus nashvillae*	80
New Providence formation	
Coarsely crystalline, white to gray, crinoidal limestone layers 12 to 18 inches thick, formed by lenses of organic remains, separated by thin green to blue shale bands and overlain by gray-green to blue shales. Upon weathering these limestones and shales break up into fragments, forming glades covered with crinoidal remains. At the base are light-blue to green clay shales with *Rhombopora incrassata*, *Cystodictya lineata*, *Fenestella regalis*, *Streblotrypa major*, and other characteristic New Providence fossils	35
Layers of decomposed chert	0-1
Green shale containing layer with widely scattered phosphatic concretions (Maury shale)	0.5
Chattanooga shale	
Black, fissile shale, sandy phosphatic shale and sandstone (details under discussion of Chattanooga)	24+

As the Ridgetop and New Providence formations do not have the wide distribution of the underlying Chattanooga shale and the overlying Fort Payne formation and are limited to the same or closely related embayments upon the Nashville Dome, sections showing the characteristics and variations of both are given below. Dry Fork of Whites Creek, just west of the foregoing section shows the following arrangement of these strata.

Section along Dry Fork of Whites Creek, Davidson County, Tennessee

	Feet
Warsaw	
Massive arenaceous claystone and argillaceous limestone weathering into yellow, sandy, ocher-like layers 1 to 2 feet thick separated by thin layers of yellow shale. Porous chert with Warsaw fossils abundant in upper part	125

	Feet
Fort Payne (Rosewood phase)	
Light-blue to dark-blue siliceous shale in beds 1 to 4 feet thick weathering into brown irregular flat fragments. Many of the beds are studded with 1 to 4 inch geodes and at intervals of 1 to 3 feet there are darker strata, which yield platy chert upon weathering along bedding planes	80
Ridgetop shale	
Light blue-gray shale massive when fresh but breaking into thin flat pieces on weathering. Layers with characteristic Ridgetop ostracoda observed up to 40 feet above the base, so the upper 35 feet might represent the New Providence.	75
Chattanooga shale. Black fissile shale.	

The type section at Ridgetop, given on a previous page, shows 30 feet of New Providence without any conspicuous development of the crinoidal limestone, which occurs only when fossil remains are abundant enough to constitute limy strata. Two and a half miles east of Ridgetop the Ridgetop shale increases to a thickness of at least 200 feet and the New Providence disappears. Farther east along the northern edge of the Basin is another embayment of New Providence covering the area north of Hartsville. The formation is again absent until it appears in the region east of Red Boiling Springs in a broad embayment extending to the east side of the Lillydale quadrangle. At Spivey, northeast of Red Boiling Springs, the New Providence is about 20 feet thick, but as shown in the next section it increases to 40 feet near Celina.

Section along Celina-Red Boiling Springs Road, 2 miles west of Celina, Tennessee

	Feet
Mississippian:	
Fort Payne (Rosewood) shales	
Siliceous blue shales not weathering into chert.	
Siliceous shaly limestone weathering into 2 to 4 inch layers of flint nodules.	30
New Providence formation	
Massive light-blue crinoidal limestone	40
Maury shale	
Green shale with layer of kidney phosphate nodules	1-2
Chattanooga shale	
Typical fissile black shale.	
Silurian:	
Even-bedded massive clay limestone and dolomite the top bed crowded with elongate rounded chert nodules in parallel layers.	
Ordovician:	
Leipers formation.	

Along the west edge of the Lillydale quadrangle the basal beds of the New Providence, crowded with typical bryozoa, can be observed in many sections, with the basal phosphatic-nodule layer resting upon the Chattanooga shale.

Section up Shanky Branch 2 to 3 miles southeast of Celina, Tennessee

	Feet
Warsaw to top of hill.	
Fort Payne	
Dark-blue siliceous shale with a few layers weathering into chert	75
New Providence	
Massive light-blue crinoidal limestone	12
Shale and yellow clay layers with many geodes	53
Bluish unfossiliferous clay shale with geodes	30
Blue-green shale with various calcareous layers weathering marly, filled with New Providence bryozoa and with several 4-inch layers of chert in basal part	60
Maury shale. Green shale with layers of phosphatic nodules	1
Chattanooga shale. Fissile black shale	20
Leipers limestone.	

The hill just east of Celina shows the overlapping edge of the Ridgetop, for here the Chattanooga shale is followed by 5 feet of Ridgetop shale with its 2-foot basal chert bed and above this comes the typical New Providence shale crowded with bryozoa. One and a quarter miles south of Celina the Chattanooga is followed by 30 feet of massive crinoidal limestone of New Providence age.

At Neelys Cross Roads School, southeast of Celina, the black shale exposed in the hollow on the south at altitude 715 feet is followed by typical New Providence shale up to 910 feet. A 3-foot siliceous limestone weathering into chert begins the Fort Payne here, and this formation continues with light-blue shale up to 970 feet where it is succeeded by the Warsaw. Pilot Knob, 4½ miles northeast of Celina, exposes an interesting section of the Mississippian rocks.

Section up east side of Pilot Knob near northwest corner of Lillydale quadrangle, Clay County, Tennessee

	Feet
Cypress sandstone. Coarse-grained, grayish massive sandstone	20
Monte Sana limestone. Light-gray thick-bedded oolitic limestone	310
St. Louis limestone. Grayish-blue fine-grained massive limestone	140
Warsaw formation	
Coarsely crystalline, gray to blue granular limestone below, followed by blue and yellow shale, then massive sandy limestone, and at top the Garretts Mill sandstone member	80
Fort Payne	
Dark-colored siliceous shale and argillaceous limestone weathering into yellow chert	50
New Providence formation	
Blue shale with marly beds containing crinoid fragments and bryozoa	60
Olive-green shale with few fossils	21
Thin-bedded crinoidal limestone and yellow shale crowded with crinoidal remains	40
Ridgetop shale	
Light-blue to gray shale with few fossils. Typical ostracoda noted in a few bands with a 2-foot chert band at the bottom and under this 2 feet of the green Maury shale with a layer of kidney phosphate nodules	90
Chattanooga shale. Fissile black shale of usual type.	

West of Pilot Knob the section along the Cumberland River north of Celina shows the Catheys underlying 100 feet of Leipers, which is followed by the Chattanooga shale and this immediately by the New Providence shale. In the vicinity of Willow Grove in Clay County the following sections are exposed, the first east of the town and the second south of it.

Section from Willow Grove to top of hill 4 miles east, Clay County, Tennessee

	Feet
Warsaw limestone	
Massive sandy fossiliferous limestone weathering into sandy soil. Few beds are exposed, but soft chert and porous sandstone result from weathering.	
Fort Payne (Rosewood phase)	
Dark-blue siliceous shale with some layers weathering into a small amount of chert	60
New Providence shale	
Massive blue, red, and green speckled, coarsely crystalline limestone in layers 8 to 24 inches thick. Geodes 1 to 5 inches in diameter abundant	12
Light-blue to olive-green shale with an occasional 2-inch flinty bed full of fossils	20
Light-blue to light-gray shale and massive clayey limestone with marly beds and small geodes	10
Green and olive shale, some layers crowded with bryozoa	20
Ridgetop shale	
Light-blue to dark-blue shale with Ridgetop ostracoda	120
Chattanooga shale	
Black fissile shale with 2-inch bed of silicified sandstone at base	23
Leipers limestone	
Massive gray argillaceous limestone with blue granular, fossiliferous layers crowded with *Platystrophia ponderosa*	25

Section at Pleasant Hill School and along road 2 to 3½ miles south of Willow Grove, Clay County, Tennessee

	Feet
St. Louis limestone. Base at 930 feet, usual character and fossils finely shown with bed of green shale at base.	
Warsaw limestone	
Garretts Mill sandstone	3
Massive, granular, fossiliferous limestone with short and long hinged spirifers	6
Sandy, shaly brown limestone weathering into yellow-brown shale	22
Blue argillaceous limestone weathering into shale	24
Dark-blue massive, crystalline, fossiliferous limestone	6
Massive arenaceous limestone decomposing into thin sandy beds	28
Fort Payne (Rosewood phase)	
Dark-blue siliceous shale weathering into thin slivers with an occasional 6 to 8 inch brown sandy clay bed containing geodes 1 to 4 inches wide	28
Dark-blue to black fissile shale much resembling the Chattanooga	6
Massive, siliceous to argillaceous, gray limestone forming base of Fort Payne	6
New Providence shale	
Coarsely granular crinoidal limestone full of large crinoid columns	6
Blue shale weathering gray to olive-green with an occasional limy bed weathering into banded chert	30
Massive gray crinoidal limestone with chert bands and a layer of stylolites; some of beds 6 feet thick	23

Ridgetop shale	
Light-blue to dark-blue clay shale weathering gray to drab with an occasional 6 to 8 inch bed of yellow claystone	53
Brown argillaceous limestone in 6-inch beds separated by yellow shale zones	20
Dark-blue shale	10
Massive, gray, crystalline, crinoidal limestone	6
Dark-blue shale	40
Crinoidal limestone weathering cherty	4
Shale as above with a 6 to 8 inch sandstone at the base	52
Chattanooga shale	20
Leipers limestone.	

Farther east, in the Byrdstown quadrangle, this New Providence embayment apparently comes to an end.

Section at Wolf River north of Jones Chapel, Byrdstown quadrangle, Tennessee

	Feet
St. Louis limestone	
Massive limestone weathering into red soil with platy yellow chert and containing *Lithostrotion canadense*.	
Warsaw formation	
Soft sandy layer with a few thin shaly beds (Garretts Mill sandstone)	22
Dark-blue coarsely crystalline fossiliferous limestone in beds 1 to 3 feet thick, weathering into a sandy soil, and porous strata full of fenestellid bryozoa	40
Yellow shale with several interbedded massive sandy mudstones 1 foot thick	22
Fort Payne (Rosewood phase)	
Calcareous shale with crinoid fragments	35
Dark-blue siliceous shale, weathering gray	20
Ridgetop shale	
Usual Ridgetop shale with ostracods abundant in upper part	75
Heavy beds of clay shale alternating with thin sandy layers having Ridgetop ostracods	50

At Chestnut Mound the road ascending to the Highland Rim shows the Leipers formation followed by the Chattanooga black shale and this by 1 foot of the Maury green shale above which is the Fort Payne chert.

The New Providence is well exposed along the road on the south side of Eagle Creek, about 8 miles northeast of Livingston, where typical shale of this age 100 or more feet thick with the layers at the top crowded with crinoidal remains passes into 23 feet of massive gray-blue, pink-speckled crinoidal limestone beds full of large columns and with occasional heads of *Agaricocrinus*. These crinoidal beds are 3 to 18 inches thick and are separated by thin bands of yellow shale. Succeeding them is dark-blue to dull-gray shale of the Fort Payne to the top of the hill, some layers of which weather into the characteristic chert. The lower beds of the New Providence formation here are blue shale, but the upper beds are filled with fossils. Well-preserved calyces of considerable numbers of crinoids and blastoids were obtained here.

The bluff on the north side of Eagle Creek shows quite clearly that at least 50 feet of the New Providence shale has been cut out within a short distance, and the remainder is overlapped by the Fort Payne formation (plate 44, fig. B). The line between the two formations shows no sign of subaereal erosion, so the shale was apparently removed by marine scour.

Good exposures of the New Providence may be seen along the west side of the Basin in the Franklin quadrangle, where the following section may be noted.

Section along road just east of Popes Chapel, southwestern part of Williamson County, Tennessee

	Feet
Fort Payne chert.	
New Providence formation	
Blue shale with *Baryphyllum verneuillianum*, *Zaphrentis*, *Athyris*, etc.	50
Massive blue crystalline limestone made up largely of crinoid fragments particularly segments of the columns, changing to calcareous shale; contains many fossils	20
Ridgetop shale	30
Maury shale. Green shale with kidney layer	0.5
Chattanooga shale. Black fissile shale	10
Leipers formation.	

The New Providence shale, like the succeeding Fort Payne formation, exhibits an abundance of geodes upon many weathered outcrops. These are usually found to have originated in fossil remains such as a crushed crinoid column or brachiopod, where the silica-bearing water percolating through the strata started the deposition of silica along the fractures in the fossils. The expansive force of the growing quartz crystals thus formed in the fractures caused the walls to separate more and more, until finally a hollow rounded mass or geode lined with inward-pointing crystals and preserving remnants of the fossil on the outside was the result. Geodes of such origin are particularly common in shaly strata, and most of them arise from crinoid columns, which when crushed in the shale usually develop five longitudinal fractures on account of their five-sided symmetry. If such fractured specimens occupy a position where water has ready access, as along joint planes, the central canal and the fractures are soon filled with silica. Continued growth, as explained above, produces an elongate, rounded geode, which may reach a considerable size, even as much as 2 feet in length and may lose all trace of the crushed fossil in which it originated.

Characteristic fossils of the New Providence are shown on Plate 28.

FORT PAYNE CHERT

Capping all the high hills of the southern two-thirds of the Basin and covering much of the adjoining part of the Highland Rim is a massive, siliceous to argillaceous limestone that weathers into great quantities of blocky yellow chert. The formation, originally named the Fort Payne chert by Smith and described by C. W. Hayes in 1890 (Geological Society of America Bull., vol. 2, p. 142), has for its type locality Fort Payne, Alabama. In early folios of the U. S. Geological Survey, Hayes described the Fort Payne as a very siliceous limestone with heavy beds of chert at the base, occupying the interval between the Chattanooga black shale and the Bangor limestone and ranging in thickness in Alabama and East Tennessee from 75 to 200 feet.

As originally defined the term thus included formations from the Chattanooga shale to the Chester, but more recent investigations by Butts and others have eliminated all the strata except those of Keokuk age. As the Keokuk strata make up the cherty beds well shown at Fort Payne, this widely used name is retained, even though the term "Lauderdale chert" was applied to this restricted Fort Payne formation by Smith in Alabama. Previously, in 1869, the formation had been included in the Protean member of the Siliceous group by Safford (Geology of Tennessee), and in 1900 Safford and Killebrew (Elements of Geology of Tennessee, p. 339) renamed it the Tullahoma formation from Tullahoma, Tennessee, said to be located upon it. The terms Fort Payne and Tullahoma have been thought hitherto to refer to exactly the same formation, but, as the following section at Tullahoma shows, the overlying Warsaw limestone was included in the Tullahoma formation, as much of the town rests upon it.

The details of this section are exhibited at the old Cascade distillery, 4½ miles north of Tullahoma on the road to Normandy, and at the Nashville, Chattanooga & St. Louis Ry. cut 2 miles northwest of Tullahoma, where the divisions of the Warsaw are well shown.

Geologic section, vicinity of Tullahoma, Tennessee

Mississippian:	Feet
Warsaw limestone	
Arenaceous, coarsely crystalline, blue limestone weathering into sandy soil	20+
Sandy, incoherent, rotten, yellowish-brown chert with few fossils	3-6
Vesiculose and solid chert in irregular plates 1 to 6 inches thick, separated by thin seams of red residual clay.	
Chert made up of fossils, particularly long-hinged *Spirifers*, *Rhipidomella dubia* and bryozoa	0-3
Incoherent, conglomeratic, rotten chert consisting chiefly of comminuted fossils. Evidently a silicified beach deposit	0-2
Fort Payne chert	
Siliceous, gray-blue limestone weathering into thick irregularly stratified bands of chert masses. Upper part showing only knotty places and nodules of chert. Large crinoid columns in chert at top	90

	Feet
Layers of chert but in thinner beds than above and blocky...............	8
Dark-brown, sandy clay with sandy, soft, brown to black chert nodules of irregular form and with siliceous geodes............................	2
Greenish shale with a layer of 2 to 4 inch geodes at top. Phosphatic nodules and glauconite not noted. (Maury shale)..........................	1.5
Chattanooga shale.	
Black fissile shale usually in close contact with underlying limestone, although occasionally 1 inch of phosphatic Hardin sandstone is at base..	22
Ordovician:	
Catheys limestone	
Thick-bedded, blue-gray, fine-grained and subcrystalline limestone usually in close contact above with Chattanooga shale. *Constellaria teres, Hebertella frankfortensis, Rafinesquina alternata, Orthorhynchula linneyi* and other fossils present	11

Chert, the common siliceous rock of impure chalcedony, is such an important characteristic of the Fort Payne formation and has been mentioned so often throughout this work that a few remarks as to its origin may be given at this point. Various theories for its origin have been advanced, the most plausible being that it either is formed as nodules by the direct precipitation of silica from sea water at the time when the sediments are deposited or that it is the result of surface weathering of such sediments, usually limestone containing siliceous impurities, with the segregation of the silica into the characteristic nodules or fragments. Other theories explain its origin by the replacement of the solid rock with silica, by the filling of cavities, or by the partial replacement of unconsolidated lime sediments. Chert may have originated from any one or a combination of these causes in special cases, but usually all the evidence shows it to be the result of weathering of more or less impure limestone. The silica is derived from the impurities, or it may be obtained from adjacent strata through which the surface waters pass.

An interesting feature of cherts so formed is that the composition of the various formations differs so that each gives rise to its own type of chert. The differences between many of these cherts are quite small, but with proper discrimination a formation can be recognized by its characteristic type. The solid, blocky chert of the Fort Payne with crinoid columns is quite different from the porous spongy chert with matted bryozoa of the succeeding Warsaw limestone. It should be remembered, however, that many formations yield no chert at all on weathering.

Cherts formed by surface weathering need not be of present-day origin alone, for in some places a bed of chert marks the boundary between two formations and clearly indicates that it was formed in the time interval marked by the unconformity. Again, cherts may originate along joint planes where percolating waters produce the same changes as at the surface. The zone of chert formation must, then, be within the limits of ground waters.

Organic calcite such as that composing fossils is readily replaced by silica, so that silicified fossils are left on the surface of many weathered limestones. The Fort Payne, for example, is characterized by the abundance of silicified crinoid stems in the débris left by weathering. The usual calcified stems can be noted in the unweathered Fort Payne limestone, but in places where weathering has commenced the changes from the calcareous condition in the fresh rock to the silicified form in the exposed parts can be seen in the same specimen.

The Fort Payne formation weathers into a sandy soil usually crowded with chert. Prolonged leaching has deprived it of its lime and phosphorus, so that although it is easily worked it is too poor for abundant crops. Growing of fruits, particularly apples and peaches, is most suitable for it.

As usually seen in weathered outcrops, the Fort Payne formation of the southern two-thirds of Tennessee has the aspect of a shaly sandstone with many cherty beds. The actual limestone that yields these weathered products is seldom seen, and for that reason few sections of this phase of the Fort Payne are introduced here. In northern Tennessee this cherty limestone is replaced or changes into a light or dark blue calcareous to siliceous shale, which gives less chert on weathering and which is also more often seen in natural outcrops. In Kentucky this phase of the Fort Payne or Keokuk is known as the Rosewood shale. Possibly the Rosewood shale is older or younger than the typical Fort Payne or possibly it intergrades into it, as noted above.

Along Wolf River in the Byrdstown quadrangle dark-blue calcareous and siliceous shale of the Rosewood phase make a total of 55 feet. South of Willow Grove, in Clay County, 34 feet of such shale is preceded by 6 feet of massive siliceous to argillaceous gray limestone more like the typical Fort Payne and possibly indicating an overlap. East of Willow Grove 60 feet of the Rosewood shale occurs between the typical New Providence and the Warsaw limestone. Pilot Knob, in Clay County, shows 50 feet of shale and argillaceous limestone, and west of this locality (2 miles west of Celina) the Rosewood phase is preceded by 30 feet of siliceous shaly limestone weathering into layers with flint nodules. Along Dry Fork of Whites Creek in Davidson County the blue shale of the Rosewood amounts to 80 feet, but the Ridgetop section shows 120 feet. Thus the Rosewood appears to be a well-defined formation in northern Tennessee, although it has not been separated from the typical Fort Payne on the maps.

WARSAW FORMATION

The Warsaw limestone, named from Warsaw, Illinois, on the Mississippi River, where it succeeds the typical Keokuk limestone, is a widespread formation extending eastward to the Appalachians and in Tennessee outcropping over wide areas of the Highland Rim. Outcrops of the limestone itself in the State are rather few, for weathering has in many places reduced the strata to a sandy soil containing comparatively little hard chert but an abundance of soft, easily disintegrated cherty rock. The formation as a whole weathers into brick-red soil and much sandy porous chert, but when subjected to extended weathering the soil loses its red color and comes to resemble very closely that of the Fort Payne formation. The distinguishing characteristic of the Warsaw is its chert, which is a mealy, spongy, porous rock much of it filled with matted bryozoa. With these porous chert beds are interspersed layers of blocky flint, resembling that of the Fort Payne but distinguished from it by characteristic fossils of the associated porous chert. The soil of the Warsaw is deeper and more fertile than that of the Fort Payne and not so clayey as the latter. The formation has so changed in composition from its type region in Illinois that in Tennessee, where it is about 100 feet thick, it consists of about equal parts of limestone, shale, and calcareous sandstone. As shown by the sections given under the discussion of the New Providence, gray-blue, arenaceous, granular limestone and shale predominate in the lower part, blue and yellow shale in the middle, and a calcareous sandstone, which has received the special name of Garretts Mill sandstone, almost invariably forms the top.

The thick-bedded limestone of the Warsaw is coarsely crystalline and so crowded with fragments of bryozoa, crinoidal plates, and other fossils that the soft incoherent chert with the broken fossils scattered through it that results from weathering readily distinguishes the formation. Fenestellid bryozoa predominate among these fossils, the cherts containing many examples of such characteristic forms as *Fenestella tenax*, *F. serrulata*, *Polypora varsoviensis*, *Worthenopora spinosa*, *Hemitrypa proutana*, and *Fenestralia sanctiludovici*. Among the echinoderms, many of which occur as molds left in the chert by solution and removal of the fossil, are abundant examples of the characteristic blastoid *Pentremites conoideus* and fewer specimens of *Tricoelocrinus woodmani*. The brachiopods *Spirifer lateralis*, *S. bifurcatus*, *Brachythyris suborbicularis*, *Rhipidomella dubia*, and *Reticularia salemensis* have been noted at Tennessee localities.

As shown in the Tullahoma section given under the discussion of the Fort Payne chert, the basal beds of the Warsaw have weathered into layers of various types of chert, ranging from conglomeratic, rotten chert filled with comminuted fossils to vesiculose and solid cherts—all evidently derived from beach deposits of the initial Warsaw. One phase of the basal Warsaw is shown in the vicinity of Moss, Clay County, where a bed of white cauliflower chert in rounded balls 2 to 6 inches thick introduces the formation, whereas at places along the east edge of the Rim sandy beds several feet thick are to be found at the base.

The topmost beds of the Warsaw are almost invariably calcareous sandstones, much resembling limestones when unweathered but weathering into layers of loosely aggregated quartz grains. These beds are so pervious to water that this zone, the Garretts Mill sandstone, may be readily recognized by the many springs issuing from the strata, the one at Garretts Mill being large enough to supply the water power for the mill. Like the Black shale this member is an important horizon marker for working out the structure of areas on the Highland Rim.

The unconformity between the Warsaw and Fort Payne is well shown at an outcrop near the sawmill just south of the depot at Tullahoma, where the slightly inclined beds of the Fort Payne are overlapped by the sandy strata of the basal Warsaw. Cross-bedding and ripple marks are present in these introductory sandy beds as well as in the closing phase of the formation, the Garretts Mill sandstone.

ST. LOUIS LIMESTONE

Just as the Fort Payne chert forms the predominating surface rock over that portion of the eastern Highland Rim nearest the Central Basin, the St. Louis limestone outcrops at the surface over a large portion of the Rim farther east as well as the higher portions of the western Rim. Safford early recognized in the Tennessee strata the characteristic fossil of the St. Louis of Missouri, *Lithostrotion canadense*, and separated the formation as the upper Lithostrotion bed or St. Louis limestone, which division with the lower Protean member formed his Siliceous group of the Lower Carboniferous. Years later in the Standingstone folio the U. S. Geological Survey regarded this division as a transition from the Waverly to the Newman limestone, the Waverly including the Warsaw and underlying Lower Carboniferous rocks and the Newman all the limestone to the top of the system. Today the St. Louis is recognized as one of the widespread formations of the Mississippian system, easily distinguished by its lithologic character and highly characteristic fossil corals.

In general the St. Louis limestone is a medium to massive, thick-bedded, fine-grained, grayish-blue, bluish, or dark-colored limestone 120-140 feet thick, which weathers into a very red, iron-stained soil strewn with blocks of yellow, angular, solid chert and at certain horizons with the corals *Lithostrotion canadense* and *L. proliferum*.

In distinction from overlying gray oolitic limestone of the Monte Sana division the St. Louis is usually known as the blue limestone.

Owing to the long weathering to which it has been subjected, the St. Louis is rarely exposed and is known chiefly from its aspect after decomposition. As the underlying Warsaw and Fort Payne formations are also represented largely by weathered products, the contact between each of the three and the next higher is seldom seen, and the dividing line must be located by differences in soil, chert, and fossils, as well as topography. Thus the St. Louis forms rolling land with a red soil more fertile than the Fort Payne with its yellow, somewhat barren soil and rockier slopes. The special nature of the cherts and their accompanying fossils of the formation has been noted previously.

The purity and great solubility of the St. Louis limestone, especially in areas where it has more than the normal thickness, causes the development of many underground streams, caves, and sink holes. This limestone is noted for the iron-ore banks of the western Highland Rim, which mark the site of old bogs in which the mineral was deposited after solution from higher strata.

CHESTER SERIES

The Mississippian formations succeeding the St. Louis limestone and comprised in Safford's Mountain limestone are classified today in the Chester series, which, because of its economic interest and because of disagreement as to the correlation of several of its members, has been studied with care by a number of geologists. An excellent account of the series is given in the Mississippian Series of Western Kentucky, by Charles Butts and E. O. Ulrich, published by the Kentucky Geological Survey in 1917. For details the student is referred to this volume. As the present work is concerned but little with the Chester formations, short descriptions only of its several units are here included.

MONTE SANA LIMESTONE

A light-gray oolitic limestone 200 to 300 feet thick, which has received the name of Monte Sana limestone from its outcrop at Monte Sana near Huntsville, Alabama, follows the St. Louis limestone on the higher elevations of the eastern Highland Rim and along the western escarpment of the Cumberland Plateau and extends to the base of a sandstone formation that caps many high hills of the former area. In Tennessee this limestone forms the lower part of the Newman limestone as mapped in the Standingstone folio, the overlying sandstone here being called the Newman sandstone lentil.

Much of this oolitic limestone, which is made up of small spherical bodies like fish eggs, has a glassy texture and a light-blue to pearl-gray color. Investigation has shown that two distinct formations of early Chester age, named from Kentucky localities, are included in this limestone, the Fredonia oolite making up the lower 100 to 130 feet and the Gasper oolite composing the upper 140 to 160 feet. As the rock in each formation is indistinguishable in character from the other, and an easily recognizable dividing line can seldom be found in Tennessee, the term Monte Sana limestone, proposed by Ulrich for the same combination of formations in Alabama, has been employed in the Lillydale quadrangle. In western Kentucky and southern Illinois these two formations are separated by 200 feet of sandstones and limestones, the Rosiclare sandstone, Ohara limestone, and Bethel sandstone. Usually no trace of these formations is to be seen in Tennessee, but their horizon is indicated in the vicinity of Livingston, 100 feet above the base of the Monte Sana, by 2 feet of shale followed by a 1-foot limestone layer containing limestone pebbles. Fossils will readily separate the Fredonia and Gasper oolites, the crinoid *Platycrinus huntsvillae* with its regularly twisted columns being common throughout the Fredonia and species of *Pentremites* and the crinoid *Talarocrinus* in the Gasper. Unfortunately the fossils although common are not often found weathered out of these oolitic limestones in good recognizable condition. A good description of these two oolites and their fossil contents is given in the Mississippian Series of Western Kentucky, mentioned above, in which reports by E. O. Ulrich and Charles Butts give illustrations of the fossils and detailed general information regarding these rocks.

CYPRESS SANDSTONE

The high hills and flat-topped ridges that expose the Monte Sana limestone on their slopes are usually capped by the only persistent sandstone of the Mississippian of the Highland Rim, the Cypress sandstone, so named from Cypress Creek, Union County, Illinois. In Tennessee this sandstone ranges from 1 to 70 feet in thickness with an average of about 40 feet. In spite of its varying thickness its lithologic character—a grayish, coarse-grained, massive, firmly cemented sandstone—is so persistent that it serves as an excellent datum bed in working out the structure of a region. Being so easily followed from place to place, this sandstone has been traced from its type outcrops in Illinois across Kentucky and into Tennessee, where it was early mapped, in the Standingstone folio, as the Newman sandstone lentil of the Newman limestone. Its use for paving stones and chimney stones has caused it to be quarried at various places.

The Cypress sandstone caps the highest hills of the Lillydale quadrangle and is the youngest formation delineated in the four maps here presented. However, short descriptions of the four still higher Chester formations, all exposed in the Standingstone quadrangle just south of the Lillydale area, are included for the sake of completeness.

GOLCONDA SHALE

Soft marly green shale with a few red-shale layers, altogether amounting to 20 or 30 feet, usually immediately overlie the Cypress sandstone in the eastern Highland Rim. This shale, well shown at the east base of Gullett Mountain, 3 miles southeast of Livingston, is believed to be the thinned southeastern edge of a formation, which at Golconda, Illinois, is 140 feet thick. In the Obey River country, where the Cypress sandstone is very thin, a conspicuous bench several rods wide formed along the outcrop of the Golconda shale serves in many places as a roadway because of its level character and freedom from stones.

HARDINSBURG SANDSTONE

Another important formation of western Kentucky and southern Illinois that is represented in the eastern Highland Rim by apparently a thinned eastern extension, is the Hardinsburg sandstone, a formation of alternating friable sandstone and shale reaching a maximum thickness of 40 feet in the Standingstone quadrangle.

GLEN DEAN LIMESTONE

The preceding Golconda shale and Hardinsburg sandstone are inconspicuous strata in most Mississippian areas of Tennessee, in many places being absent entirely, so that the first prominent formation to follow the Cypress sandstone is a limestone of some thickness—the Glen Dean limestone named from Glen Dean, Breckinridge County, Kentucky.

In the Tennessee Highland Rim area this formation was mapped as the part of the Newman limestone above the sandstone (Cypress) member. Blue, coarsely crystalline, highly fossiliferous, massive, compact limestone makes up the lower three-fourths of the Glen Dean, passing upward into thin-bedded clayey non-fossiliferous strata in the upper fourth, the latter bed indicating a change to the shaly condition of the overlying Pennington shale.

Geodes generally 2 to 4 inches but ranging up to a foot in diameter, are found in abundance in the Glen Dean, and many areas underlain by this limestone show these siliceous hollow balls, in which clear quartz crystals line the walls of the interior cavity. These geodes afford good evidence as to the presence of the Glen Dean. Its contained fossils are highly distinctive, especially a prism-shaped bryozoan with triangular cross-section, *Prismopora serrulata*, a blastoid, *Pentremites pyramidalis*, and the bryozoan, *Archimedes*, with a solid screw-shaped axis.

PENNINGTON SHALE

The uppermost Chester formation of Tennessee is the Pennington shale, so named from calcareous shale strata outcropping north of Cumberland Gap, at Pennington Gap, Va. In the Highland Rim area the Pennington forms a well-defined unit 200 feet thick, occupying the interval between the base of the Coal Measures and the Glen Dean limestone.

Limestone and sandstone make up a small proportion of the Pennington, the main rock being gray calcareous shale with a considerable amount of red shale. The few limestone beds are of an earthy nature, and the sandstone is shaly and laminated. Fossils are usually not common, although brachiopods and bryozoa are fairly abundant in some of the limestone beds.

A great stratigraphic gap or unconformity follows the Pennington shale, for in Alabama, between it and the immediately overlying Coal Measures, there are, as pointed out by Butts, 2,000 feet of the Parkwood formation still of Mississippian age, and in the Cahaba coal field of Alabama a portion of the Coal Measures 6,000 feet thick. Thus 8,000 feet of shales is absent at this unconformity in parts of Tennessee.

PENNSYLVANIAN SYSTEM

Formations of the Coal Measures or Pennsylvanian System are not present in any of the quadrangles here considered, post-Paleozoic erosion having removed them, as well as the Mississippian rocks down to the Cypress sandstone. Just east of the Woodbury quadrangle is an outlier of the Cumberland Plateau, Short Mountain, in Cannon County, in which the lower divisions of the Pennsylvanian are still preserved. A shale below and a sandstone above, probably corresponding to the Vandever shale and the Rockcastle sandstone of the Lee group comprise this part of the Coal Measures.

The Vandever shale, comprising sandy shales and thin sandstone beds with locally one or more coal beds, rests unconformably on the Upper Mississippian Pennington shale. Its thickness although variable is about 140 feet. Above it is a coarse thick-bedded sandstone locally conglomeratic with a thickness ranging from 30 to 200 feet, named the Rockcastle sandstone from the Rockcastle River, in Kentucky. These and the higher divisions of the Pennsylvanian in Tennessee are described in the State reports dealing with the Coal Measures of the Cumberland Plateau.

POST PALEOZOIC HISTORY

Since the beginning of Mesozoic time the Central Basin has been a land area, and its geologic history is recorded in weathering and erosion instead of the deposition of limestones, shales, and other sedimentary rocks under the sea. As explained by Galloway in Bulletin 22 of the State Geological Survey, middle Tennessee by the end of the Mesozoic had been reduced to a plain called the Cretaceous peneplain, now preserved only on the Cumberland Plateau and the top of Short Mountain and in Wayne and Lawrence Counties in West Tennessee, but with all trace of it removed from the Central Basin and the Highland Rim. This peneplain was then elevated, and during the Eocene period a second peneplain, that of the Highland Rim, was formed. Patches of river gravel on the Highland Rim far from the present rivers give evidence that this was once a base-levelled area traversed by the characteristic meandering streams of such a region. Since the Eocene period the geologic history has recorded only the erosion that has taken place in the Basin and the deposition of alluvium of different sorts on the flood plains of present streams.

DESCRIPTIONS OF QUADRANGLES

FRANKLIN QUADRANGLE

Topography and stratigraphy.—The Franklin quadrangle, named from Franklin, the county seat of Williamson County, Tennessee, lies almost entirely within that county, only a few square miles in the extreme southwestern corner belonging to Maury County. This quadrangle, embracing about 250 square miles, extends from latitude 35° 45′ on the south to 36° on the north and from 86° 45′ on the east to 87° on the west. It is situated on the western side of the Central Basin in an area containing hills in ranges or isolated left by the dissection of the Highland Rim. About a third of the quadrangle is occupied by the outliers from the Rim and a small area along the western side by the Rim proper; the greater part exhibits the gently undulating surface characteristic of the Central Basin. The elevated areas north and south of Leipers Fork represent the Highland Rim proper. Duck River ridge, the ridge and series of high hills of which Shamblers Knob and Harvey Knob are conspicuous elevations, extending southeastward across the quadrangle north of Franklin, and a similarly directed range of hills south of Franklin are the most conspicuous outlying elevations. Between the two latter ridges Harpeth River flows through a lowland area more characteristic of the Central Basin, and southwest of this, another lowland area is occupied by West Harpeth River. The most characteristic Central Basin topography is exhibited in the middle portion of the south third and in the similar division of the east third of the quadrangle, where erosion has exposed the oldest rocks of the region at the surface.

In this quadrangle is exhibited the less sharp dissection of the Western Highland Rim in contrast with the eastern Rim as shown in the Hollow Springs quadrangle. Instead of the deep linear, crestlike forms prevalent on the east side, rounded spurs predominate along the west. Although the greater part of the quadrangle is drained by Harpeth River and the West Harpeth and its other tributaries, part of the southern third lies within the drainage basin of Duck River and is occupied by the headwaters of the tributaries of that stream.

A study of the Franklin quadrangle or of any other Central Basin area exhibits particularly well that present topography has resulted from the dissection of a gently undulating surface, which if restored would have an altitude between 1,000 and 1,100 feet. Such a restored plain would coincide with the summits of the hills and spurs around the margin of the Central Basin, which indicates that a continuous plain at that elevation once existed over the entire region. This plain was developed in the basal cherty limestone of the Mississippian period, the Fort Payne chert, which now outcrops at the summits of most of the high hills of the quadrangle. The plain was probably produced by the slow process of subaereal erosion and when completed occupied a position near sea level. Owing to the doming of the Cincinnati arch, the cherty limestone suffered more erosion in the region occupied by the Central Basin and thus became thinner than elsewhere. When the region was again uplifted, and the streams had cut down to the underlying Ordovician limestone, erosion went on rapidly, and the formation of the present Central Basin had commenced. Duck River, Stones River, Harpeth River, and other streams, which now have their sources in the lowlands of this region, were largely instrumental in cutting away the upper strata of the original plain and lowering the surface. Terraces of gravel at different altitudes along some of these streams show that the present elevation of the region was reached by uplifting, which occurred at several times separated by intervals of rest. Duck River, for example, cut a broad valley down to about 400 feet below the surface of the old plain, and when the region was again uplifted, cut a much narrower valley within this broad one. Similar stages of erosion can be determined in the valley of Harpeth River and other streams. All the strata here exposed at the surface are composed of various limestones and shale formations that appear horizontal, although in reality they dip or bend slightly in various directions. The quadrangle lies on the western flank of the Cincinnati anticline, the low, broad fold running northeast through central Tennessee and central Kentucky. The distribution and general features of the various formations here exposed are given in the following composite section.

Composite section of Paleozoic strata that crop out in the Franklin quadrangle, Tennessee

Mississippian System:

Warsaw limestone — Feet

Thick-bedded, gray to blue, mainly coarsely crystalline limestone weathering into clay and chert débris, much of the chert containing molds of brachiopods, *Pentremites conoideus,* and fenestellid bryozoa. Occurs only in the highest parts of the quadrangle along the western edge.... 100

Fort Payne chert

Massive argillaceous limestone and siliceous shale weathering into solid, blocky, brittle, yellow chert with many large crinoid stems but few other fossils. The main surface formation of the Highland Rim area and caps the highest hills in the Central Basin portion........................ 200

New Providence shale

Bluish clay shale with a lens of massive, light-colored, crinoidal limestone in the middle part. Corals, particularly *Baryphyllum verneuillanum,* not uncommon in the upper shales, and crinoid remains abundant in the middle limestone beds. Occurs only in vicinity of Popes Chapel, Sugar Ridge area.. 50

	Feet
Ridgetop shale	
Gray-blue shale, usually unfossiliferous except in bands crowded with ostracoda, weathering gray, with Maury green shale composed of green-sand grains and kidney phosphatic nodules at base. Widely distributed over quadrangle	20
Chattanooga shale	
Black, fissile, carbonaceous shale with a few inches of Hardin sandstone at the base, the latter deposit sometimes replaced by blue phosphate. Outcrops in higher hills and along edge of Highland Rim	10
Silurian System:	
Niagaran group:	
Osgood limestone	
Light-gray to blue compact limestone, developed only in two ancient bays, one heading in the northwest corner of the quadrangle and the other extending eastward to point near Southall	10
Richmond group:	
Fernvale formation	
Soft, green or chocolate-colored, fossiliferous shale above (10 feet) and coarsely crystalline, light to dark red limestone below (30 feet). Developed only in ancient bays entering the quadrangle from the north and west	40
Arnheim formation	
Blue, granular, nodular, fossiliferous limestone with *Dinorthis carleyi* and *Rhynchotrema dentatum arnheimensis*. Developed only in small area west of Southall	4
Ordovician System:	
Cincinnatian series:	
Leipers formation	
Thin-bedded, nodular, blue, clayey limestone with many fossils especially *Platystrophia ponderosa*. Present only in the western and northern parts of the quadrangle	40
Mohawkian series:	
Catheys formation. Composed of the following divisions and developed usually on the hill slopes throughout the quadrangle.	
Massive, fine-grained, argillaceous limestone giving a fetid odor upon fracture	30
Fine-grained, argillaceous, light-blue to dark-blue limestone weathering cobbly	35
Granular, blue limestone some of it speckled and semiphosphatic	40
Coarsely granular, light-blue limestone and interbedded yellow shale crowded with *Constellaria emaciata* and other branching bryozoa	20
Cannon limestone	
Massive, gray, much of it dolomitic, limestone above and pure, dove layers in lower part, weathering into an abundance of platy, yellow chert. Present throughout the quadrangle but only a few feet thick along the west edge, increasing to 200 feet on the east side. Contains semiphosphatic beds in the lower part above the basal dove beds	0-200
Bigby limestone	
Coarsely granular, crystalline, laminated and crossbedded, phosphatic limestone full of comminuted fossils. Ranges in thickness from 80 feet in the western part to a thin edge in the southeast corner	0-80

Hermitage formation — Feet

Upper 10 feet of thin-bedded, dark-blue, argillaceous limestone with shells of *Modiolodon* and lenses crowded with *Dalmanella fertilis*, then 40 feet of massive, dark-blue, crystalline limestone full of *D. fertilis*, and at the base 25 feet of rather unfossiliferous shale and thin, dark-blue, argillaceous limestone with *Prasopora patera*. Developed throughout the quadrangle........................ 75

Lowville limestone

Consists of an upper division (Tyrone member) of thin-bedded, dove and clayey limestone, 0-20 feet thick, in many places crowded with narrow ribbon-like bryozoa, with a band of unctuous green clay (bentonite) in the middle, and a lower massive dove-gray magnesian or light-blue cherty limestone 60 feet thick (Carter member).. 80

Chazyan series:

Stones River group:

Lebanon limestone

Thin-bedded, usually dove-colored limestone outcropping only in the southern and eastern parts of the quadrangle........30+

Sections showing the details of the stratigraphy of special areas in the quadrangle have been given on preceding pages in the discussion of Williamson County and the descriptions of the Cannon, Catheys, and Fernvale formations.

Mineral resources.—The important mineral resources of the quadrangle are rock phosphate, limestone suitable for a variety of purposes, and chert used for road metal. The rock phosphate is found not only in the Bigby formation, composed almost entirely of phosphatic limestone, but also locally in the Hermitage, Cannon, and Catheys formations. These four limestones, which outcrop at the surface over a large part of the quadrangle, weather into rich soils. From the Chattanooga shale, rich in bituminous matter, oil can be distilled, although at present this is not profitable. The chances for discovering oil in the quadrangle are not good, for the oil-bearing strata outcrop at the surface, and whatever oil they may have contained has been lost.

Structural features.—The quadrangle exhibits interesting features of structural geology, among which are the ends of the embayments of the Fernvale and Niagaran seas, mapped in the Columbia quadrangle on the west. It also shows an embayment entering from the west, in which the early Richmond (Arnheim) limestone was deposited, and still another with the Mississippian New Providence shale developed. The Ridgetop shale here has practically the same distribution as the Chattanooga shale and is therefore mapped with it. It will be noted that the Fernvale and Osgood now appear in a small outcrop southwest of Southall in an isolated basin. It is believed that a local elevation of these strata on the west and erosion in later Silurian and Devonian times, removed them from the intervening area. The oscillatory movement of the Cincinnati axis is brought out in the quadrangle by the distribution of the Ordovician formations. For example, the Bigby limestone, 80 feet thick in the southwestern part, dies out entirely in the southeast corner. The Cannon limestone only a few feet thick along the west side increases to over 200 feet in the northeastern portion. The Leipers formation, well-developed in the northwestern part, diminishes and disappears entirely in the southeast. In addition to these major structural features the quadrangle exhibits interesting minor synclinal and anticlinal areas, which can not be discussed in detail at this point.

THE WOODBURY QUADRANGLE

SITUATION AND TOPOGRAPHY

This quadrangle, named from Woodbury, the county seat of Cannon County, extends from latitude 36° on the north to 35° 45′ on the south or 17.5 miles, and from longtitude 86° on the east to 86° 15′ on the west or 14.25 miles, covering nearly 250 square miles. The only adjacent quadrangle with the geology mapped is the McMinnville quadrangle on the east. The greater part of the Woodbury quadrangle lies within Cannon County, only about two-fifths being divided equally between Wilson and Rutherford Counties, and the extreme northwestern corner, approximately 3½ square miles, lying in Dekalb County.

The gently undulating surface of the Central Basin of Tennessee at an altitude of about 600 feet and the more or less deeply dissected plateau about 1,000 feet above sea level, known as the Highland Rim, bounding it on the east, are the conspicuous topographic features of the Woodbury quadrangle. Outliers of the plateau extending far into the Basin in the form of spurs or isolated hills make the outline of the eastern border of the Central Basin extremely irregular. Indeed the Woodbury quadrangle is especially interesting topographically in the development of the greatly dissected border of the western Highland Rim and its reduction to isolated hills and rows of hills.

About two-thirds of the area mapped in the Woodbury quadrangle lies in this greatly dissected westernmost portion of the Highland Rim, a very small area in the southwest corner belongs to the Highland Rim proper, and the rest of the region forms a roughly semicircular portion in the typical Central Basin.

The surface of a small part of the Highland Rim, occupying the southeast corner of the quadrangle, has an altitude of nearly 1,200 feet. This altitude is unusual, however, as the average height of the Highland Rim in the quadrangle on the east is about 1,000 feet. The streams from the Highland Rim flow in narrow channels until they approach the Central Basin and then plunge into narrow gorges several hundred feet deep. Only the larger streams, such as Caney Fork of the Cumberland

River, have cut their channels back into the Rim to a notable distance, so the Rim is well preserved as a physiographic unit, the descent from it to the Central Basin being in most places very steep.

Three-fourths of the quadrangle lies within the drainage basin of Stones River, the eastern fork of this river flowing westward across the quadrangle through the southern half. Carsons Fork, Hollis Creek, and Hill Creek on the south, and Rock House Branch, Cavender Branch, Doolittle Branch, Rush Creek, and Locke Creek flowing from the north are its principal tributaries. The northwest quarter of the quadrangle is drained by the northeastward-flowing streams Saunders Fork and its tributaries. These streams have caused the deep dissection of the Highland Rim, well shown in the quadrangle, and have formed valleys that are as a rule level and narrow with steep slopes.

STRATIGRAPHY

The rocks exposed at the surface in the Woodbury quadrangle are sedimentary formations of limestone and shale, differing considerably in composition and appearance, and belonging to the Ordovician and Mississippian systems. A great gap in geologic history is thus present in this area, as strata of Silurian and Devonian age are entirely unknown. The general geologic section for the region is as follows:

Generalized section of Paleozoic rocks of the Woodbury quadrangle

	Feet
Mississippian System:	
St. Louis limestone	
Massive, grayish-blue, fine-grained limestone	50+
Warsaw formation	
Coarsely crystalline, gray to blue, heavy-bedded sandy limestone weathering into a red-brown soil with blocks of porous friable chert	100
Fort Payne chert	
Massive, earthy, siliceous limestone giving rise to abundant yellow, brittle, blocky chert with greenish clay shales at the base, in places bearing a layer of phosphatic concretions.	
Chattanooga shale	
Black carbonaceous fissile shale with thin basal sandstone layers (Hardin sandstone) seldom developed	30+
Ordovician System:	
Cincinnatian series:	
Leipers formation	
Nodular, argillaceous blue limestone with interbedded blue and yellow shale crowded with fossils, developed only in northeast corner of the quadrangle by overlap from the north	0-20
Mohawkian series:	
Catheys formation	
Thin-bedded, blue, fossiliferous limestone weathering cobbly and containing *Cyclonema varicosum*, *Constellaria emaciata*, *C. teres*,	

Hebertella sinuata, Orthorhynchula linneyi, etc. Overlaps upon the Cannon limestone from the north, thinning out to extinction in the northern third of the quadrangle........................ Feet 0-40

Cannon limestone

Thin-bedded and massive, blue, fine-grained, crystalline limestone with many of the layers weathering into porous and blocky yellow chert containing silicified fossils in abundance, massive argillaceous limestone with large ostracoda and various species of *Tetradium*, and massive gray impure limestone............200-250

Hermitage formation

Granular, crinoidal, slightly phosphatic limestone at the top, then sandy argillaceous beds with some limy, rubbly layers crowded with bryozoa and species of *Lichenaria*, below this a clay limestone with the *Modiolodon oviformis* fauna and small species of *Ctenodonta*, then sandy, shaly beds with large branched fucoids, and at the base thin-bedded, blue, granular, fossiliferous limestone with *Heterorthis clytie* and associated fossils............70-100

Black River group:

Lowville limestone (Tyrone member)

Massive, compact, white, dove, or light-blue cherty limestone with thinner-bedded dove limestone layers and with yellowish-gray shale at the top. *Tetradium cellulosum* and other characteristic Lowville species not uncommon.............50-70

Stones River group:

Lebanon limestone

Thin-bedded, compact, flaggy limestone, most of it dove-colored but in places fine-grained blue, in layers 1 to 6 inches thick with shaly partings, some of the layers crowded with fossils. A heavy-bedded layer 3 feet thick near the middle and a similar layer near the base..........................110-125

Ridley limestone

Massive, fine-grained, blue-gray to drab, cherty limestone weathering into a brick-red soil with platy chert fragments..50+

ORDOVICIAN FORMATIONS

Ridley limestone.—The lowest formation of the Woodbury quadrangle is a massive, compact, fine-grained, light-blue or dove-colored limestone—the Ridley—attaining a maximum thickness of 95 feet in the Central Basin. Its outcrops in this quadrangle are confined to the valleys of Cripple Creek and the East Fork of Stones River. Just north of Readyville in the bluff along the East Fork good exposures may be seen. In the bed of neither stream, however, is the base exhibited. Compared with succeeding strata, fossils in this formation are few, the small brachiopod *Protorhyncha ridleyana* Safford being characteristic.

Lebanon limestone.—The red-cedar glades of Middle Tennessee most commonly form in areas of Lebanon limestone, which, because of this association, was called the "Glade limestone" by Safford. The formation consists of compact, thin-bedded, dove-colored, homogeneous limestone with thin seams of yellow to grayish shale, reaching a thickness of 118 feet in the bluff at Readyville and elsewhere in the quadrangle reaching 125 feet. The surfaces of many of the limestone layers are crowded with fossils, of which bifoliate and ramose bryozoa and the bean-shaped ostracod *Leperditia fabulites* are most abundant. Near the middle of the formation is a heavy-bedded layer 3 to 5 feet thick, closely resembling the overlying Tyrone strata. The lower lands in the western third of the quadrangle are occupied by this limestone, although in some places the strata rise with the hills and therefore outcrop on higher ground.

Lowville limestone.—As explained earlier in this volume, the Carter member of the Lowville limestone, which normally follows the Lebanon limestone in Central Tennessee, is absent along the eastern side of the Basin, the next formation here being the upper or Tyrone member. The Tyrone strata along the northern and eastern sides of the Basin are composed of thin-bedded dove-colored, pure, fossiliferous limestone, 70 to 80 feet thick, with gray to white shale at the top. In the gorge of the Kentucky River at High Bridge, Ky., the relationship between these two members is well shown, the thin-bedded Lebanon strata being followed by magnesian beds correlated with the Carters, and these in turn being succeeded by the dove-colored strata named the Tyrone from a Kentucky locality and equivalent to the similar rocks in Tennessee.

In the Woodbury quadrangle the Tyrone is the most conspicuous formation in the western half, where it occupies the higher lands. In the eastern half of the quadrangle most of the creek beds and the lower parts of the hills show outcrops of this white, fine-grained limestone.

The lowest part of the Tyrone is fine grained, dove to gray limestone in layers ranging from 3 inches to 2 feet in thickness, 1 foot to 2 foot layers predominating. Some of these strata upon weathering give rise to black or gray nodular chert. A branching fucoid completely fills some of these layers, although the characteristic coral *Tetradium cellulosum* is also abundant. Above these lower fucoidal layers, which are about 30 inches thick, is 8 to 10 inches of massive, in part conglomeratic and cherty dove limestone with the corals *Columnaria* sp., *Streptelasma profundum*, and *Stromatocerium* as the most abundant fossils. A second group of massive dove limestone, 20 inches thick, crowded with fossils, overlies the coral beds. This upper fucoidal bed in places forms the top of the Tyrone, although in complete sections about 20 feet of fossiliferous light-colored strata are shown.

Two miles northwest of Hall's Hill the Tyrone is terminated above by the "fucoid layer", the platy argillaceous Hermitage resting directly upon it.

Portions of the Tyrone limestone, especially the upper shaly layers, are abundantly fossiliferous. Bryozoa are quite common, especially the solid ramose form, *Homotrypa arbuscula* Ulrich, and the narrow bifoliate, ribbon-like species, *Rhinidictya nicholsoni* Ulrich. Among the brachiopods are *Dinorthis deflecta*, *Orthis tricenaria*, *Rafinesquina minnesotensis*, and *Strophomena incurvata*. The surfaces of some of the limestone layers are crowded with the minute ostracods *Leperditella tumida*, *L. sulcata*, and *Drepanella crassinoda*. The most diagnostic Tyrone fossil, however is the coral *Tetradium cellulosum*, whose tubes of crystalline calcite penetrating the fine-grained homogeneous rock early suggested the name Birdseye limestone for similar rocks in New York.

Hermitage formation.—Resting unconformably upon the Tyrone limestone are shales and thin-bedded argillaceous limestones that contain the characteristic fossils of the Hermitage formation. In the type area the Hermitage is made up almost entirely of thin-bedded siliceous limestone layers separated by seams of gray or bluish shale, many of the layers being crowded with the brachiopod shell *Dalmanella* (*Orthis*) *fertilis*. Along the northern and eastern borders of the Central Basin shales are more abundant in the lower part of the formation, and yellowish or brown slightly phosphatic sandstone and shale make up the upper portion.

In the Woodbury quadrangle a typical section of the Hermitage is as follows: The basal 10 feet is thin-bedded blue limestone interbedded with shale. Some of the layers are extremely fossiliferous, brachiopods and bryozoans being particularly abundant. The succeeding 40 feet is made up of dirty-yellow, sandy shale and thin-bedded nodular, argillaceous limestone. Fossils are less abundant in these strata, a branching fucoid an inch wide being most conspicuous. Limestone layers 1 to 4 inches thick, with yellow interbedded shale in many places form the upper 10 feet of the Hermitage. Many of these limestones are crowded with small lamellibranchs belonging to the genus *Ctenodonta*, and the shales yield many specimens of the coral *Tetradium minus*. In the northern part of the quadrangle extremely fossiliferous, nodular, clayey limestone and shale, reaching 20 feet in thickness, close the Hermitage.

Cannon limestone.—The Cannon limestone is the most conspicuous formation of the Woodbury quadrangle, where its strata make up the lower or the middle portion of practically all the important hills. The formation consists almost entirely of blue to gray, massive, fine to coarse grained crystalline limestone, 200 to 250 feet thick. Shale beds and thin-bedded limestones occur so infrequently that the massiveness of the formation as a whole is an aid in its detection. Although, as a rule, the beds are of rather pure limestone some are argillaceous and included in the formation are many cherty layers. The basal 2 or 3 feet of the Cannon in this area is usually quite phosphatic, and although the percentage of phosphate is too small for mining it is enough to lend fertility to the soil. These phosphatic strata do not represent the Bigby limestone, because elsewhere in the Central Basin they are preceded by dove limestones with typical Cannon fossils.

The base of the Cannon limestone is marked by the largest springs in the district. The surface water makes its way through the joints and crevices of the limestone until the basal layers are reached, where, striking the impervious Hermitage shale, it is forced to seek an outlet. Owing to these same conditions, small caves are not unusual in the massive strata of the limestone.

Although comparatively plentiful the fossils in this region do not furnish good specimens except as siliceous pseudomorphs formed by the natural weathering of the limestone. Gastropods are particularly abundant, especially in the upper part, where *Bellerophon troosti* and *Lophospira sumnerensis* are often seen.

Leipers formation.—Except in a small area in the extreme northeast corner, the Cannon limestone in this quadrangle is immediately succeeded by the Chattanooga shale. This small area occurs at the top of a hill near the edge of the quadrangle, about 2 miles east of Cottage Home, where 20 feet of nodular argillaceous limestone and yellow shale separate the two formations mentioned. These intervening strata are abundantly fossiliferous and contain the fauna of the Leipers formation, which is best developed on the west side of the Central Basin. The bryozoa *Amplexopora columbiana*, *Homotrypella nodosa*, and *Constellaria florida* and the brachiopods *Orthorhynchula linneyi* and *Platystrophia laticosta* are most characteristic among the fossils, but other Leipers species are equally common. This single occurrence of the Leipers is interesting in that it apparently represents the southernmost point reached by this formation along the eastern Central Basin.

MISSISSIPPIAN FORMATIONS

The unconformity between the middle Ordovician limestone and the Mississippian black shale along the eastern part of the Basin has been already noted, and the long period of time, during which this area was either dry land or if covered by the sea at all received no deposits of sediment, has been indicated.

Chattanooga black shale.—The earliest deposits of Mississippian age are represented in the Woodbury quadrangle by black, highly carbonaceous shale, ranging from 40 to 70 feet in thickness. Lithologically this shale is one of the most uniform and widely distributed deposits in Tennessee. Throughout this quadrangle the only variation noted is its thickness. A discussion of the characteristics of this shale may be found on an earlier page.

Fort Payne formation.—Capping the higher hills of the quadrangle and succeeding the Chattanooga black shale are siliceous shales and limestones known, from their development in the vicinity of a town in Alabama by this name, as the Fort Payne chert. Only the lower 100 feet of the formation is exposed in this quadrangle, but in the area on the east its full thickness of 250 feet is developed. The lowest beds of the Fort Payne are of grayish-green, calcareous shale several feet in thickness, which pass upward into exceedingly siliceous and argillaceous limestone weathering into blocky yellow chert. Massive calcareous strata giving rise to abundant chert make up the rest of the formation. These decomposed shales and limestones afford excellent road material, which can be obtained from the creek beds of the region, where abundant deposits of large and small chert fragments have collected.

In the weathered débris of the lower 50 feet of these siliceous shales and limestones occur many quartz geodes, ranging in diameter from an inch to a foot or more. These hollow quartz spheres lined with quartz crystals are particularly abundant along the McMinnville Road at Bell Hill, several miles southeast of Woodbury, where many fine specimens washed down from the higher beds can be found in the creeks.

MINERAL RESOURCES

The important mineral resources of the Woodbury quadrangle include building stone, limestone for flux, lime, and a variety of rocks suitable for road metal. Rock phosphate is one of the possible mineral resources in the area, but at present it is valued mainly for the enrichment that it gives to the soil.

The several limestone formations of the area furnish an abundance of building stone suitable for various purposes. Of most value are the materials that may be obtained from the Lebanon and Tyrone limestones. Both formations are widespread over the quadrangle and have many rather easily accessible exposures. Quarrying is attended with few difficulties, for the rock parts readily into slabs that can be handled with ease. However, as many layers of these two formations are from 6 to 12 inches in thickness, the rock must be carefully selected.

Many beds of these limestone formations are composed of high-grade rock admirably suited for flux and the making of quicklime, the dove layers of the Lebanon and Tyrone limestones as well as the many granular blue beds in the Cannon limestone containing a high percentage of lime carbonate.

The thin flaggy layers of the Lebanon limestone are particularly adapted for road metal, for they are easily quarried, handled, and crushed to the proper size. A very excellent road metal consists of the chert derived from the decomposition of the siliceous Fort Payne limestone, which on weathering yields flinty masses in time breaking up into small angular pieces. These flint or chert fragments are segregated by the continual solution and removal of the clay débris of the limestone until considerable beds of such material result. Long-distance hauling of such material for use on the roads in the Central Basin is obviated by the fact that most of the stream beds of the region hold considerable quantities of this chert derived from the Highland Rim area.

Rock phosphate, mentioned as a possible mineral resource of the quadrangle, is present in the Hermitage formation and in the basal layers of the Cannon limestone. Each of these occurrences is of interest locally, but neither can be deemed of sufficient importance at present to warrant mining. The sandy layers of the Hermitage in many places contain sufficient calcium phosphate to make their areas of outcrop exceedingly fertile, so that its importance lies in the increased value of farm land situated upon the formation. The second occurrence of phosphate rock is of more economic interest, as the material, if found in sufficient quantity, is worth mining. This occurrence is at the base of the Cannon limestone, where a few layers have all the characteristics of the important phosphate rock in the Columbia region. The greatest thickness of this rock observed was 2 feet.

SOILS

Except in a few of the larger stream valleys the soils of this quadrangle are due entirely to the decay of the rock formations at the surface. For this reason the geologic map of the region may with proper interpretation be used as a soil map.

The lowest formation exposed in the area, the Ridley limestone, occurs mainly along the larger streams and with such slight extent that its soils need not be considered. The two succeeding formations, the Lebanon and Tyrone limestones, give rise to very similar soils. The soil from the former is apt to be shallow and rocky, but wherever the slopes are gentle the land is fertile and valuable agriculturally. The red-cedar glades of the Central Basin are characteristic products of the Lebanon limestone. The soil resulting from the Tyrone limestone, although similar in fertility and use to the Lebanon limestone, is deeper and therefore of more value. The Hermitage formation likewise gives a very good soil, the fertility of which is increased by the calcium phosphate included in some of its layers. All the soils so far discussed are clayey and are derived from pure or argillaceous limestones and shales.

A second class of soils in the area is that on the Highland Rim, where the calcareous portions of the siliceous limestones and shales making up the Fort Payne formation are removed by solution, leaving a deep mantle of chert fragments upon the surface. The soil resulting from the lower part of the formation, where the shales are more conspicuous, is rather fertile, although the presence of the chert fragments makes cultivation difficult. The upper part of the formation gives rise to a gray siliceous soil containing angular chert fragments. This latter soil characterizes the "Barrens" of the Highland Rim, but the land is by no means barren and has obtained its name only by contrast with the richer limestone soils of the adjacent Central Basin.

A third class of soils, shown along the larger streams of the area, consists of the alluvium deposited in the flood plains of the streams. As the flood plains in the Woodbury quadrangle are, however, of small extent, these soils are of less importance than those mentioned before.

HOLLOW SPRINGS QUADRANGLE

This quadrangle is 14.38 miles by 17.5 miles, containing therefore about 252 square miles. The area is situated in the eastern part of middle Tennessee on the east flank of the Cincinnati anticline with about three-fifths of it upon the Highland Rim and the remainder in the greatly dissected eastern part of the Central Basin. A considerable portion of Coffee County and a small part of Cannon County form the greater part of the quadrangle, and a narrow strip of Rutherford County lies along the western and northern borders. The Highland Rim area belongs to that portion designated the Plateau of the Barrens, a more or less level region with an altitude averaging 1,100 feet. The Central Basin portion, although greatly dissected by the many streams cutting back into the Highland Rim, has many cultivated slopes so that it is quite rich agriculturally. The Hollow Springs quadrangle is particularly interesting because of the extremes in topographic structure shown by the extensive area covered by the Barrens and the greatly dissected western edge of the Highland Rim with its many long, narrow, sharp spurs extending out into the Central Basin.

Duck River is the only stream that has cut very deeply into the Highland Rim in this quadrangle, and even this stream has not carved its way here below the Mississippian limestones. In the Central Basin portion the Ordovician limestones are exposed at the surface.

The larger part of the quadrangle is occupied by the Plateau of the Barrens, or as known locally "the Barrens", a name used as early as 1869 by Safford in his Geology of Tennessee to designate that portion of the Highland Rim that was, comparatively, barren for farming. He wrote as follows: "Immediately around the Central Basin at many points, extensive tracts occur which are known by the significant name of the Barrens. In these the soil is generally thin and greatly deficient in calcareous matter. They are, in a great part, level and thinly wooded. At some points scrub oaks occupy whole square miles." In the McMinnville folio, No. 22, U. S. Geological Survey, C. W. Hayes, in 1896, in speaking of the soil derived from the Fort Payne formation on weathering said: "This gray siliceous soil characterizes the Barrens of the Highland Rim. The land is by no means barren, but has obtained the name by contrast with the seemingly inexhaustible red-clay lands adjacent."

The Barrens consist of a gently undulating plain that has neither long, deep, narrow valleys nor high, steep hills and ridges. Instead the region is covered for the most part by large marshy or swampy areas that feed the sluggish streams draining the country.

The soils of the Barrens are residual and have been formed in place, for the most part, by the decay and disintegration of the Fort Payne formation. Their color is usually light gray to brownish gray for prolonged leaching has robbed the soil not only of its color but also of its phosphate, lime, and humus content. The vegetation throughout the Barrens is rather sparse, consisting of small blackjack trees and scrub oaks in the drier parts and vines, mosses, and water-loving oaks in the swampy areas. Farms in general in the Barrens are rather unproductive, but where the practice of rotating crops and of employing fertilizer or crushed limestone has been adopted excellent results have been obtained.

The Barrens are drained by the Duck River on the south and by the tributaries of Caney Fork of Cumberland River on the northeast. Duck River flows as a sluggish stream southward to a point south of the quadrangle, where it descends rapidly in a succession of falls and is joined by the Little Duck River. At the first prominent fall it cuts deeply into the Chattanooga black shale and the overlying Maury green shale, leaving the hard Fort Payne rocks unsupported. This locality is of special interest because of the Old Stone Fort situated on the high ridge between the two streams. This fort, originally constructed of slabs of the Chattanooga black shale found below the falls, is thought to have been built by the Indians and is probably the stone fort discovered and described by DeSoto in his journey from Florida to the Mississippi River. The excellent exposures of the Fort Payne formation at this place illustrate the weathering of the siliceous limestone into hard, flinty chert. Although the face of the cliffs is almost solid flint, nevertheless fresh surfaces of the characteristic bluish-gray Fort Payne limestone are exposed when large chunks are broken off. At many places the stages by which the calcareous matter is leached from the rock, leaving the siliceous substances to accumulate as hard, flinty chert are well shown.

The rock strata outcropping at the surface in this quadrangle are various limestone formations with a thin shale, the Chattanooga shale, forming a small part of the series. These formations belong to the Ordovician and Mississippian periods, the intervening Silurian and Devonian periods being not represented there, because this part of Tennessee is believed to have been above water during those times. The Ordovician formations are, in ascending order: the Lebanon limestone, the Lowville limestone, the Hermitage formation, and the Cannon limestone. Resting unconformably upon the latter are the Mississippian formations, consisting first of the Chattanooga black shale, followed by the Fort Payne chert, and lastly the Warsaw limestone.

ORDOVICIAN FORMATIONS

Lebanon limestone.—This formation, consisting of thin-bedded, dense, dove and blue limestone with shaly partings as elsewhere in the Central Basin, is the oldest formation of the area and outcrops only in the northwestern part of the quadrangle, where it occurs along the principal streams.

Lowville limestone.—The Lowville limestone is represented here by the Tyrone member, a pure non-magnesian limestone white to dove-colored, massive below and thin-bedded above, in all about 70 feet thick. It outcrops only along two of the streams in the western part of the quadrangle and several streams of the northwestern part but elsewhere is deeply buried. Over part of this area the Tyrone is capped by a flint layer several inches thick or by a 4-foot band of iron-stained magnesian limestone followed by the flint bed, each indicating uplift and weathering before the beginning of Hermitage time. This is further indicated by the fragments present of Tyrone dove limestone in the overlying Hermitage at places.

Hermitage formation.—Resting upon the Lowville limestone are sandy shales and thin-bedded clayey limestones about 40 feet in thickness. Fossils are somewhat uncommon in these beds except in the uppermost layers, which are in many places crowded with masses of the coral, *Tetradium minus.* Like the preceding formations the Hermitage is restricted to the lower courses of the streams in the western part of the quadrangle. The following two sections illustrate the characters of the older limestones of the quadrangle.

Section two-thirds of a mile north of Beech Grove, Coffee County, Tennessee

	Feet
Cannon limestone	
Massive blue crystalline and gray argillaceous limestone to top of hill	220
Hermitage formation	
Irregularly nodular clayey limestone crowded with *Tetradium minus* but also containing occasional *Lichenaria*	12
Gray-blue, massive, laminated semiphosphatic limestone composed of comminuted fossils	6
Unfossiliferous blue shales with a few bands 1 to 2 inches thick of gray-brown sandy argillaceous limestone containing small pelecypods (*Ctenodonta* beds)	14

Section 1 mile south of Beech Grove, eastern edge of Rutherford County, Tennessee

	Feet
Cannon limestone	
Massive gray and blue limestone.	
Hermitage formation	
Nodular clayey limestone crowded with *Tetradium minus*	3

	Feet
Massive, blue to gray, crystalline, semiphosphatic limestone weathering into thin laminae	6
Sandy shales and thin, platy, sandy, argillaceous blue limestone weathering brown, with few *Dalmanella fertilis* and many *Ctenodonta* but other fossils rare	30
Lowville (Tyrone member)	
Thin-bedded dove limestone with *Phyllodictya frondosa* and *Tetradium cellulosum.*	

Cannon limestone.—With regard to actual outcrops this is the most conspicuous formation of the quadrangle, as its strata make up the lower and middle portions of almost all the important hills formed by the dissection of the western edge of the Highland Rim. The Cannon here consists almost entirely of massive, fine-grained, gray and dove limestone with some coarse-grained, crystalline, blue limestone layers, having a total thickness of 250 feet. The individual strata differ in thickness from several inches up to 3 or 4 feet with average layers of about 1 foot. Although fossils are comparatively abundant, good specimens can be had only, as elsewhere in Tennessee, as siliceous pseudomorphs formed by the natural weathering of the limestone. Gastropod shells characteristic of the *Lophospira sumnerensis* fauna, described before, are particularly abundant. The Cyrtodonta bed and layers with *Scolithus*, as noted on preceding pages, occur at the base of the Cannon limestone in this quadrangle as elsewhere on the west. Here also the Cannon gives rise upon weathering to much chert, which is found strewing the soil over its areas of outcrops. The surface water makes its way through the joints and crevices of the limestone and issues as springs. Small caves are also not unusual in these massive strata.

Sink holes, too, are not uncommon and in some places have produced unusual arrangements of the usually horizontal strata. For example, along the road 2 miles southeast of Beech Grove the Chattanooga shale and Fort Payne chert are found in horizontal outcrops encircling the hills at their normal altitude of about 1,090 to 1,120 feet. Much lower in the stream valley and cutting through the Cannon limestone these strata are again found, here dipping at an angle of about 30° toward the center of an old sink hole.

MISSISSIPPIAN FORMATIONS

Chattanooga black shale.—Throughout this quadrangle, as elsewhere along the eastern side of the Central Basin, all the upper Ordovician, Silurian, and Devonian rocks are absent, and the first formation overlying the Cannon limestone is the Chattanooga black shale of early Mississippian age. This black, highly carbonaceous shale here has a rather uniform thickness of 30 feet and usually contains few fossils aside from minute plant spores. Upon breaking a fresh piece of the shale a distinct odor of oil can be noted, and if placed on a hot fire the shale will burn for a while. The organic matter contained in considerable amount in this shale is undoubtedly the source of the oil found in the Highland Rim, but a porous rock as a reservoir and a cap rock to retain the oil are necessary conditions for accumulation, and these are furnished by the shale and the underlying limestone. The Chattanooga black shale has been used for the determination of the geologic structure in this area because of its uniform thickness and wide distribution. The altitude of the top of this shale was determined exactly at many points within the quadrangle, and the points of equal altitude were connected by lines, thus outlining the several anticlines and synclines marked on the map. The black shale outcrops along the edge of the Highland Rim at altitudes ranging from 1,050 to 1,250 feet and marks out the slight undulation of the strata very clearly. The layer of kidney phosphatic nodules at the top of the black shale is well developed in few places in this quadrangle, but an inch of this bed may be seen at the head of Jernigan's Branch.

Fort Payne chert.—The Fort Payne chert is here a very siliceous limestone 200 feet thick, weathering into heavy beds of blocky, solid, brittle chert and a gray sterile soil known as "crawfish land". Its occurrence is confined to the Highland Rim and to the highest hills and the ridges of the dissected Central Basin. Although it is a limestone formation, this type of rock is seldom seen in the quadrangle because long weathering has resulted in the decay of the limestone and the formation of the chert blocks that now cover the surface. Large crinoid stems are abundant in these cherts, but other fossils are rare. The base of the Fort Payne is marked in places by a layer of green shale 1 foot thick—the equivalent of the Maury shale.

Warsaw limestone.—The youngest sedimentary rocks of the quadrangle are siliceous dark-blue to dark-gray coarsely crystalline, granular limestones 100 feet thick, weathering into a red-brown soil with blocks of very porous gray chert. This porous chert is quite distinct from the solid brittle chert of the underlying Fort Payne formation, and it can be further distinguished usually by the abundance of lacelike fenestellid bryozoa in it and the characteristic *Worthenopora spinosa*. Other fossils are not uncommon and show that this formation is the equivalent of the Warsaw limestone of the Mississippi Valley. Outcrops of the Warsaw limestone in its unweathered condition are very rare in the quadrangle, so that the nature of the soil with its characteristic porous chert and contained fossils must be considered in mapping it.

Subsequent divisions of the Mississippian and probably some of the Pennsylvanian undoubtedly covered this area at one time, but erosion has completely removed them. The weathering over the Highland Rim has been so thorough that nowhere in the area is there a section of the Fort Payne chert and Warsaw limestone sufficiently exposed to give the details of these two formations.

LILLYDALE QUADRANGLE

The Lillydale quadrangle, 14 miles by 17.375 miles and with an area of approximately 243 square miles, extends north from latitude 36° 30′ in Tennessee to 36° 45′ in Kentucky and from longitude 85° 15′ west to 85° 30′. The quadrangle was named from the town of Lillydale in the northeastern corner of Clay County. The greater part of this county together with small portions of Overton and Pickett Counties make up that part of the quadrangle—slightly less than half its area—which lies in Tennessee.

Geologically the Tennessee portion is located in a section of the eastern Highland Rim that is much dissected by the Obey River and its tributaries; the Obey River emptying into the Cumberland River, which skirts the western edge of the quadrangle. Because this deep dissection and the consequent exposure of the older strata afford opportunity for studying the extension of the Central Basin formations eastward, this quadrangle has been included in the present report.

The surface of the area, although lying entirely within the Highland Rim province, is unlike that of the typical Rim country on the south, which erosion has worn to a general level. Here in northern Tennessee the surface has been left quite hilly. Again, from the general plane of elevation here representing the Highland Rim, there rise isolated high knobs. Such a one, Pilot Knob in the northwest corner of the quadtangle, capped by the Cypress sandstone of later Mississippian age, indicates that this area was once a part of the Cumberland Plateau. In general the level nature of much of the Highland Rim is due to the fact that the plane of erosion has reached the Fort Payne chert.

In this area, however, erosion has gone below the chert into an unusual development of soluble Ridgetop and New Providence shales and thin limestones, the weathering of which produces the uneven surface. The deep stream channels and high hills of the quadrangle afford many clear-cut sections of the strata. Particularly is this true of the Mississippian series above the black shale, in which details of each formation can be studied and the rocks traced from place to place.

Many sections were taken in the course of mapping the quadrangle, four of which are reproduced on previous pages in the discussion of the New Providence formation. Reference to these will give the details of the several Mississippian formations, so that it is necessary only to reproduce a generalized composite section of the quadrangle here.

Generalized geologic section in Lillydale quadrangle, Tennessee

	Feet
Mississippian System:	
Cypress sandstone. Coarse-grained, grayish massive sandstone	20
Monte Sana limestone. Light-gray, thick-bedded, oolitic limestone	310
St. Louis limestone. Grayish-blue, fine-grained, massive limestone	140

	Feet
Warsaw formation. Coarsely crystalline, gray to blue, granular limestone followed by blue and yellow shale, thin massive sandy limestone, and at the top sandstone beds forming the Garretts Mill sandstone member........	80
Fort Payne formation. (Rosewood phase). Dark-colored siliceous shale and argillaceous limestone, some of the layers weathering into yellow chert....	50
New Providence formation. Blue shale with marly beds and thin to thick bedded crinoidal limestone containing crinoidal fragments and bryozoa..........	0-120
Ridgetop shale. Light-blue to olive and gray shales with few fossils other than small ostracoda, which occur in bands at intervals throughout the formation. Base marked by the Maury green shale with a layer of kidney phosphate nodules........	0-120
Chattanooga shale. Fissile black shale with occasionally a bed of sandstone an inch or two thick at the base........	20
Ordovician System:	
Leipers formation. Nodular argillaceous limestone with interbedded shale, weathering into small, irregularly rounded fragments. *Platystrophia ponderosa* not uncommon........	100
Catheys formation. Knotty, earthy, even-bedded, dark-blue limestone in thin layers and shale with heavier beds of impure blue limestone.............	75+

ORDOVICIAN FORMATIONS

The Catheys formation of Trenton age and the Leipers formation of the Cincinnatian group are the only representatives of the Ordovician system that outcrop in this area.

The Catheys formation outcrops only in the western third of the quadrangle, in the valley of Obey River and its branches and in shorter tributaries of the Cumberland. Its characteristics can best be seen perhaps along the Cumberland north of Celina. Here the bluffs show its characteristic thin to massive, even-bedded, dark-blue argillaceous to finely crystalline limestone, 75 or more feet thick, containing the characteristic fossils *Cyclonema varicosum* and *Columnaria alveolata*. Aside from the fossils the formation can be distinguished from the overlying Leipers by its more even bedded strata, which do not weather so noticeably into a rubbly mass of fragments.

Seventy-five to one hundred feet of argillaceous gray-blue to light-blue limestone and shale, massive when fresh but readily weathering into a rubble of small irregular fragments, succeeds the Catheys formation and forms the main limestone outcrops in the valley of Obey River throughout the quadrangle. Abundant examples of the brachiopod *Platystrophia ponderosa*, characteristic of the Leipers formation, with other typical fossils give its age relationships. The Leipers is here invariably followed by the early Mississippian black shale, indicating that this area was land or at least received no deposits during Silurian and Devonian times.

MISSISSIPPIAN FORMATIONS

Chattanooga black shale.—As just noted, the Ordovician is followed directly by the oldest Mississippian formation, the widespread Chattanooga black shale. As the shale in this quadrangle is quite similar in all its characteristics, save in slightly less thickness, to the same formation as described in the Hollow Springs quadrangle, repetition is unnecessary. A detailed study of the Chattanooga black shale was not a part of the present investigation. Undoubtedly, however, future researches will show it to be composed of several members of distinct age, the lower one even of Devonian age in places.

Ridgetop shale.—Immediately west of this quadrangle the massive crinoidal limestone of the New Providence formation with a thin basal layer of kidney phosphate rests directly upon the Chattanooga black shale. The same sequence is found in the northwest and southwest corners of the quadrangle, but commencing just east of Celina and continuing eastward the pale-blue to gray-green shales of the Ridgetop develop in increasing thickness from a few feet on the west to several hundred on the east. The sections given under the general discussion of the Ridgetop and New Providence elsewhere in this volume illustrate the details of its occurrence. Above the Chattanooga black shale, which outcrops in the river valleys or near the base of the hills in this region, the Ridgetop is an inconspicuous formation in the western half of the quadrangle, but as it thickens toward the east it becomes of such importance that in the northeastern third of the area it constitutes most of the hills.

New Providence formation.—The blue shale and crinoidal limestone of this formation are so well developed in the quadrangle, and outcrops are so numerous, that the major part of the general discussion given on a preceding page is based upon sections of the strata exhibited here. The slopes of hills throughout a large part of the quadrangle are composed of these strata, and the characteristic fossils may often be found strewing their surface.

Fort Payne chert.—Succeeding the New Providence are dark-blue calcareous to siliceous shales, which in Kentucky are known as the Rosewood shales but in Tennessee are still classified as the Fort Payne chert. In Clay County these shales, which average about 50 feet in thickness, do not weather into the abundance of chert characteristic of the typical Fort Payne, and their outcrops are restricted to a narrow band just below the general upland plain of the area.

Warsaw formation.—Below the Fort Payne and the massive limestone forming the surface of the upland plain is about 80 feet of various types of limestone, shale, and sandstone, which contain the fossils of the Warsaw division. The details concerning the strata of this formation as it occurs in the quadrangle are given in the sections reproduced in the general discussion of the New Providence formation. It may be noted, however, that usually alternating beds of limestone and shale comprise the lower third, more massive fossiliferous limestone the middle third, and a sandstone described as the Garretts Mill sandstone the upper third. The last is an important water stratum, and the many springs that issue from it aid in its identification and in working out the structure. The Warsaw outcrops over rather extensive areas of the upland plain in the eastern half of the quadrangle, but in the more dissected western half it occurs as a narrow band near the tops of the higher hills.

St. Louis limestone.—This widespread formation of massive fine-grained blue limestone is the surface rock over the larger part of the upland plain in the Lillydale quadrangle, but actual outcrops of the strata are rare. Through long weathering the formation where it appears at the surface has been reduced to a red clay soil, in which yellow angular solid chert is abundant and in places specimens of the coral *Lithostrotion* are not uncommon. The St. Louis weathers into rolling lands more fertile than the other Mississippian formations of the region.

Chester Series.—The high knobs and hills rising above the general upland plain of this region are composed of the two lower members of the Chester series, an oolitic limestone 200 to 300 feet thick, the Monte Sana limestone, and above this the Cypress sandstone, which occupies such elevations as Pilot Knob. More detailed descriptions of these two formations are given under the general discussion of the Mississippian on preceding pages.

STRUCTURAL FEATURES

As noted under the discussion of the Ridgetop shale and the New Providence formation, the Lillydale quadrangle illustrates the distribution of these two divisions in embayments developed in the Cincinnati uplift. In the northwestern and southwestern parts of the quadrangle the Ridgetop shale is absent, this formation appearing east of Celina as a feather edge and thickening eastward to at least 200 feet. The New Providence is well developed over all the quadrangle except the eastern and northeastern parts, where it thins out and disappears. Detailed mapping of the contiguous areas is necessary before the exact outlines of these embayments can be determined, but enough has been done to show that the limits indicated on the map of the Lillydale quadrangle are correct. The other Mississippian formations of the area have a more uniform and widespread distribution.

Prior to the writer's geologic mapping of the quadrangle Gene Perry made a structural contour map of the region, using the Chattanooga black shale as a datum plane. Mr. Perry found that although the dips of the strata were small he could make out the existence of a series of small domes and corresponding basins trending northeast across the area by observing, in addition, the exact altitude of outcrop of the shale. These small domes are the source of the oil in this part of Tennessee and nearby Kentucky.

PLATES

1—29. Fossil plates (see also fig. 3, p. 114)
30—49. Illustrative plates.

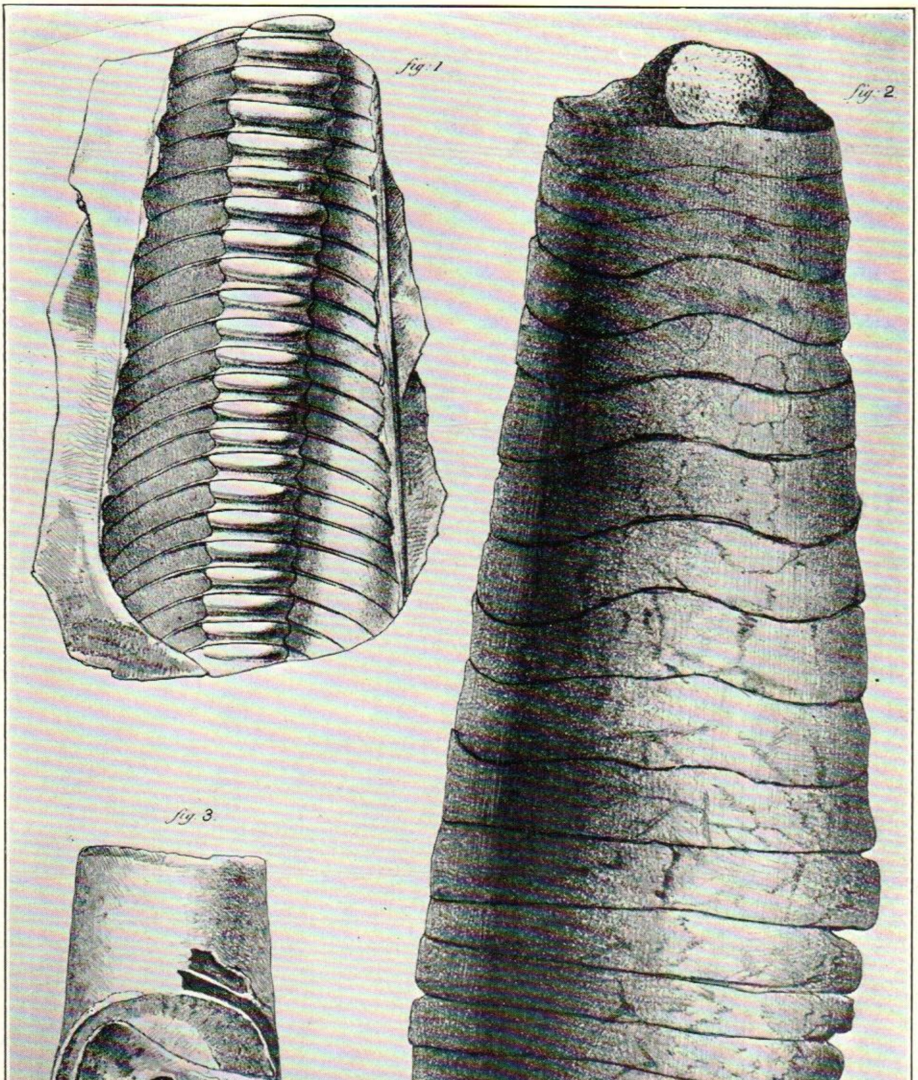
Separates of plates 1—29 and their titles maybe obtained from the state geologist.

PLATE 1. (Copy of Troost's plate 9 reduced about 5 to 3.)
(Société géologique de France, Memoir 3, 1838.)

FIGURE 1. *Conotubularia cuvierii* Troost.
Mohawkian (probably Bigby or Cannon), vicinity of Nashville.

2. *Conotubularia brongniarti* Troost.
Mohawkian (probably Hermitage), Cumberland River banks, Nashville.

3. *Conotubularia goldfussi* Troost.
Mohawkian (Cannon or Catheys), Nashville.

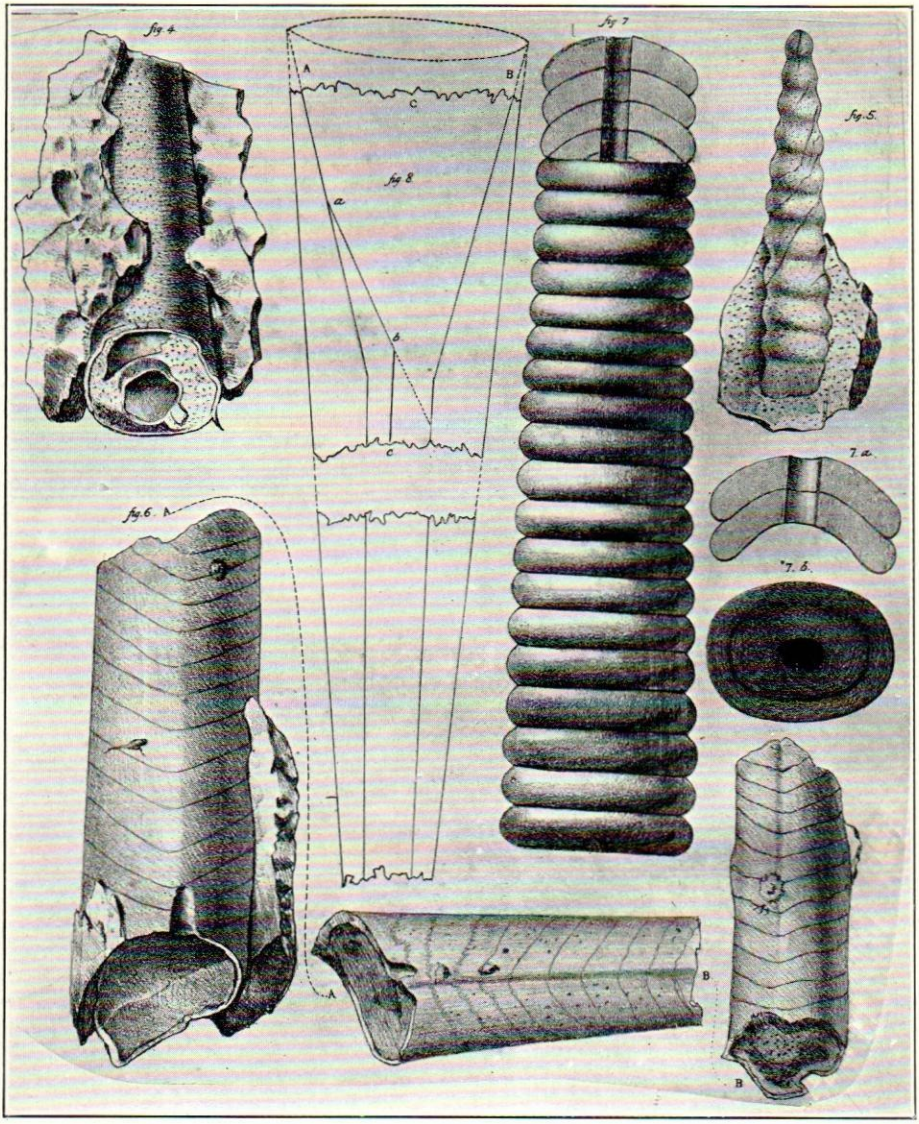


Troost's Plate 9, (1838)

PLATE 2. (Copy of Troost's plate 10 reduced about 5 to 3.)
(Société géologique de France, Memoir 3, 1838.)

FIGURES 4, 5, 6, 8. Species of *Conotubularia?* from the Mohawkian, vicinity of Nashville.

7. *Orthoceratites defrancii* Troost.
Longitudinal and transverse section; natural size. Silurian, Perry County.



Troost's Plate 10, (1838)

PLATE 3. (Copy of Troost's plate 11 reduced about 5 to 3.)
(Société géologique de France, Memoir 3, 1838.)

FIGURES 1-5. *Asaphus megalophthalmus* Troost.

1. Specimen, natural size. 2. A part enlarged to show the eye. 3. Posterior part of the cephalon. 4. Profile of the type specimen. 5. Eye highly magnified.

A species of *Phacops* from the Silurian or Devonian, Perry County.

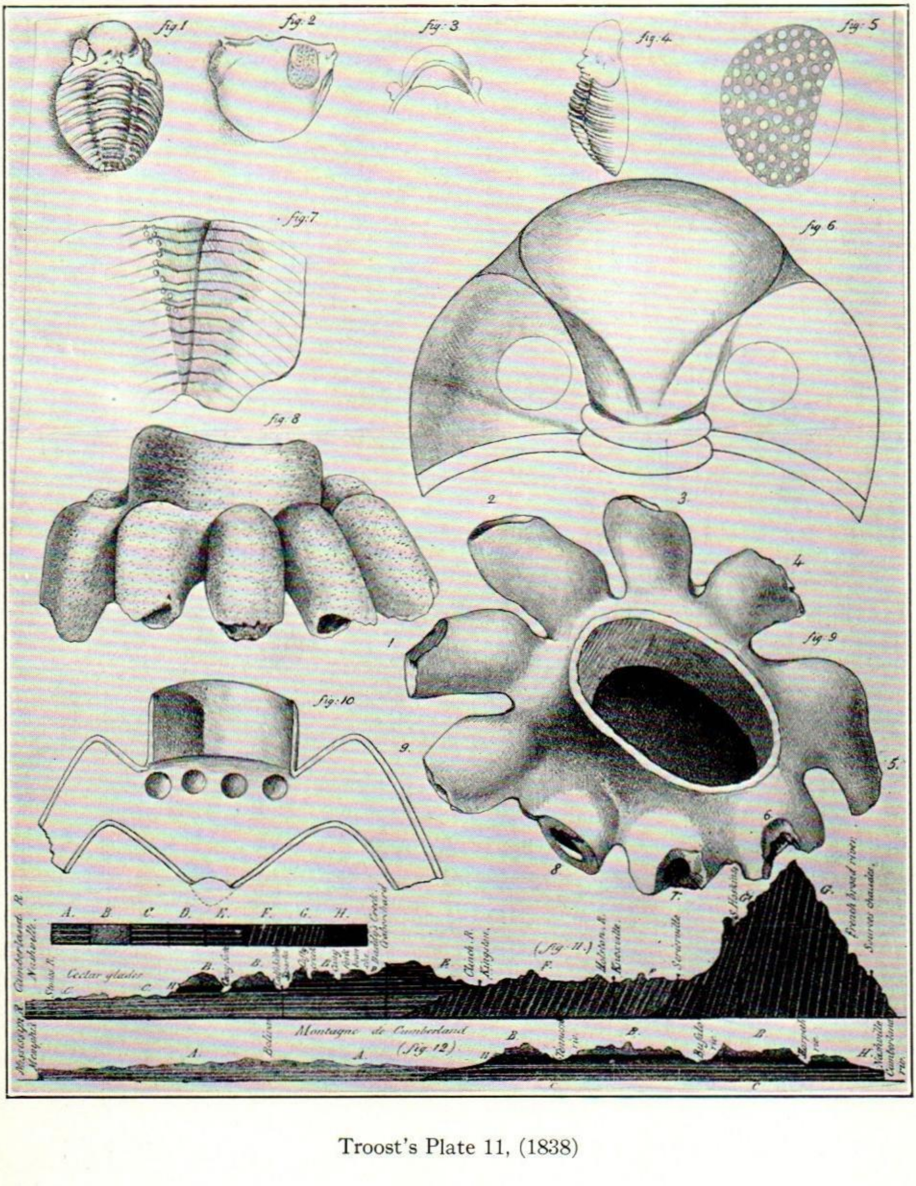
6. Cephalon of an undetermined species.

7. Fragment of the pygidium supposed to belong to the same species as Figure 6.

Silurian or Devonian, Perry County.

8-10. Three views of a fossil described without name by Troost and said to have been discovered in Davidson County. It probably represents the remarkable sponge *Brachiospongia digitata* (Owen), occurring in the Bigby (Benson) of Franklin County, Ky., and possibly also discovered by Troost at a similar horizon in Tennessee.

11, 12. Structure section across Tennessee from Memphis on the Mississippi River to Nashville (fig. 12) and from Nashville to the mountains of East Tennessee (fig. 11).

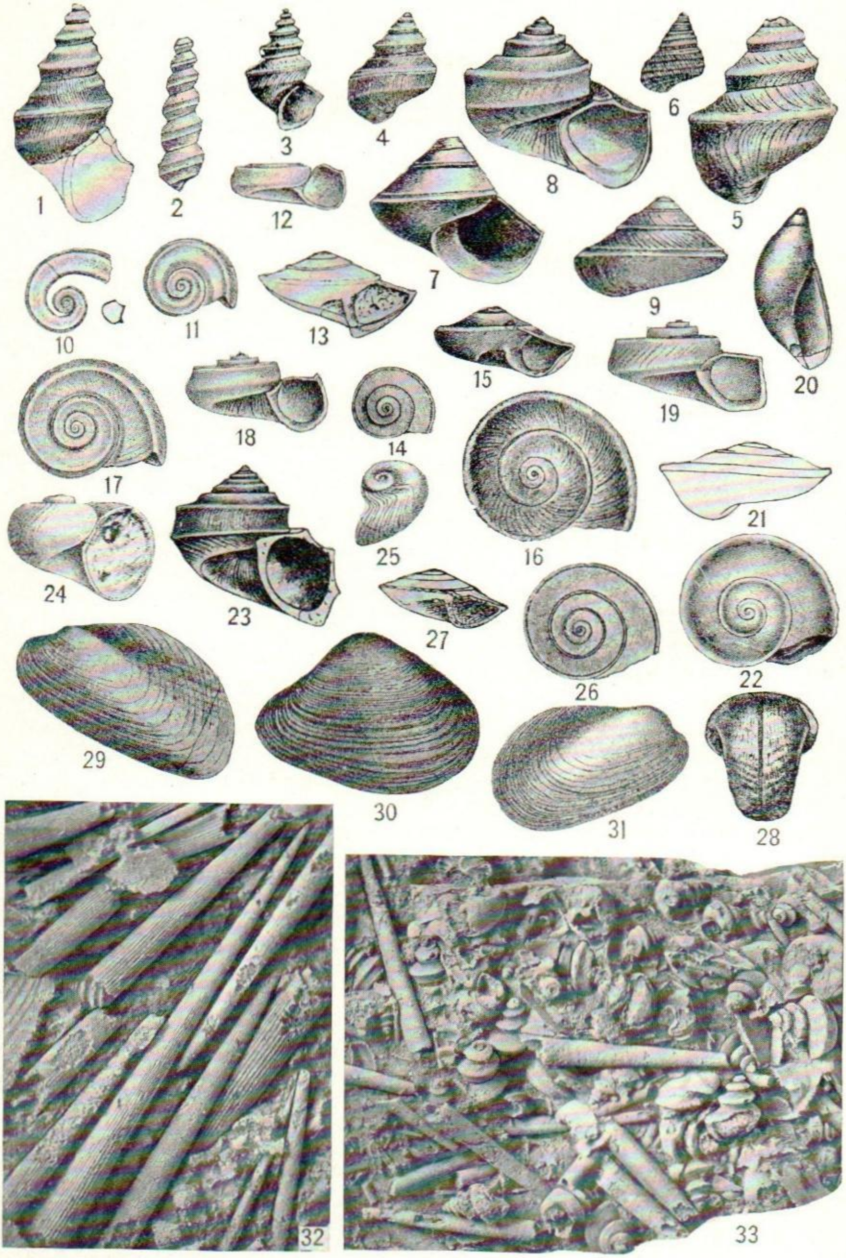


Troost's Plate 11, (1838)

PLATE 4. Characteristic fossils of the Murfreesboro limestone.

All the following species are from the Murfreesboro limestone at Murfreesboro, Tenn.; the illustrations are natural size unless otherwise indicated and except Figures 32 and 33 are after Ulrich.

FIGURE 1. *Lophospira procera* Ulrich.
2. *Ectomaria prisca extenuata* Ulrich.
3. *Lophospira perangulata* Hall. A rather large specimen.
4. *Lophospira bicincta* Hall.
5. *Lophospira centralis* Ulrich.
6. *Cyclonema (?Gyronema) praeciptum* Ulrich.
7. *Eotomaria labiosa* Ulrich.
8. *Lophospira? trochonemoides* Ulrich.
9. *Eotomaria canalifera* Ulrich.
10. *Ophiletina sublaxa depressa* Ulrich.
11, 12. *Helicotoma declivis* Safford. Top and side views.
13, 14. *Liospira abrupta* Ulrich and Scofield. Side view of one specimen and top view of another.
15, 16. *Liospira subconcava* Ulrich. Side and top views.
17, 18. *Helicotoma tennesseensis* Safford. Top and side views.
19. *Helicotoma subquadrata* Ulrich. Side view.
20. *Cyrtospira tortilis* Ulrich. Side view.
21, 22. *Raphistomina modesta* Ulrich. Side and top views, x 2.
23. *Trochonema bellulum* Ulrich. Apertural view.
24, 25. *Eccyliomphalus contiguus* Ulrich. Apertural view and a smaller example of the same species.
26, 27. *Liospira decipiens* Ulrich. Top and side views.
28. *Bucania emmonsi* Ulrich and Scofield. Dorsal view.
29. *Whiteavesia saffordi* Ulrich. Dorsal view of this bivalved shell.
30. *Ctenodonta gibberula* Salter. Side view of a large valve.
31. *Modiolopsis consimilis* Ulrich.
32, 33. *Salterella billingsi* Safford. Fig. 32. Broken shells, x 2, showing the elongate, fluted character. Fig. 33. A fragment of chert with this species and many gastropods.



Fossils of the Murfreesboro limestone

PLATE 5. Fossils of the Lebanon limestone.

FIGURE 1. *Escharopora briareus* (Nicholson).
A zoarium natural size, showing the base pointed for articulation and the many branches. Upper part of Lebanon limestone at Lebanon, Tenn.

2, 3. *Escharopora ramosa* Ulrich.
The type specimen, natural size and surface, x 20. Upper part of Lebanon limestone at Lebanon, Tenn.

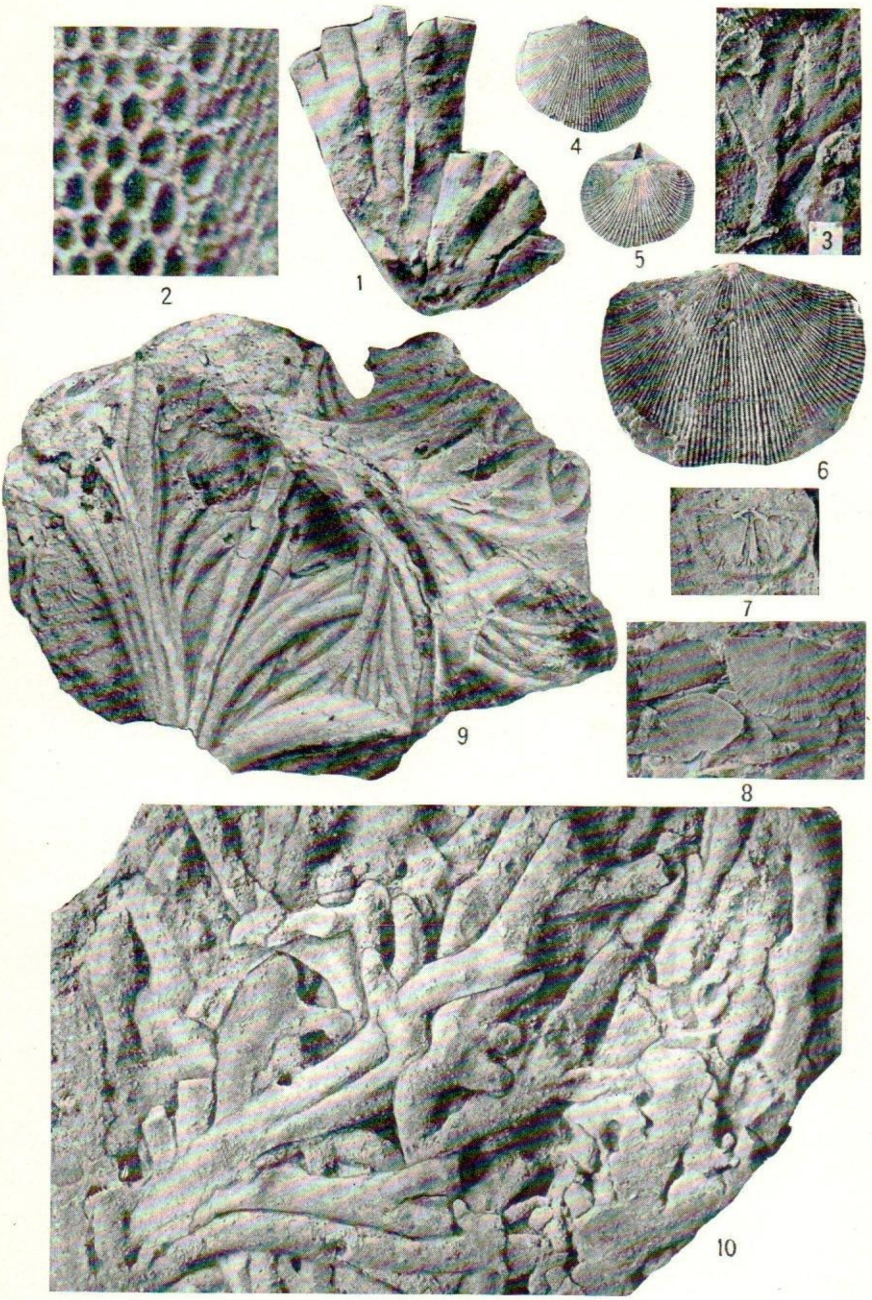
4, 5. *Pianodema subequata* (Conrad).
Two examples showing opposite valves. Upper beds of Lebanon limestone at Lebanon, Tenn.

6. *Dinorthis* (*Valcourea*) *deflecta* (Conrad).
Valve, x 1.5. Upper bed of Lebanon limestone at Lebanon, Tenn.

7, 8. *Sowerbyella lebanonensis* n. sp.
An example showing interior of valve and a slab with several specimens. Lebanon limestone at Shelbyville, Tenn.

9. *Licrophycus libana* n. sp.
The type specimen natural size showing several examples. Lebanon limestone 2 miles south of Murfreesboro, Tenn.

10. *Camarocladia implicatum* n. sp.
Surface of slab covered with the closely matted remains of this organism, natural size. Lebanon limestone, Lebanon, Tenn.



Fossils of the Lebanon limestone

PLATE 6. Fossils of the Lebanon limestone

Unless otherwise marked the illustrations are natural size. Figures 1-16 are after Ulrich and 17-26 after Hall and Clarke.

FIGURES 1, 2. *Lophospira peracuta* Ulrich and Scofield. Opposite views of this sharply carinated species.

3, 4. *Subulites nanus* Ulrich. Opposite views of this small elongate shell.

5, 6. *Trochonema umbilicatum latum* Ulrich.
Lateral and basal views of this broad variety.

7, 8. *Trochonema eccentricum* Ulrich.
Basal and apertural views.

9,10. *Eccyliomphalus undulatus* Hall.
Lateral view and lower side of specimen.

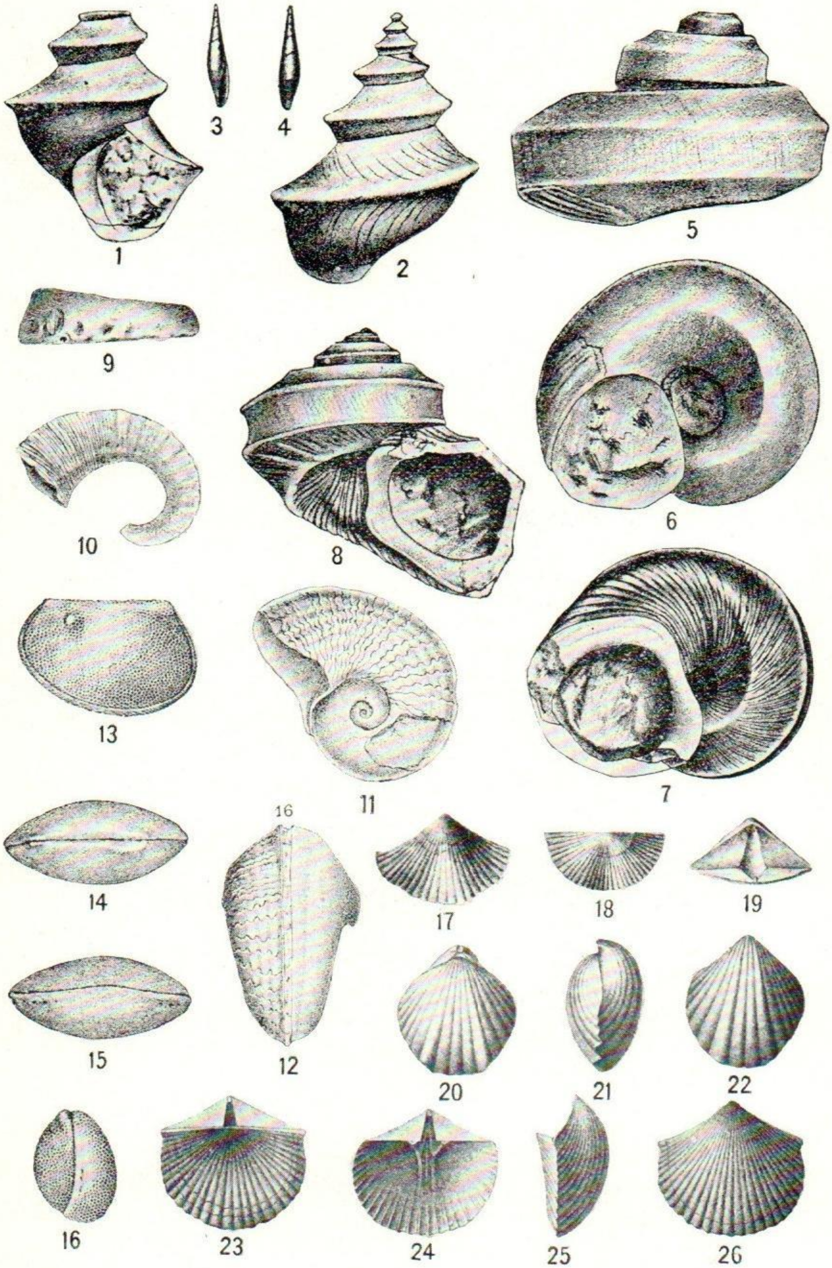
11,12. *Phragmolites grandis* Ulrich. A large specimen showing the transverse lamellae and dorsal view of the same.

13-16. *Leperditia fabulites* Conrad. Various views of a complete carapace of this characteristic ostracod, x 2.

17-19. *Scenidium halli* Safford.
Three views of the same specimen, x 4.

20-22. *Zygospira saffordi* Winchell and Schuchert.
Three views of this small shell, x 4.

23-26. *Orthis tricenaria* Conrad.
Dorsal and ventral valves of this species (23, 26), a side view of the valves in position (25), and interior of ventral valve (24), all x 2.



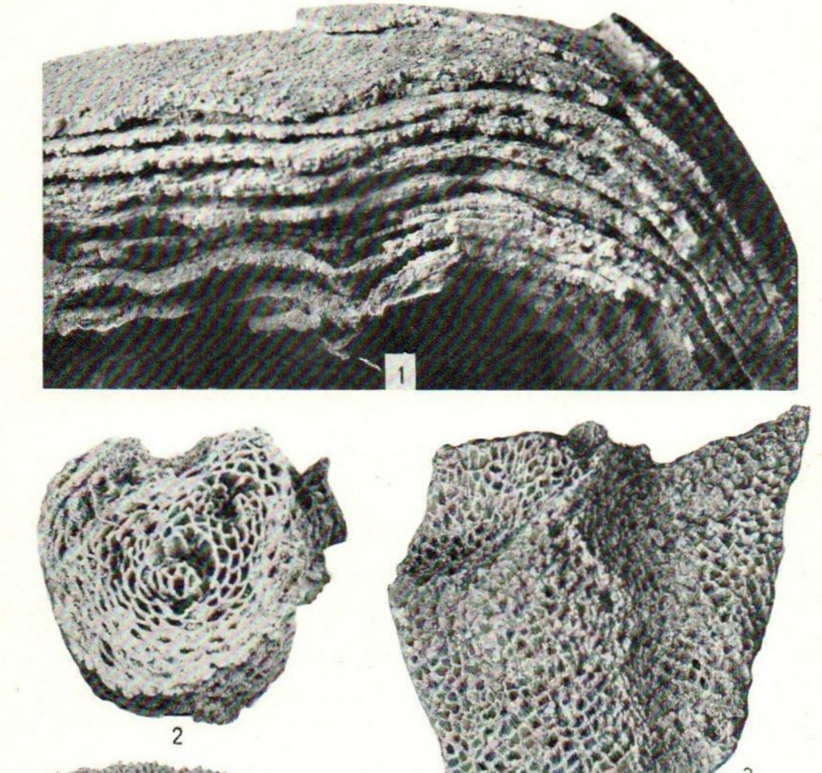
Fossils of the Lebanon limestone

Plate 7. Fossils of the Carters limestone

Figure 1. *Stromatocerium rugosum* Hall. Edge view, natural size, showing the superposed layers and the gently undulated upper surface of one. Lower part of Carters limestone at Columbia, Tenn.

2, 3. *Tetradium carterensis* n. sp. End view of branch and side view, natural size, showing the large cells and their imbricating tendency. Lower part of Carters limestone 2 miles southeast of Priest, Tenn.

4, 5. *Dystactospongia minor* Ulrich and Everett. Side and top views of this characteristic sponge. (After Ulrich.) Lower part of Carters limestone at Columbia, Tenn.



Fossils of the Carters limestone

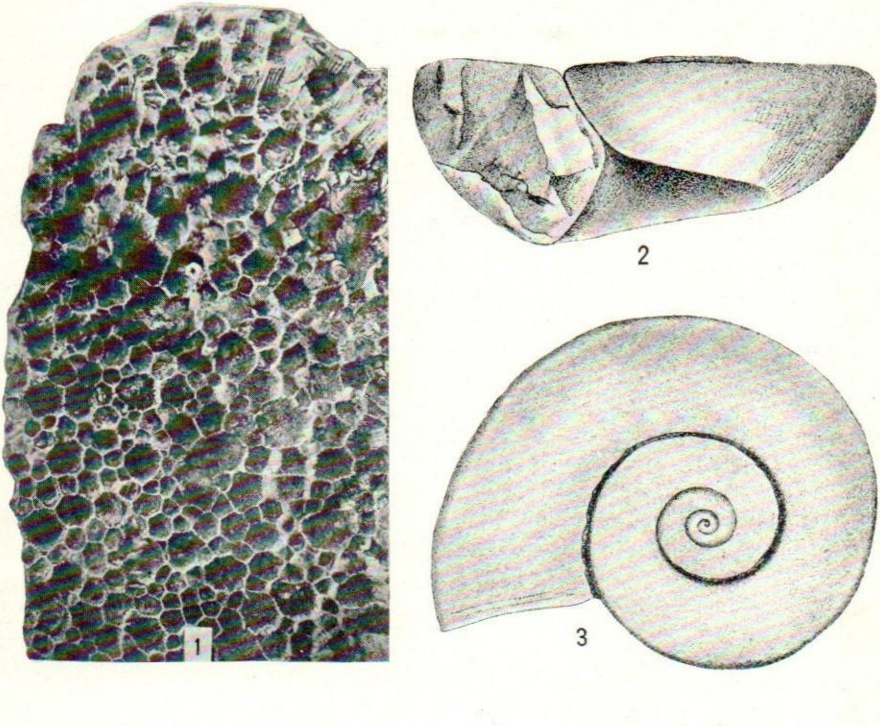
PLATE 8. Fossils of the Carters and Tyrone limestones

Figures 1-3 after Ulrich.

FIGURE 1. *Columnaria halli* Nicholson.
Top view, natural size, showing the very short septa projecting into the cell, which distinguish it from *C. alveolata*. Carters limestone, Maury County, Tenn.

2, 3. *Maclurites bigsbyi* Hall.
Lateral and top views, x2. Lowville limestone, Dixon, Ill.

4. *Camarocladia gracilis* n. sp.
The type specimen showing the slender branches; natural size. Tyrone limestone near Dixon Springs, Trousdale County, Tenn.



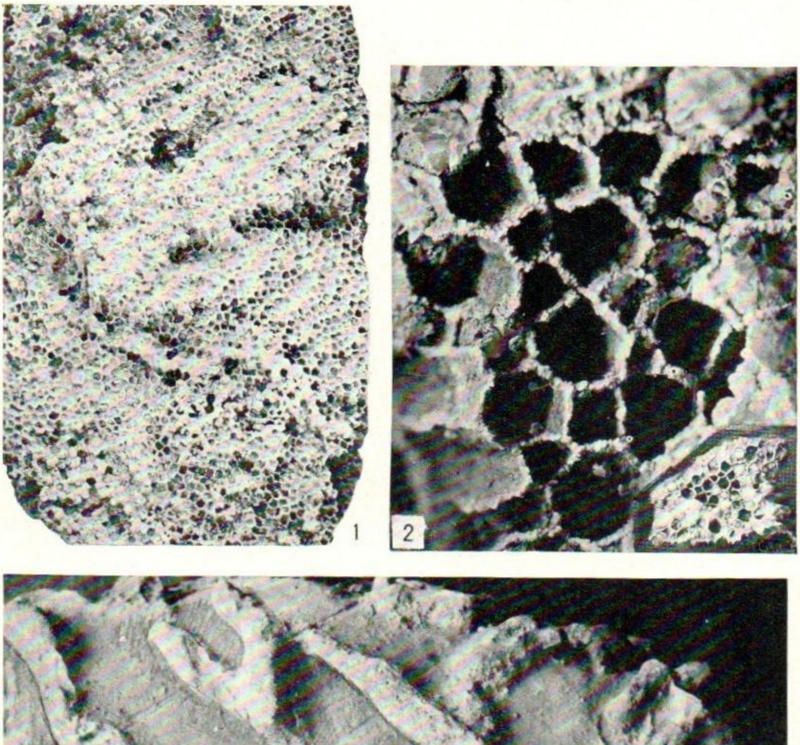
Fossils of the Carters and Tyrone limestones

PLATE 9. Fossils of the Lowville limestone.

FIGURE 1. *Tetradium columnare* Hall.
Surface, natural size, of the Carters form of the species. Lower part of Carter limestone, 2 miles southeast of Priest, Tenn.

2. *Lichenaria carterensis* (Safford).
A fragment, natural size, and surface, x 6, of this typical Carters coral described by Safford as *Columnaria carterensis*. Lower part of Carters limestone, 2 miles southeast of Priest, Tenn.

3. *Buthotrephis inosculata* n. sp.
Surface of a slab, natural size, showing the inosculating branches of this fucoid which subdivide irregularly in the same plane and also penetrate from one stratum to another (see also Plate 33). Tyrone division, Hoovers Mill, west of Woodbury, Tenn.



Fossils of the Lowville limestone

PLATE 10. Fossils of the Lowville limestone.

Unless otherwise marked the illustrations are natural size. Figures 1-14 after Ulrich and Scofield.

FIGURE 1. *Subulites regularis* Ulrich and Scofield. A complete example of this elongate shell.

2. *Hormotoma gracilis angustata* Hall. An incomplete specimen.

3-5 *Helicotoma granosa* Ulrich. Upper side of specimen, natural size, and top and side views, x 3, exhibiting the granose surface.

6. *Lophospira? notabilis* Ulrich. Apertural view of this well-marked gastropod.

7. *Lophospira oweni* Ulrich and Scofield. Apertural view.

8. *Helicotoma verticalis* Ulrich. Cast of interior.

9. *Eotomaria dryope* (Billings). Dorsal view of large shell.

10, 11. *Raphistomina lapicida* (Salter). Top and side views.

12. *Omospira laticincta* Ulrich. Dorsal view of an almost complete individual.

13. *Primitiella constricta* Ulrich. A valve and end view of same of this abundant ostracod, x 20.

14. *Eurychilina subradiata* Ulrich. A left valve showing the characteristic frill, x 20.

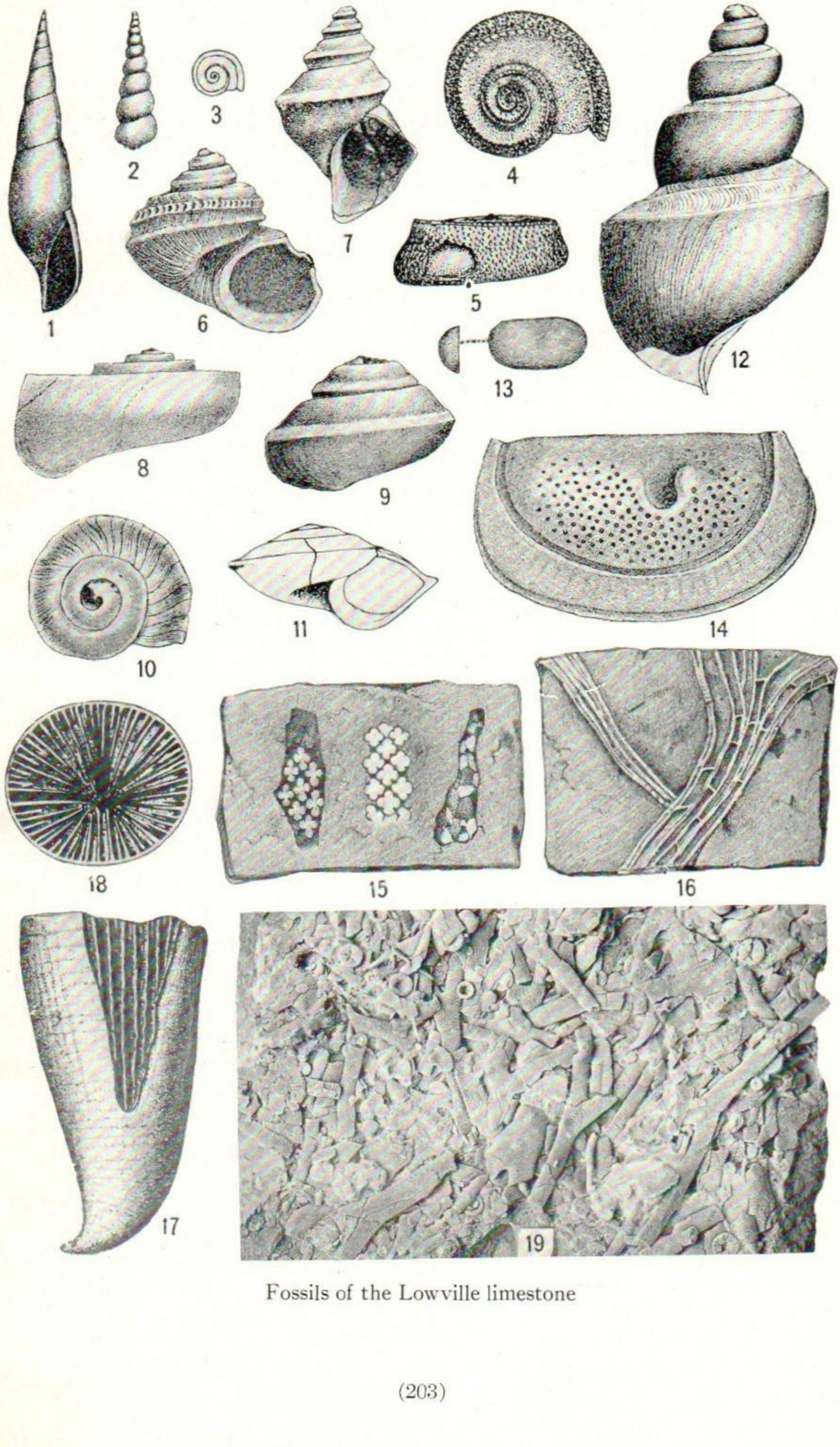
15, 16. *Tetradium cellulosum* Hall.

Fig. 15, cross section of tubes in rock, showing characteristic form of septa and arrangement in bundles in this coral; Fig. 16, section of rock showing tubes cut longitudinally (after Hall).

17, 18. *Streptelasma profundum* (Conrad).

Fig. 17, an entire specimen, x 2, with portion broken away to show the great depth of the body cavity. Fig. 18, view of the body cavity, x 3. (After Winchell and Schuchert.)

19. Thin slab of Lowville limestone, showing abundance of ribbon-like bifoliate bryozoa (*Escharopora* and *Rhinidictya*).



Fossils of the Lowville limestone

PLATE 11. Fossils of the Hermitage formation.

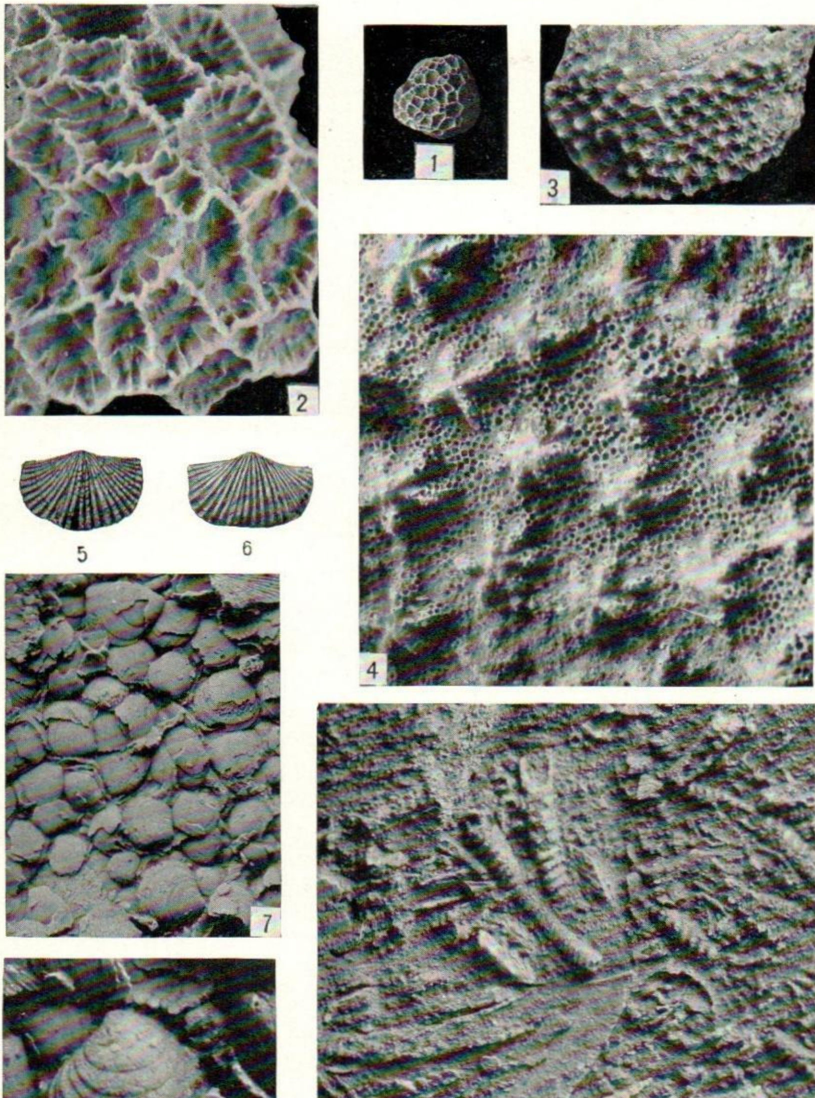
FIGURES 1, 2. *Columnaria alveolata* var. *minor* new variety.
A colony of this coral, natural size, and surface of the corallites, x 6. Basal bed of the Hermitage, 1 mile south of Belfast, Tenn.

3, 4. *Stellipora stipata* n. sp.
Zoarium, natural size, consisting of incrusting lamellae with closely spaced star clusters, and portion, x 6, showing the surface more in detail. Top of Hermitage, 2 miles east of Cottage Home, Tenn.

5, 6. *Platystrophia extensa* McEwan.
Pedicle and brachial valves, natural size. Upper beds of Hermitage at Auburn, Tenn.

7, 8. *Ctenodonta hermitagensis* n. sp.
Surface of layer, natural size, crowded with silicified examples of this bivalved shell, and a specimen, x 3. Top of Hermitage, 3 miles east of Mount Pleasant, Tenn.

9. *Tentaculites obliquus* n. sp.
Surface of slab with this slightly curved *Tentaculites* listed in 1888 by Ulrich as *T. obliquus*. Hermitage formation at Danville, Ky.



Fossils of the Hermitage formation

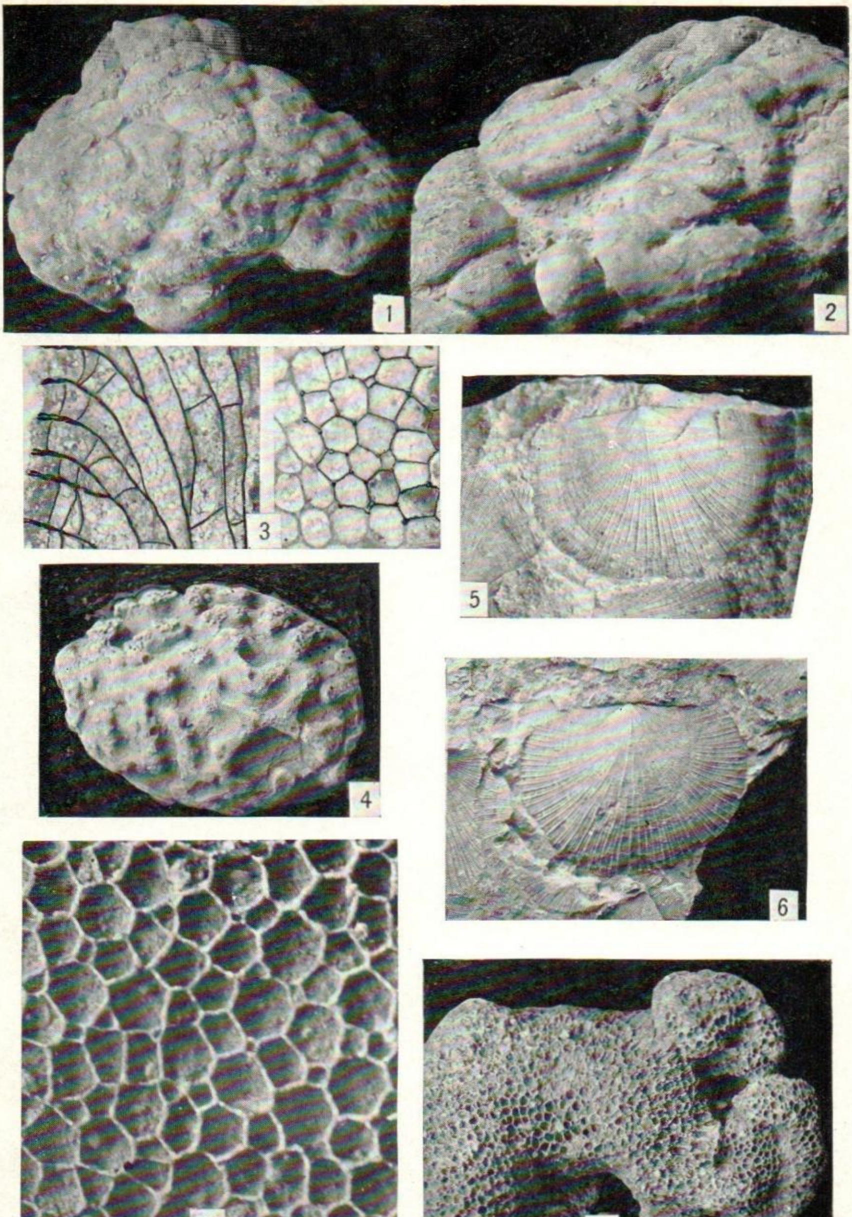
PLATE 12. Fossils of the Hermitage formation.

FIGURES 1, 2. *Solenopora compacta* var. *cerebrum* n. var.
View of entire specimen, one-half natural size, and portion of same, natural size, showing the much-convoluted surface. Top of Hermitage, 6 miles northwest of Carthage, Tenn.

3, 4. *Amplexopora convoluta* n. sp.
A zoarium, natural size, and vertical and tangential thin sections, x 30. Very abundant at top of Hermitage, 2 miles west of Hartsville, Tenn.

5, 6. *Rafinesquina hermitagensis* n. sp.
Two examples, natural size, showing breadth of shell. Near base of Hermitage, 2 miles south of Middleton, Tenn.

7, 8. *Lichenaria grandis* n. sp.
A colony, natural size, and surface, x 6. Trenton (top of Hermitage), near Bradyville, Tenn.



Fossils of the Hermitage formation

PLATE 13. Fossils of the Hermitage formation

Figs. 6, 7 are after Hall and Clarke and 11-17 after Ulrich.

FIGURES 1, 2. *Lichenaria globularis* n. sp.

A colony, natural size, and surface, x 6, showing the small cells and absence of septa. Top of Hermitage, 6 miles northwest of Carthage, Tenn.

3, 4. *Columnaria crenulata* n. sp.

Colony, natural size, and cells, x 6, exhibiting the many short septa giving the appearance of crenulated walls. Top of Hermitage, 4 miles south of Carthage, Tenn.

5. *Tetradium minus* Safford.

Two surfaces, x 6, the first showing the characteristic four septa in cells of the normal size, and the second the small cells formed by union of the four septa at the center. Upper beds of Hermitage, vicinity of Carthage, Tenn.

6. *Heterorthis clytie* (Hall).

Brachial valve. Hermitage formation of Kentucky.

7. *Dinorthis pectinella* (Emmons).

A large individual showing the strongly elevated ribs.

8-10. *Platystrophia hermitagensis* McEwan.

Figs. 8, 9, brachial and pedicle valves, natural size. Fig. 10, pedicle valve showing the broad shallow sinus. Upper beds of Hermitage, vicinity of Carthage, Tenn.

11-13. *Prasopora patera* Ulrich and Bassler.

Basal and upper surface of this abundant discoid bryozoan and the celluliferous surface enlarged. Hermitage formation, near Columbia, Tenn.

14. *Dalmanella fertilis* Bassler.

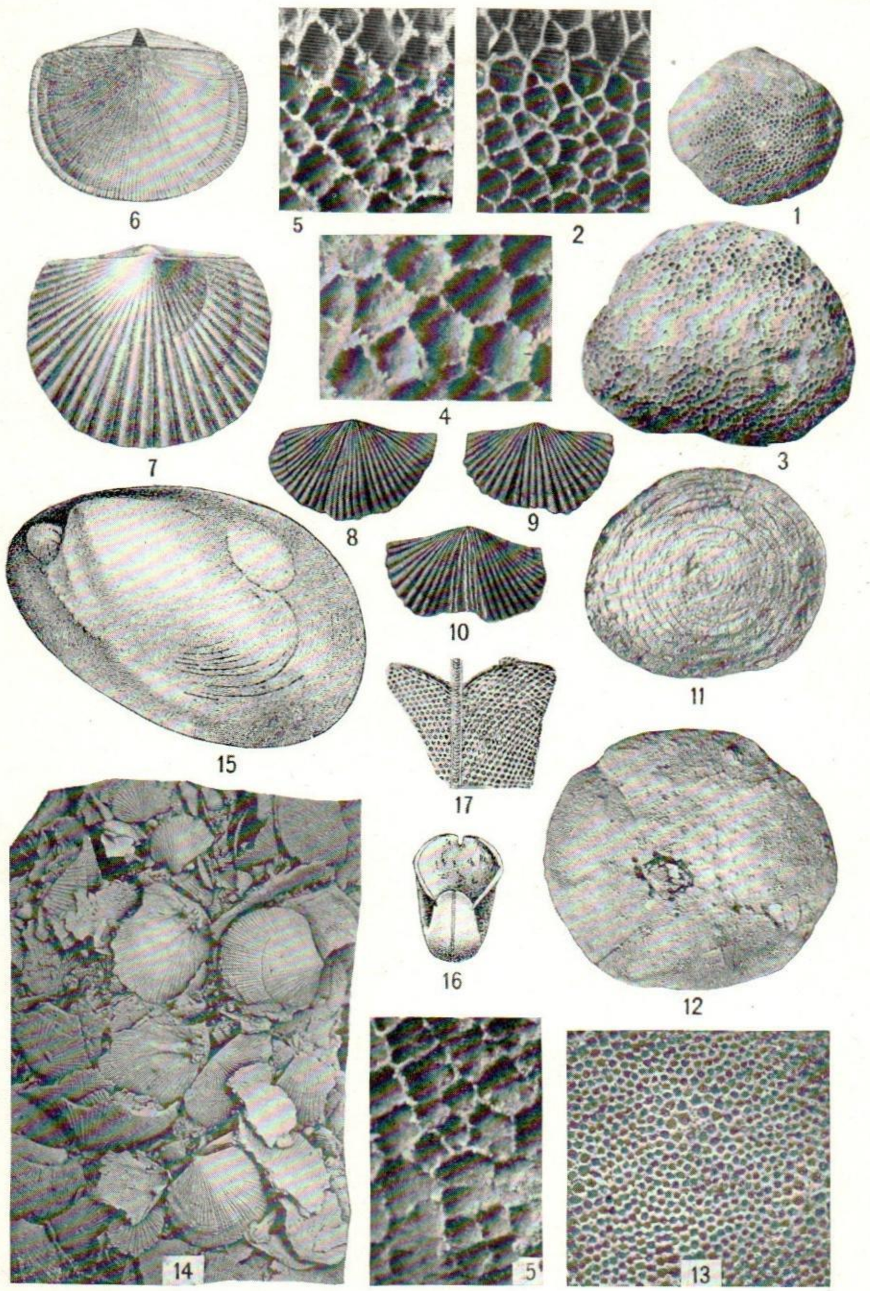
Surface of slab with silicified specimens, natural size. Hermitage formation near Mount Pleasant, Tenn.

15. *Modiolodon oviformis* Ulrich.

Impression of the interior of left valve. Hermitage formation of Kentucky.

16, 17. *Bucania punctifrons* Emmons.

Apertural view of a specimen, natural size, and surface markings. Hermitage formation, Nashville, Tenn.



Fossils of the Hermitage formation

PLATE 14. Fossils of the Bigby limestone

Figures 1-12 after Ulrich and Hall. Figures 13-15, 26, 27, after Winchell and Schuchert.

FIGURE 1. *Lingulops norwoodi* James.
View of this phosphatic shell, natural size and enlarged.

2, 3. *Cyclora minuta* (Hall).
View of side and aperture also of under side, x 8.

4. *Cyclora hoffmani* (Miller).
A complete shell, x 12.

5, 6. *Cyclora parvula* Hall.
Two views of this minute shell with its angular first whorl, x 12.

7, 8. *Microceras inornatum* Hall.
Side and edge views, x 12.

9, 10. *Ctenodonta subrotunda* Ulrich.
Exterior and interior of valve, x 2, the latter showing the characteristic teeth.

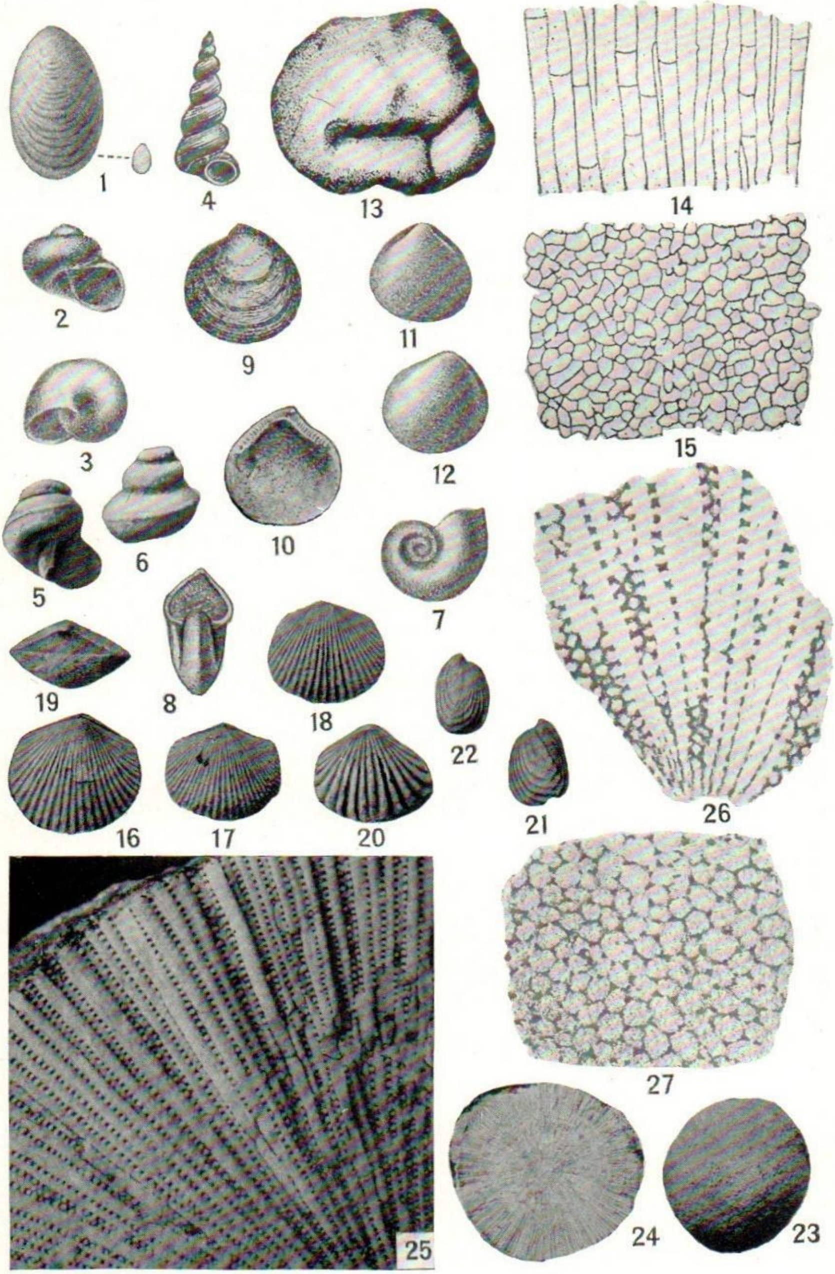
11, 12. *Ctenodonta obliqua* Hall.
Two shells showing opposite sides, x 12.

13-15. *Solenopora compacta* Billings.
A mass of this calcareous alga, natural size, and longitudinal and vertical sections enlarged.

16-19. *Hebertella frankfortensis* Foerste.
Two shells, natural size, showing the fold (16, 17) and the third illustrating the sinus.

20-22. *Rhynchotrema increbescens* Hall.
A large example, natural size, and side views of two smaller specimens.

23-27. *Hindia sphaeroidalis* Duncan var.
An entire example and one broken to show internal structure, natural size (23, 24), with part of the latter enlarged (25), and longitudinal and tangential thin section enlarged.



Fossils of the Bigby limestone

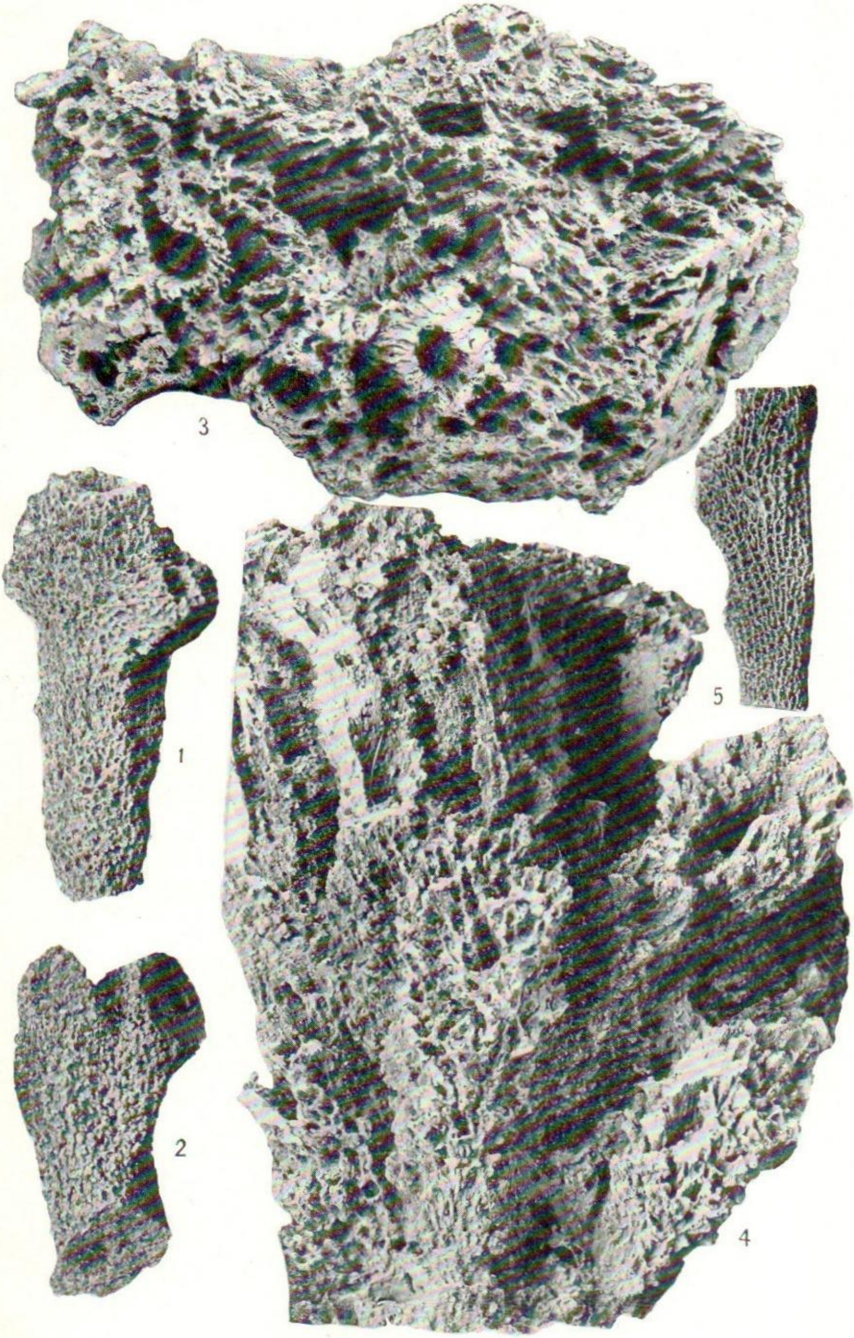
PLATE 15. Sponges of the Cannon limestone

Illustrations natural size.

FIGURES 1, 2. *Saccospongia laxata* n. sp.
Side views of this branching sponge showing the large pores. Cannon limestone, Hartsville-Carthage pike near Carthage, Tenn.

3, 4. *Saccospongia massalis* n. sp.
Top and side views of specimen illustrating the large oscula and pores. *Lophospira sumnerensis* bed of Cannon limestone, 2 miles east of Hartsville, Tenn.

5. *Saccospongia danvillensis* Ulrich.
A typical example differing from *S. laxata* in its more delicate structure. Cannon limestone, Hartsville-Carthage pike near Carthage, Tenn.



Fossils of the Cannon limestone

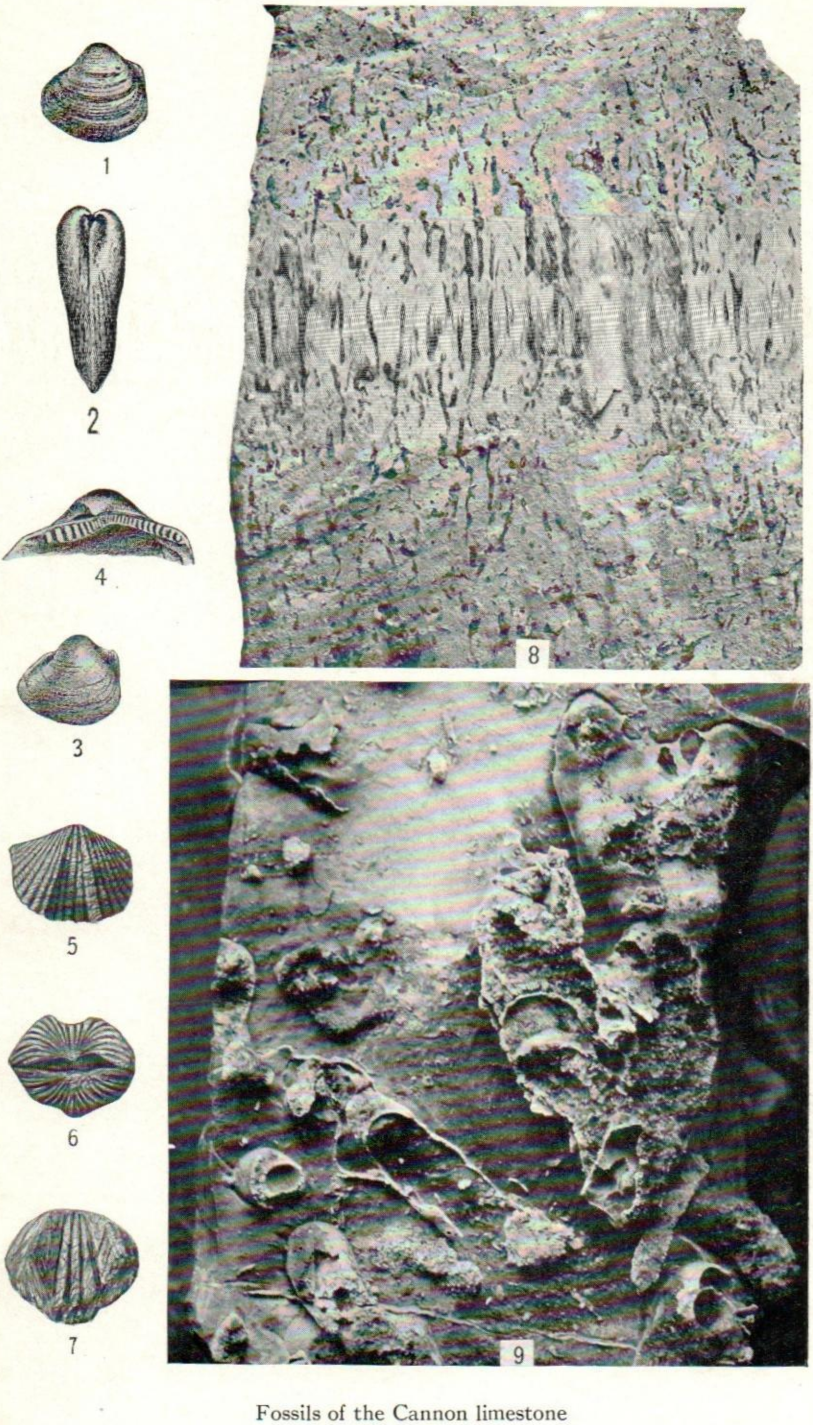
PLATE 16. Fossils of the Cannon limestone.

FIGURES 1-4. *Ctenodonta hartsvillensis* Safford.
Views of the valves, x 2, (1, 3), lateral view of a complete example (2), and illustration of hinge structure, x 4. (After Ulrich.) *Lophospira sumnerensis* beds of Cannon limestone, near Hartsville, Tenn.

5-7. *Platystrophia globosa* McEwan.
Pedicle valve, showing pattern, cardinal view exhibiting plump form and anterior view illustrating broad sinus. Lower part of Cannon limestone, Nashville, Tenn.

8. *Scolithus columbina* n. sp.
Slab, natural size, showing size and arrangement of tubes. Dove bed at base of Cannon limestone, near Franklin, Tenn.

9. *Cryptophragmus arbusculus* n. sp.
The type example of this new branching hydrozoan, natural size. Cannon limestone, 4½ miles east of Hartsville, Tenn.



Fossils of the Cannon limestone

PLATE 17. Ostracods, corals, and mollusks of the Cannon limestone.

FIGURE 1. *Isochilina saffordi* Ulrich.
A left valve, x 1.5. Dove limestone near base of Cannon, at Nashville, Tenn.

2. *Isochilina columbina* n. sp.
Right valve, x 1.5, of this elongate characteristic ostracod. Dove limestone of the Cannon, at Nashville, Tenn.

3. *Isochilina ampla* Ulrich.
Imperfect left valve of this large species, x 1.5. Cannon limestone, east of Milton, Tenn.

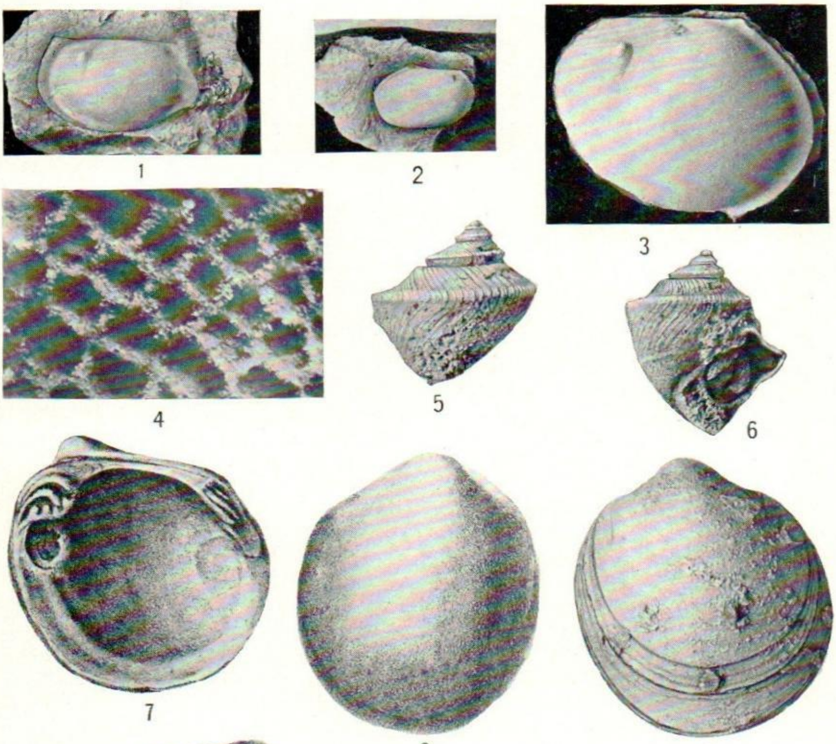
4. *Tetradium columnare* (Hall).
Surface, x 6, showing absence of septa in corallites. Cannon limestone at Nashville, Tenn.

5, 6. *Lophospira ulrichi* n. sp.
Opposite views of two shells of this new species related to *L. sumnerensis* but characterized by its unusual breadth and low spire. *Lophospira sumnerensis* bed of Cannon limestone, near Hartsville, Tenn.

7-9. *Cyrtodonta saffordi* Hall.
Figures 7, 8, Safford's illustrations from the Geology of Tennessee, 1869. Figure 9, a photograph of a specimen natural size from Safford's original lot.

10, 11. *Vanuxemia hayniana* Safford.
Safford's illustration of this characteristic Cannon species. *L. sumnerensis* bed of Cannon limestone, Trousdale County, Tenn.

12. *Cyrtodonta grandis* Ulrich.
Side view of a perfect specimen of this large bivalve (after Ulrich). Trenton limestone near Danville, Ky.



Fossils of the Cannon limestone

Plate 18. Fossils of the Cannon limestone

Illustrations natural size, unless otherwise stated.

Figures 1, 2. *Hormotoma columbina* n. sp.
(1) A free silicified specimen restored at the aperture; (2) portion of a shell partly embedded in the rock, showing usual occurrence of the species. Lower dove beds of the Cannon limestone, 1 mile southwest of Franklin, Tenn.

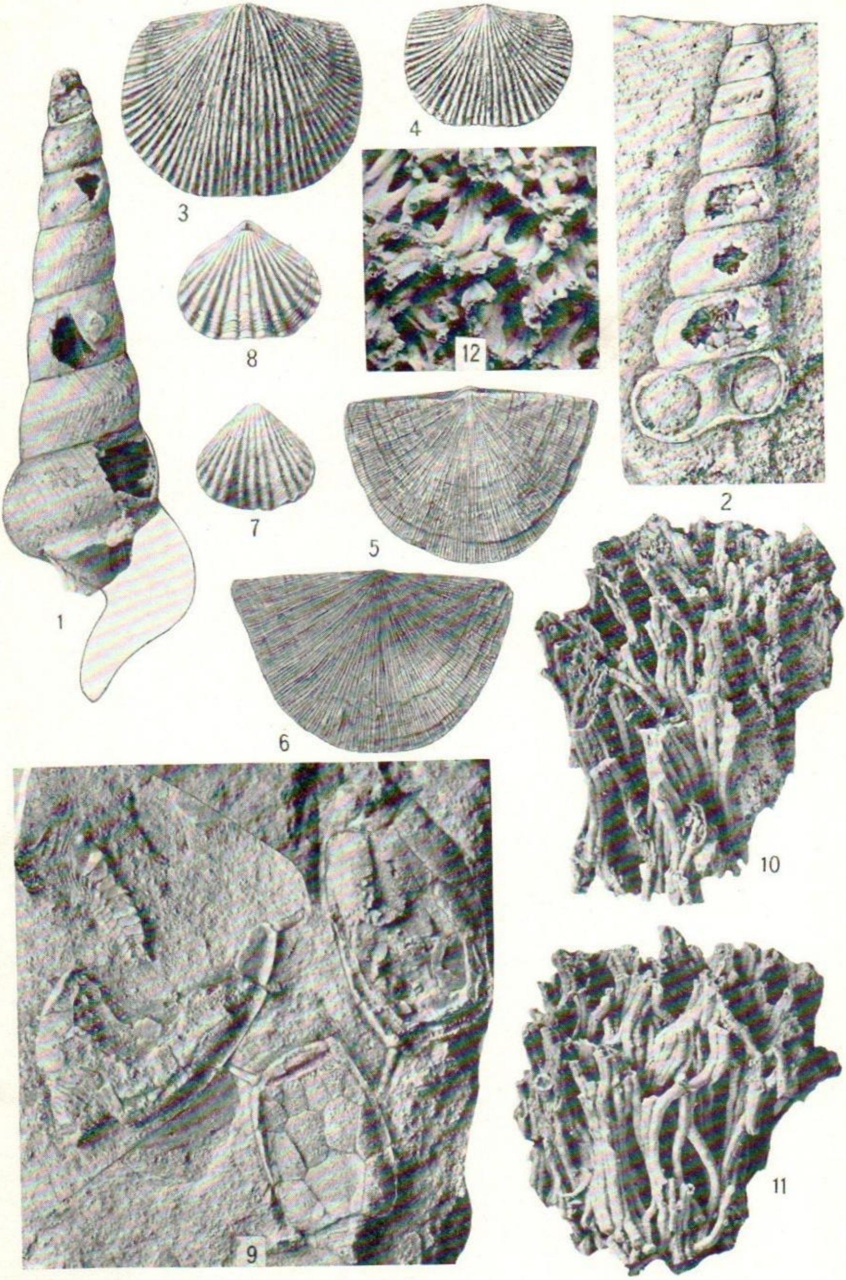
3, 4. *Dinorthis ulrichi* Foerste.
Opposite sides of two complete shells of quite different sizes. One mile south of Allisona, Tenn.

5, 6. *Strophomena vicina* Foerste.
Opposite valves of two complete specimens; 1.6 miles east of Bethesda, Tenn.

7, 8. *Rhynchotrema increbescens* Hall.
Two examples illustrating opposite valves. (After Ulrich.)

9. *Enopleura punctata* n. sp.
A slab with several calices, x 2.5, of this new cystid, which is distinguished from other members of the genus by its punctate surface. Outcrop along road half a mile north-northeast of Pulaski, Tenn.

10-12. *Tetradium laxum* n. sp.
Side view of two examples and top view of one of them illustrating loose growth; 2 miles east of Hartsville, Tenn.

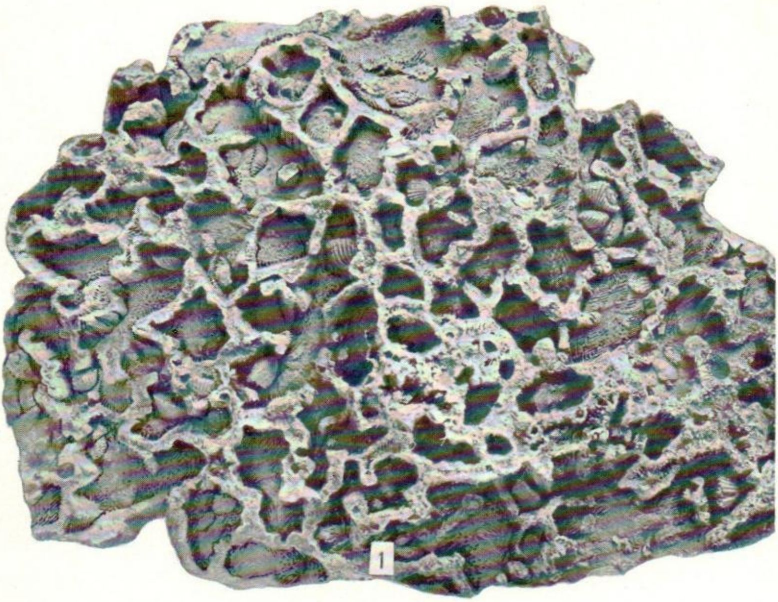


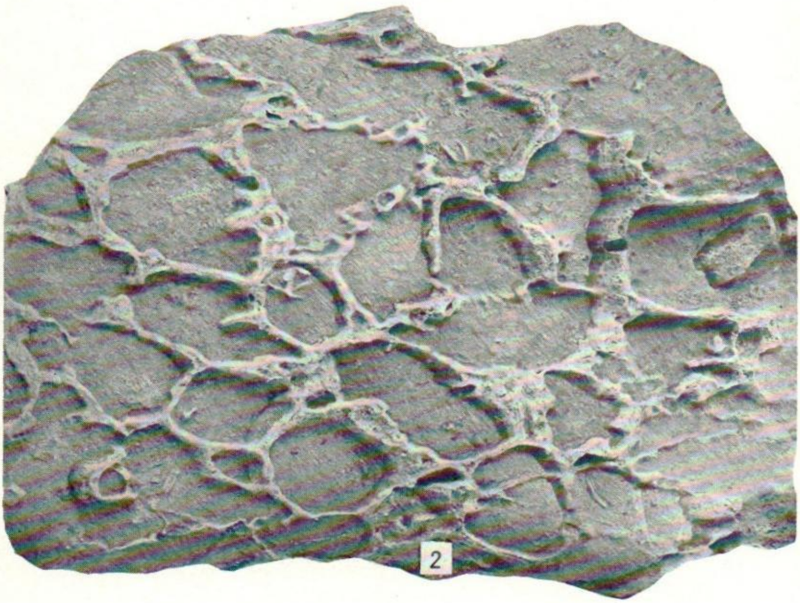
Fossils of the Cannon limestone

PLATE 19. Corals of the Cannon limestone

FIGURE 1. *Tetradium ulrichi* n. sp.
The type specimen, natural size. The meshes are about half the diameter of those in *T. saffordi*, figured below. Upper beds of Cannon, 2½ miles northwest of Woodbury, Tenn.

2. *Tetradium saffordi* n. sp.
Upper part of the reticulated colony, showing the broad meshes, natural size. Cannon limestone 2 miles east of Milton, Tenn.





Corals of the Cannon limestone

PLATE 20. Gastropods of the Cannon limestone

Illustrations natural size. (After Ulrich and Scofield.)

FIGURES 1, 2. *Lophospira sumnerensis* (Safford). Two views of this typical shell.

3. *Lophospira bowdeni* (Safford). Complete example of this abundant species.

4. *Hormotoma salteri* Ulrich. A shell with the aperture broken away.

5. *Lophospira saffordi* Ulrich.

6, 7. *Cyrtolites retrorsus* Ulrich. A large example showing the backward sweeps of the transverse markings.

8, 9. *Cyrtolites subplanus* Ulrich. Two views illustrating the strong transverse lines and weak pitting characteristic of the species.

10. *Liospira persimilis* Ulrich. Apertural view.

11, 12. *Oxydiscus subacutus* Ulrich. Apertural and lateral views.

13. *Oxydiscus cristatus* (Safford). Shell with part of the last whorl broken away.

14-16. *Bellerophon troosti* D'Orbigny. (14) view showing the open umbilicus; (15, 16) apertural and dorsal sides.

17, 18. *Bellerophon clausus* Ulrich. Lateral and dorsal views, the former showing the characteristic closed umbilicus.

19, 20. *Bucania nashvillensis* Ulrich. Two views of an incomplete specimen showing the aperture, the slit, and surface marking.

21, 22. *Carinaropsis cunulae* (Hall). Inner surface of shell showing the septum and above it a triangular plate; dorsal view of the same shell.

23, 24. *Lophospira medialis* Ulrich and Scofield. Two views of this very abundant shell.

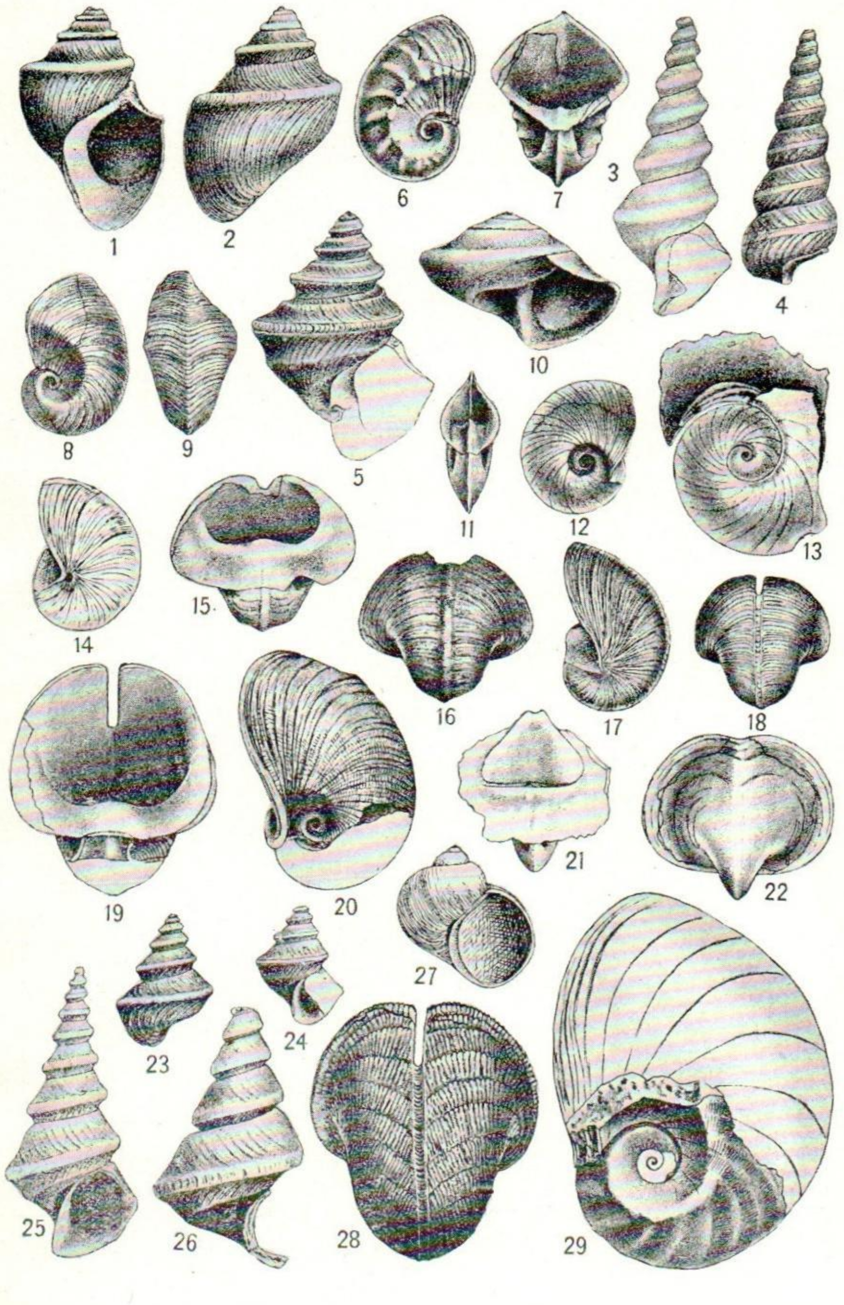
25. *Lophospira producta* Ulrich. Apertural view of the type specimen.

26. *Lophospira conoidea* Ulrich. The type specimen showing the conical shape.

27. *Holopea rotunda* Ulrich and Scofield.

28. *Bucania lindsleyi* (Safford). Showing the slit and surface marking.

29. *Bucania peracuta* Ulrich. Side view of the imperfect type specimen restored.



Gastropods of the Cannon limestone

PLATE 21. Fossils of the Catheys formation

Unless otherwise stated, the illustrations are natural size. Figures 6, 7, 11, 18 are after Ulrich.

FIGURES 1-3. *Platystrophia precursor* Foerste.
Pedicle and brachial valves and edge view along hinge, showing equal convexity. Catheys formation at Nashville, Tenn.

4, 5. *Platystrophia colbiensis* Fcerste.
The two valves of the same specimen. Catheys formation at Nashville, Tenn.

6, 7. *Hebertella frankfortensis* Foerste.
Opposite valves of two individuals.

8. *Leperditia pondi* n. sp. (Ulrich and Bassler).
Right valve, x 1.5. Named in honor of Capt. Walter F. Pond, State Geologist of Tennessee. Catheys formation at Nashville, Tenn.

9. *Isochilina apicalis* n. sp. (Ulrich and Bassler).
Right valve, x 2.3. Catheys formation at Nashville, Tenn.

10. *Isochilina nelsoni* n. sp. (Ulrich and Bassler).
Right valve, x 2.6. Catheys formation at Nashville, Tenn.

11, 12. *Bucania frankfortensis* Ulrich.
Two views of the type specimen.

13. *Cyclonema varicosum* Hall.
Shell showing the characteristic coarse revolving ridges.

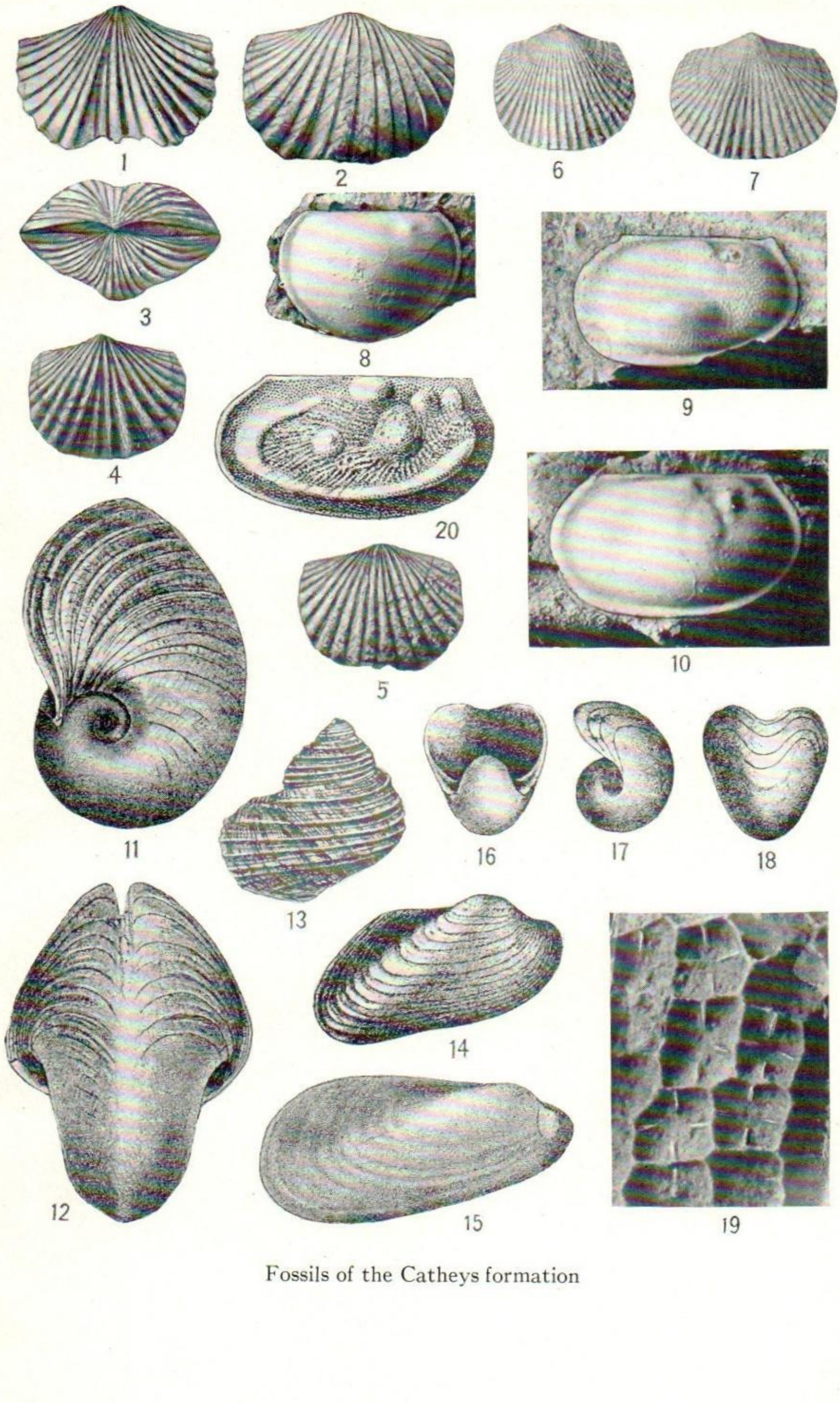
14. *Colpomya constricta* Ulrich.
Exterior of a large right valve.

15. *Whiteavesia kentonensis* Ulrich.
View of cast of the interior.

16-18. *Sinuites cancellata* Hall.
Three views of an entire shell.

19. *Tetradium fibratum* Safford.
Surface, x 6, showing the characteristic four septa. Catheys formation at Nashville, Tenn.

20. *Saffordella muralis* Ulrich and Bassler.
Left valve, x 6, illustrating the surface sculpture. Catheys formation at Nashville, Tenn.



Fossils of the Catheys formation

PLATE 22. Fossils of the Catheys formation

FIGURES 1-5. *Constellaria emaciata* Ulrich and Bassler.
Five examples showing the impoverished growth and prominent starlike clusters of this bryozoan.

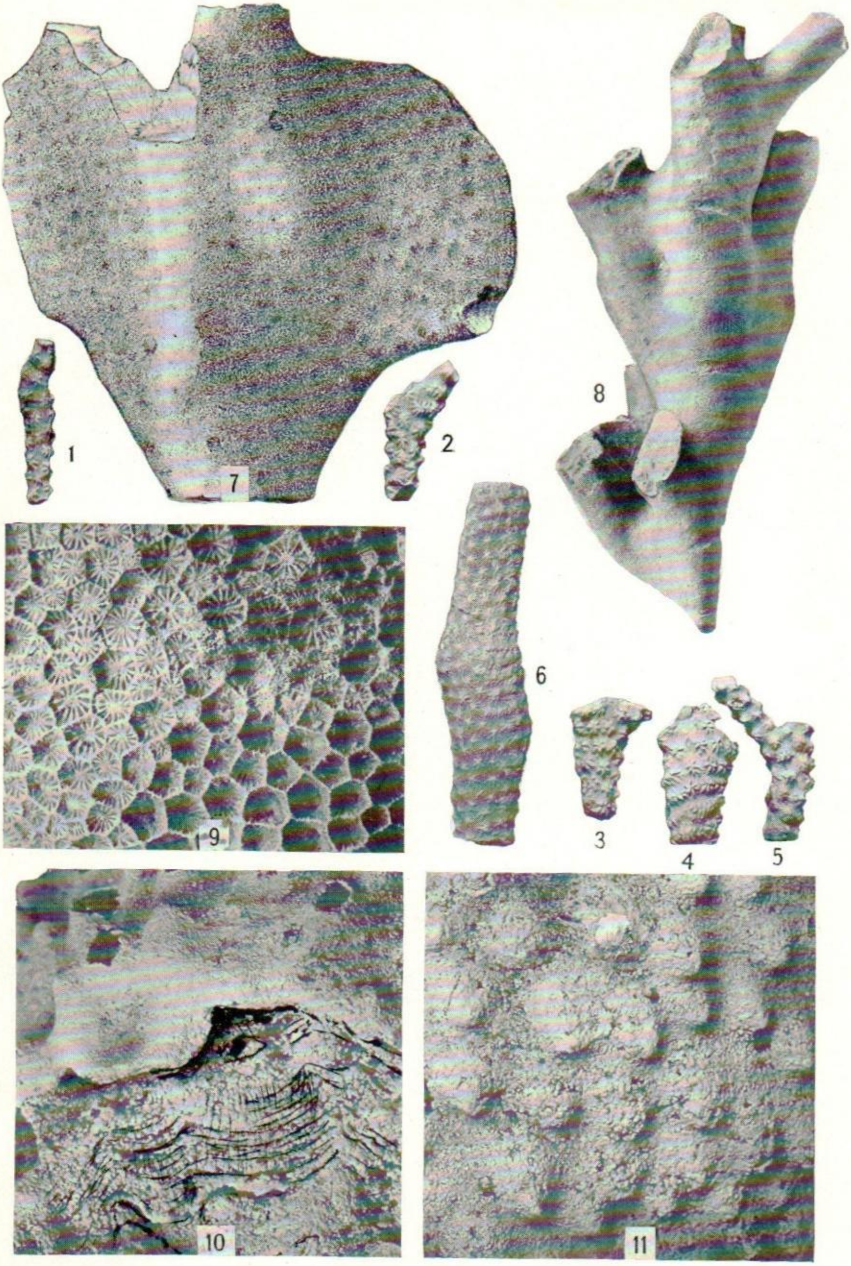
6. *Constellaria teres* Ulrich and Bassler.
Fragment showing the elongate cylindrical form of the branch.

7. *Heterotrypa parvulipora* Ulrich and Bassler.
The broad frond of this abundant bryozoan. The surface is covered with angular pores.

8. *Eridotrypa briareus* Nicholson.
A nearly complete zoarium with the characteristic pointed base.

9. *Columnaria alveolata* Goldfuss.
Surface of this abundant coral with its strongly septate corallites.

10, 11. *Stromatocerium pustulosum* Safford.
Portion of a mass of this hydrozoon, showing the laminar structure of the edge (10) and the upper surface with its pustules (11).



Fossils of the Catheys formation

PLATE 23. Characteristic Leipers fossils

Figures natural size unless otherwise stated.

FIGURES 1-3. *Zygospira modesta* Say.
Different views of this small, widely dispersed brachiopod, x 2.

4-6. *Platystrophia ponderosa* Foerste.
Dorsal, edge view, and ventral side of this characteristic large brachiopod.

7. *Hebertella sinuata* Hall.
Dorsal side of this common brachiopod.

8. *Strophomena planoconvexa* Hall.
Convex side of an entire shell, representing the dorsal side.

9. *Rafinesquina ponderosa* Ulrich.
Convex side (ventral valve) of an entire example.

10. *Monticulipora molesta* Nicholson.
The broad frond of this pustulose bryozoan.

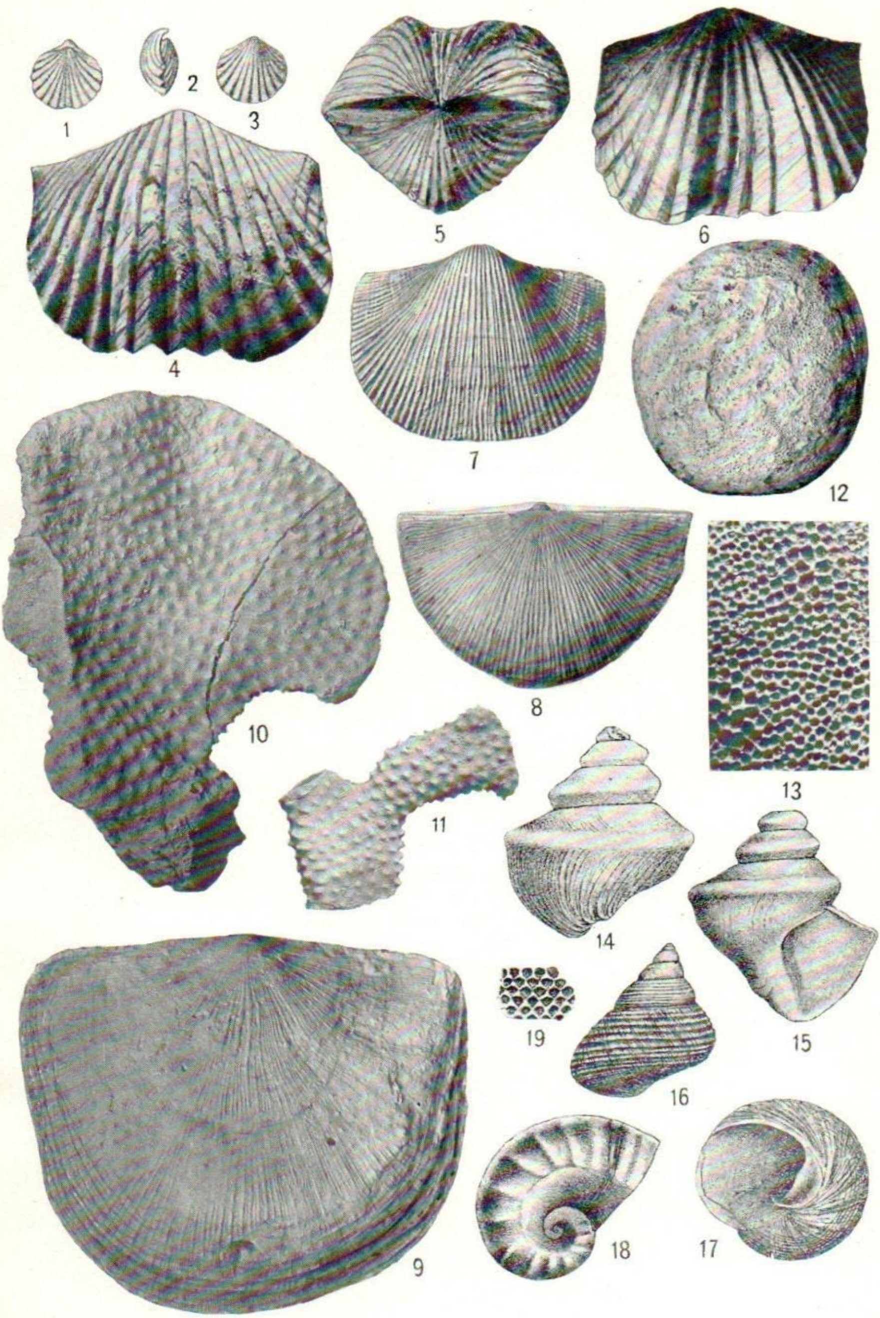
11. *Homotrypella nodosa* Ulrich and Bassler.
A branch of this bryozoan in which the small cells have very granulose walls.

12, 13. *Amplexopora columbiana* Ulrich and Bassler.
A subglobular bryozoan composed of small prismatic tubes, natural size, and surface, x 5.

14, 15. *Lophospira tropidophora* (Meek).
Dorsal and apertural views of this gastropod shell.

16, 17. *Cyclonema mediale* Ulrich.
Dorsal view and under side of a specimen.

18, 19. *Cyrtolites ornatus* Conrad.
Lateral view of a shell, natural size, and surface markings, x 10.



Fossils of the Leipers formation

PLATE 24. Fossils of the Arnheim formation

All the figures are natural size unless otherwise noted.

FIGURES 1, 2. *Hebertella insculpta* Hall.
Opposite valves of two specimens.

3. *Sowerbyella (Plectambonites) clarksvillensis* Foerste.
A large example of this abundant brachiopod.

4. *Strophomena planumbona subtenta* Hall.
Ventral valve showing markings.

5-8. *Rhynchotrema dentatum arnheimensis* Foerste.
Two complete shells showing the single plication in the sinus (5, 6), and a shell exhibiting the fold and lateral view (7, 8).

9-12. *Rhynchotrema capax* Conrad.
Side and edge views of a normal example (9, 10), and opposite side of a small specimen (11, 12).

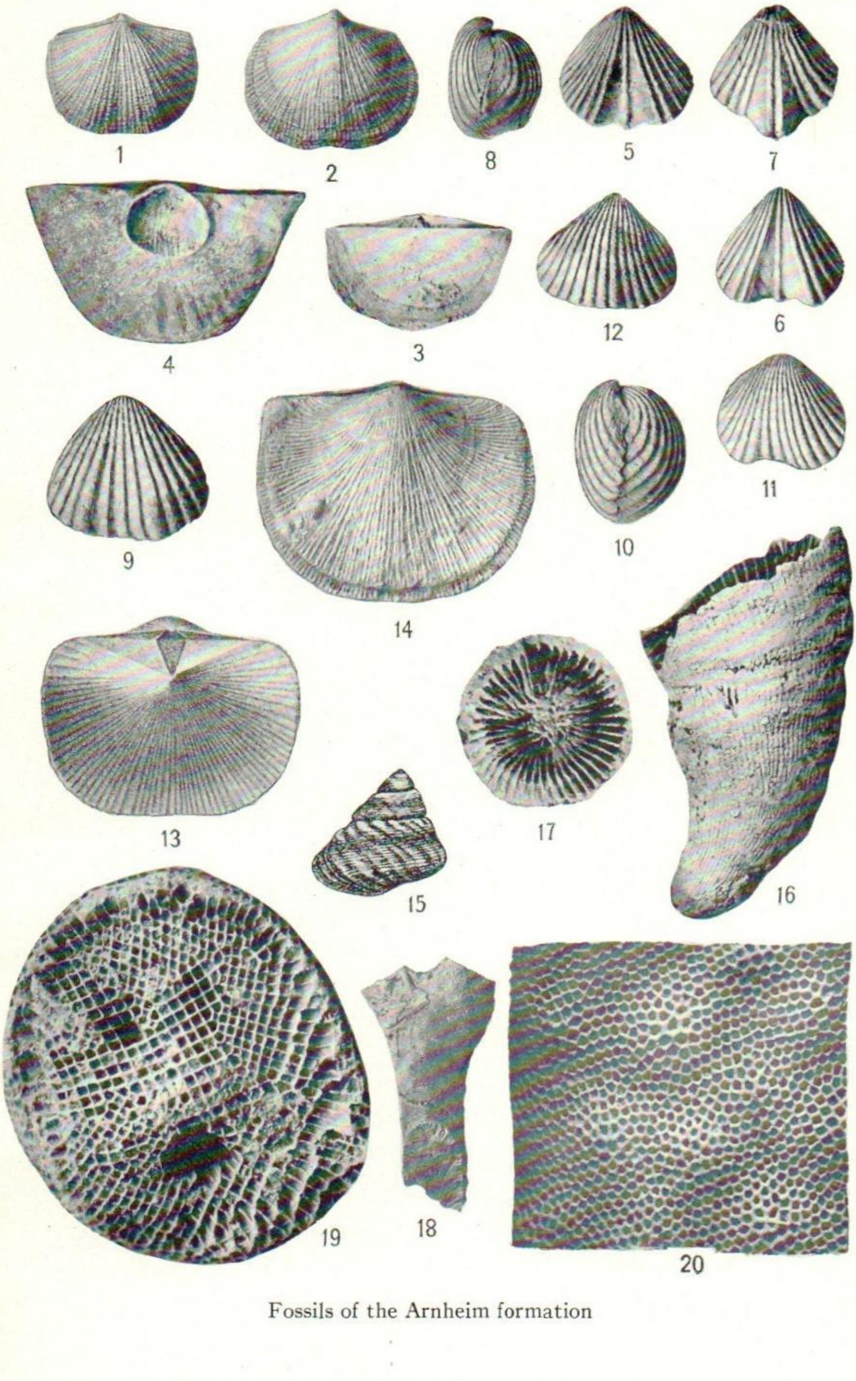
13. *Dinorthis carleyi* (Hall).
Ventral side of an entire specimen, showing the characteristic hinge area.

14. *Dinorthis subquadrata* (Hall).
A large specimen.

15. *Cyclonema fluctuatum* James.
A normal example exhibiting the usual transverse wrinkles in the last whorl.

16, 17. *Streptelasma rusticum* Billings.
Side view of a specimen and view of the calyx of a smaller example, the latter illustrating the twisted septa of the center.

18-20. *Rhombotrypa quadrata* (Rominger).
A fragment of this abundant Richmond bryozoan (18), with an end view, x 6, illustrating the quadrate arrangement of the cells (19), and the surface enlarged slightly (20).



Fossils of the Arnheim formation

PLATE 25. Fossils of the Fernvale formation

The specimens represented by Figures 1-18, 21, and 24 are from the Mannie shale division of the Fernvale, at a locality 2½ miles northwest of Pulaski, Tenn., along the Brick Church pike. Figures 19, 20, 22, and 23 are after Ulrich.

FIGURES 1, 2. *Rhipidomella* sp.
A shell, possibly belonging to *Dalmanella* but approaching *Rhipidomella* in outline; natural size and x 2.

3-6. *Sowerbyella (Plectambonites) saxea* Sardeson.
Concave side of an entire specimen, natural size and x 2, and similar views of the convex side of another example. The characteristic immature teeth along the hinge line can not be shown in such views.

7-12. *Strophomena odessae* n. sp.
Ventral valve, x 1 and x 2 (7, 8), dorsal valve similarly enlarged (9, 10), and interior of ventral valve, also x 1 and x 2, showing the marking (11, 12), of this small neat species allied to *Strophomena parvula* Foerste, but differing in its proportions, smaller size, and finer surface markings. Named in honor of Miss Odessa Powell of the Tennessee Geological Survey.

13-15. *Rhynchotrema manniense* Foerste.
Lateral and end view of very gibbose specimens (13, 14), and view of valve with sinus of another example.

16, 17. *Dinorthis proavita* Winchell and Schuchert.
Two examples illustrating opposite valves.

18. *Platystrophia acutilirata* Conrad var.
An imperfect example of this elongate brachiopod.

19. *Ptilotrypa obliquata* Ulrich.
Surface, x 12, of a bifoliate bryozoan of wide smooth fronds.

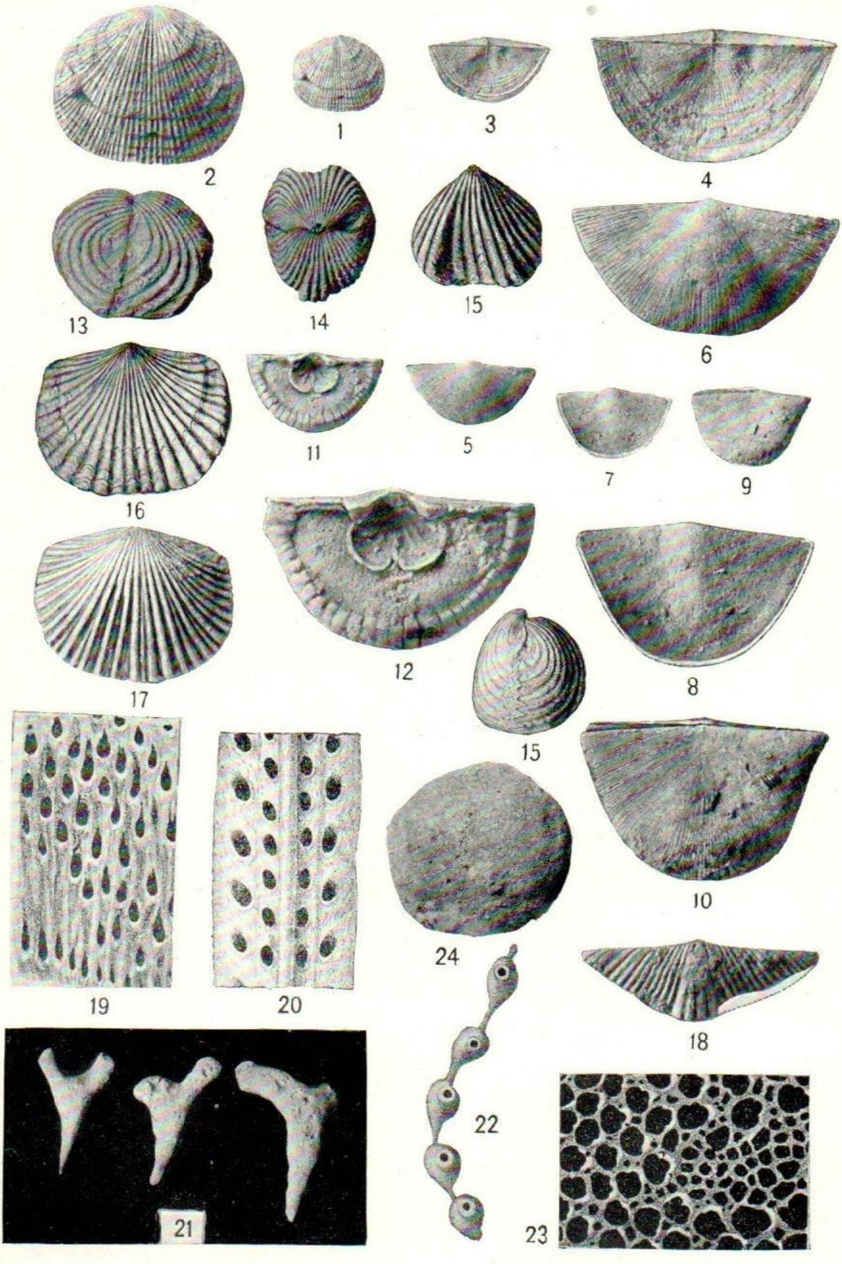
20. *Goniotrypa bilateralis* Ulrich.
Fragment of a joint of this minute bryozoan, natural size and enlarged, showing the characteristic medium keel.

21. *Lioclemella bifurcata* n. sp.
Three colonies, natural size, showing the pointed base and the bifurcating zoarium.

22. *Corynotrypa turgida* (Ulrich).
A row of cells of this linear bryozoan, x 9, which occurs incrusting shells and other fossils.

23. *Favositella epidermata* (Ulrich).
Celluliferous surface, x 9, showing the areas of small cells.

24. *Diplotrypa dubia* Ulrich.
A solid, massive, hemispherical bryozoan found abundantly in the Mannie shale.

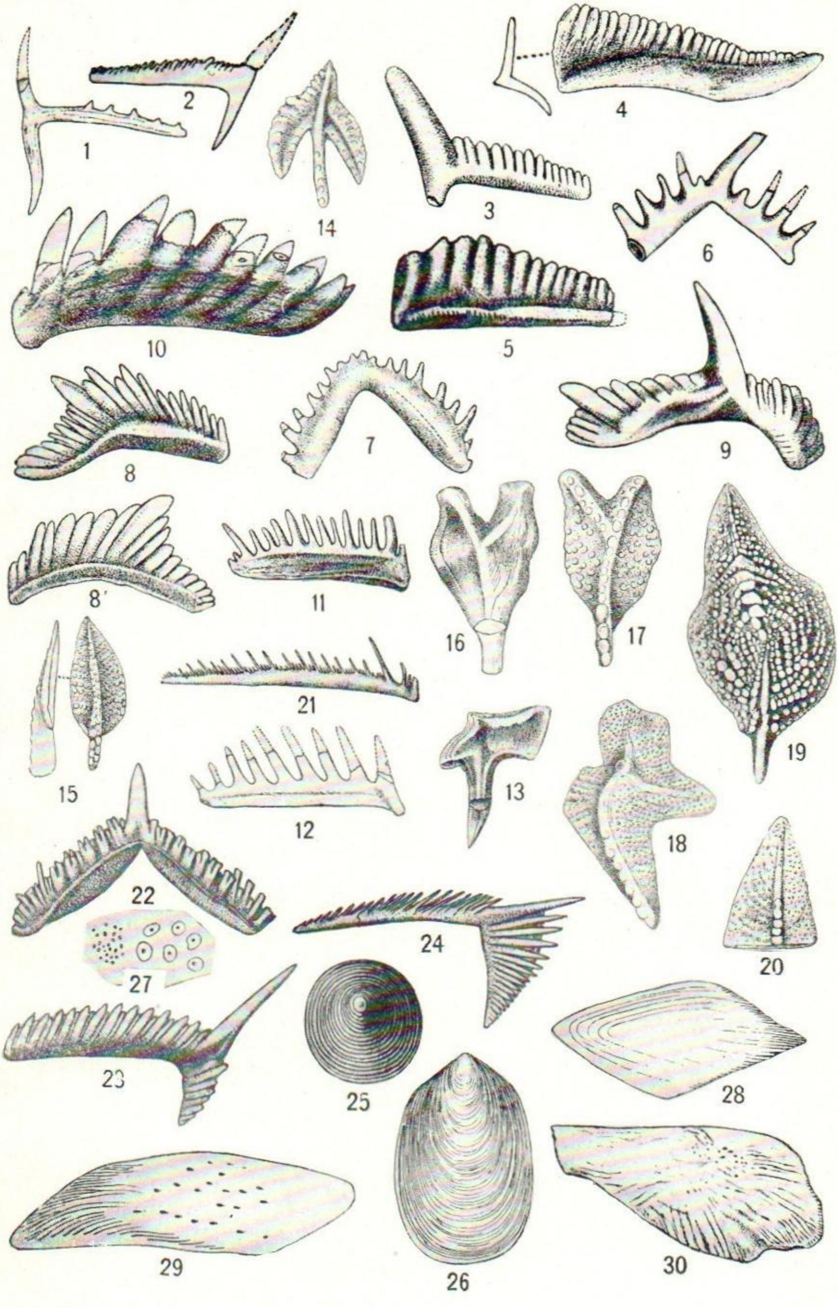


Fossils of the Fernvale formation

PLATE 26. Fossils of the Chattanooga shale and Hardin sandstone

Figures 1-12 and 21-24 represent the minute fishtooth-like organisms termed conodonts, 13-20, dermal plates of probably sharks, and 28-30, the supposed dermal plates of other types of fish. All these figures are magnified 15 diameters, and the specimens have been found in the Hardin sandstone at Mount Pleasant, Tenn., although most of them occur also in the Chattanooga black shale.

FIGURE 1. *Prioniodus spiculatus* Ulrich and Bassler.
2. *Prioniodus parvidentatus* Ulrich and Bassler.
3. *Prioniodus disparilis* Ulrich and Bassler.
4. *Panderodella truncata* Ulrich and Bassler.
5. *Panderodella subcrassa* Ulrich and Bassler.
6. *Lonchodina discreta* Ulrich and Bassler.
7. *Lonchodina rectangulata* Ulrich and Bassler.
8, 8′ *Bryantodus subradiatus* Ulrich and Bassler.
9. *Bryantodus nelsoni* Ulrich and Bassler.
10. *Prioniodella conferta* Ulrich and Bassler.
11. *Prioniodella brevispina* Ulrich and Bassler.
12. *Prioniodella gracilis* Ulrich and Bassler.
13. *Ancyrodella malleus* Ulrich and Bassler.
14. *Ancyrodella hamata* Ulrich and Bassler.
15. *Polygnathus pennatulus* Ulrich and Bassler.
16, 17. *Pelmatolepis bifurcatus* Ulrich and Bassler.
18. *Pelmatolepis perlobatus* Ulrich and Bassler.
19. *Polygnathus concentricus* Ulrich and Bassler.
20. *Polygnathus acaulis* Ulrich and Bassler.
21. *Hindeodella subtilis* Ulrich and Bassler.
22. *Diplododella bilateralis* Ulrich and Bassler.
23. *Synprioniodina alternata* Ulrich and Bassler.
24. *Palmatodella delicatula* Ulrich and Bassler.
25. *Lingulodiscina newberryi* (Hall).
26. *Lingula melie* Hall. Thin-shelled phosphatic brachiopod, x 6.
27. *Sporangites* (*Protosalvinia*) *huronensis* Dawson. Minute spore cases of lycopod plants. These spores occur by the million in certain beds and their resinous bodies are probably the source of the hydrocarbons in the shale.
28-30. Supposed dermal plates of fish, x 6.



Fossils of the Chattanooga shale and Hardin Sandstone

PLATE 27. Fossils of the Ridgetop shale

The ostracoda here illustrated are from the Ridgetop shale at Mount Pleasant, Tenn., and are magnified 20 diameters.

FIGURE 1. *Beyrichiopsis pulchra* n. sp. (Ulrich and Bassler).

2, 3. *Barychilina lineata* n. sp. (Ulrich and Bassler).
(2) A right valve slightly crushed, showing the outline and delicate concentric lineate structure, (3) left valve of more complete specimen.

4. *Paracythere granopunctata* n. gen. and sp. (Ulrich and Bassler).

5. *Allostraca fimbriata* n. gen. and sp. (Ulrich and Bassler).
A left valve of this Cythere-like ostracod with its characteristic broad eye spot, granose surface, and prominent striated frill.

6. *Aechmina longicornis* n. sp. (Ulrich and Bassler).
Right valve showing the characteristic long hornlike spine and the marginal rows of minute spines.

7, 8. *Ctenobolbina loculata* Ulrich.
Exterior of a right valve and interior of left valve.

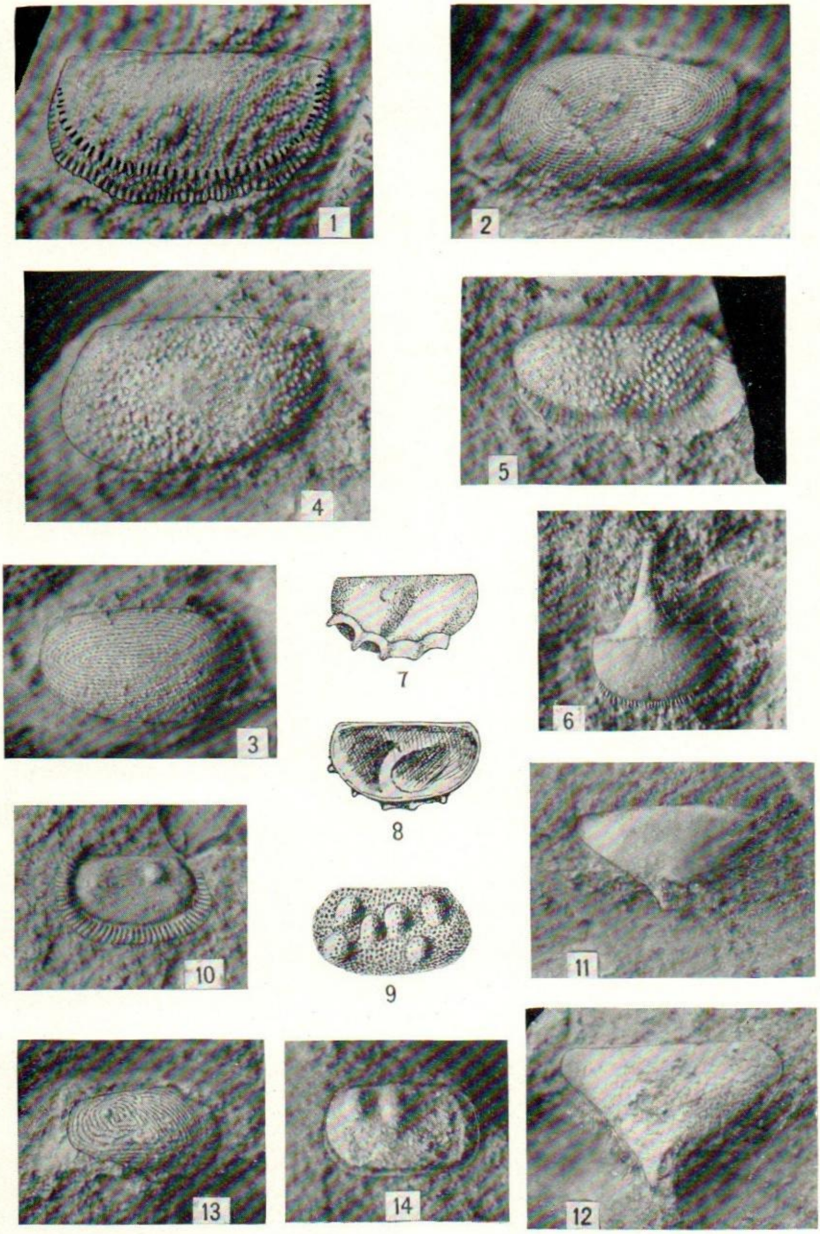
9. *Mauryella mammillata* Ulrich and Bassler.
Left valve illustrating the subcentral pit, and reticulate surface with six prominent nodes.

10. *Beyrichiopsis modesta* n. sp. (Ulrich and Bassler).
Left valve with the characteristic spinous border; a conspicuous elevation on the posterior half of the valve.

11, 12. *Bursulella? tennesseensis* n. sp. (Ulrich and Bassler).
Two specimens of this peculiar organism with its prominent ventral hornlike extension from the subtriangular carapace.

13. *Paracythere cornuta* n. sp. (Ulrich and Bassler).
Left valve illustrating the narrow anterior end with a small but prominent node, the much broader posterior end, and the surface marked by concentric lines arranged around a small submedian spot.

14. *Ulrichia tenuimuralis* n. sp. (Ulrich and Bassler).
Right valve exhibiting the two prominent nodes and the thin marginal ridge.



Fossils of the Ridgetop shale

PLATE 28. Fossils of the New Providence shale

Figures 1-10 are after Ulrich and show specimens from the New Providence shale of Kentucky. The specimens illustrated by figures 11-17 are from the same horizon at Popes Chapel, Williamson County, Tenn.

FIGURE 1. *Fenestella triserialis* Ulrich. Celluliferous side of frond, x 6.

2. *Thamniscus divaricans* Ulrich. A fragment, x ⅔ and portion of the same, x 6.

3. *Streblotrypa major* Ulrich. Surface of this rodlike bryozoan, x 12.

4, 5. *Cystodictya lineata* Ulrich. Fragment of the ribbon-shaped frond, natural size, and the surface, x 12.

6. *Rhombopora incrassata* Ulrich. The rodlike fragment of a colony, natural size, and the surface, x 12.

7. *Meekopora? aperta* Ulrich. The ribbon-shaped frond, natural size, and the surface of same, x 9.

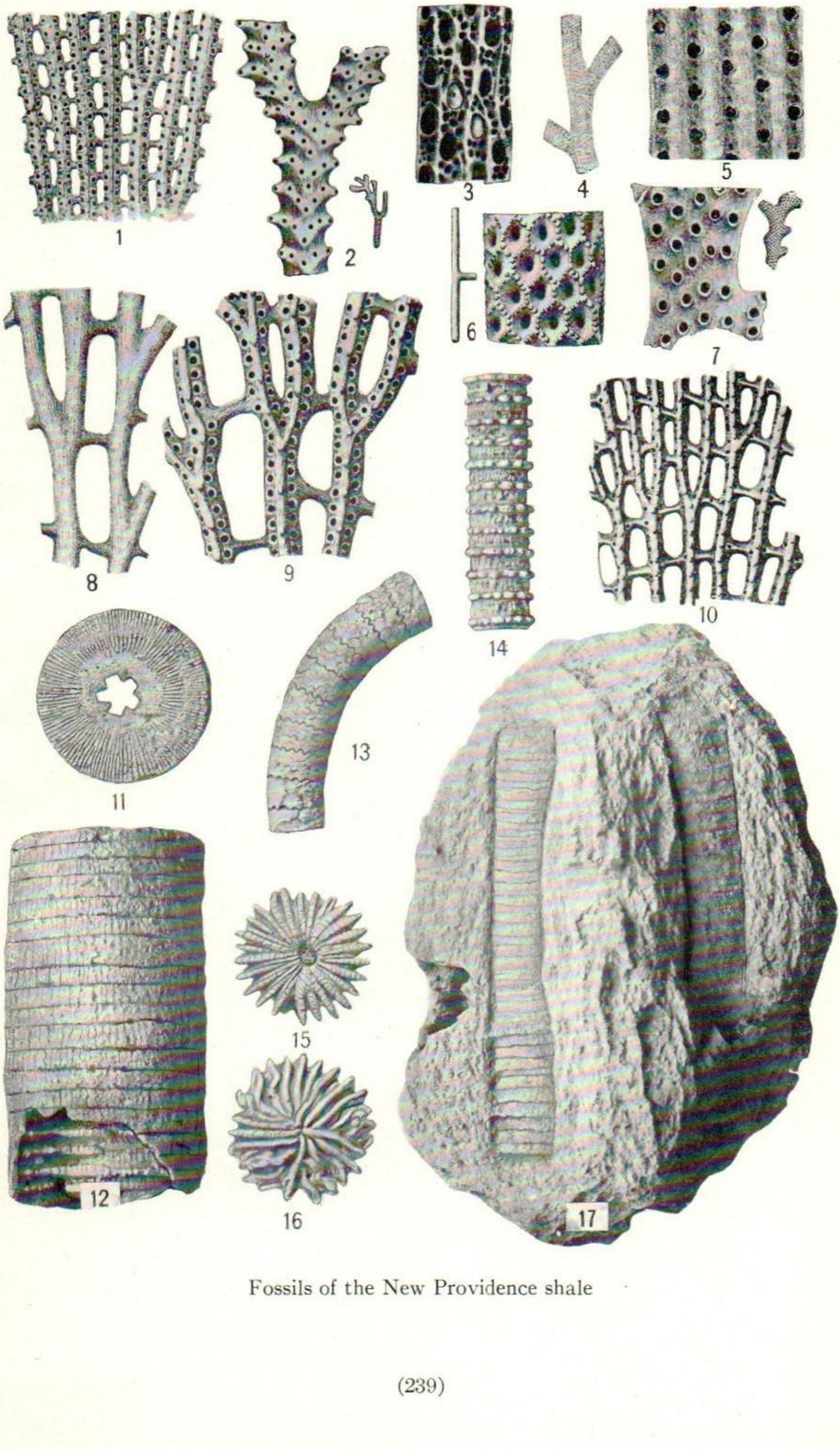
8, 9. *Fenestella regalis* Ulrich. The noncelluliferous and celluliferous sides of the colony, x 6.

10. *Fenestella compressa* Ulrich. Celluliferous side of the delicate network forming this byrozoan, x 6.

11-14. Views of various types of crinoid columns with which this shale is often crowded. Figure 11 represents the end view of a button or individual segment of a column, 12, a portion of a large column, and 13 and 14 two species showing quite different surface ornament.

15, 16. *Baryphyllum verneuillianum* Edwards and Haime. Top and basal view of this characteristic button-shaped coral, natural size.

17. Geode of New Providence shale, showing growth by formation of quartz crystals in fractured crinoid column.



Fossils of the New Providence shale

PLATE 29. Silurian and Mississippian fossils

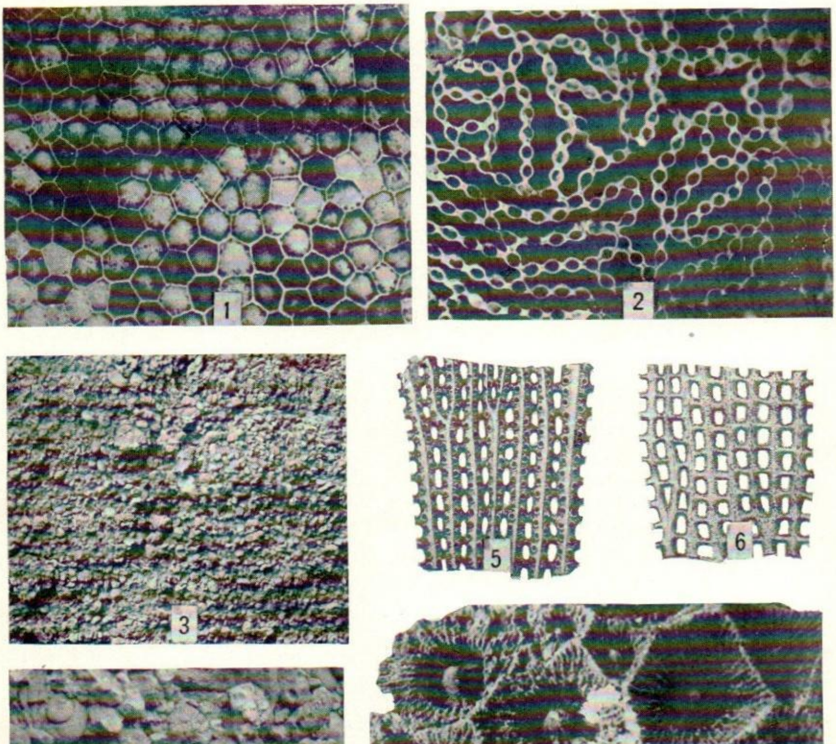
FIGURE 1. *Favosites favosus* (Goldfuss). Upper surface of Silurian honeycomb coral, natural size.

2. *Halysites catenularia* (Linnaeus). The characteristic Silurian chain coral, natural size.

3, 4. Blue phosphate. View, natural size, and portion of surface enlarged, showing the remains of minute Ordovician gastropods (*Cyclora*, etc.).

5, 6. *Fenestella tenax* Ulrich, magnified. Front and back view of one of the lacelike bryozoa with which the Warsaw limestone abounds (after Ulrich).

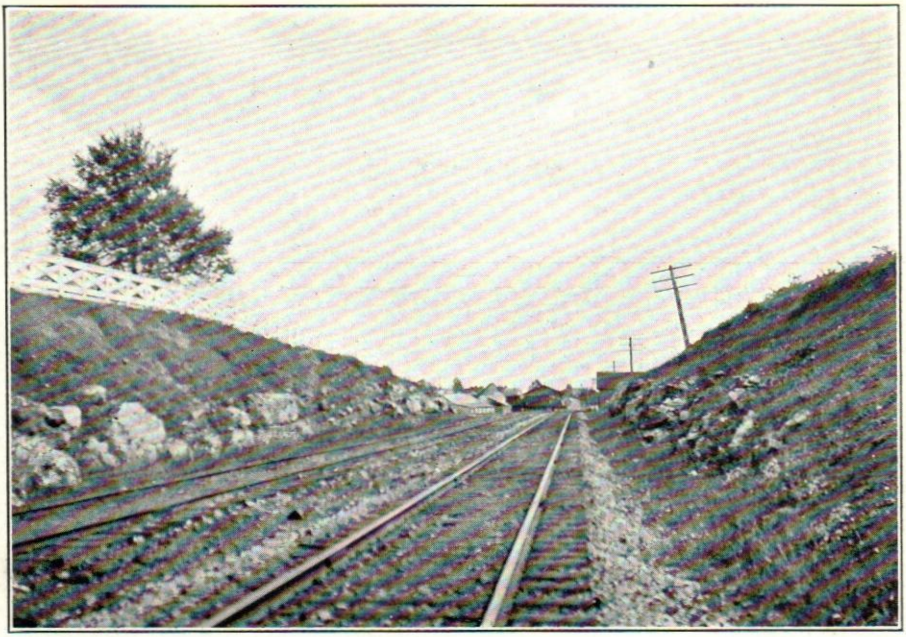
7. *Lithostrotion canadense* Castlenau. Characteristic coral of the St. Louis limestone, natural size.



Silurian and Mississippian fossils

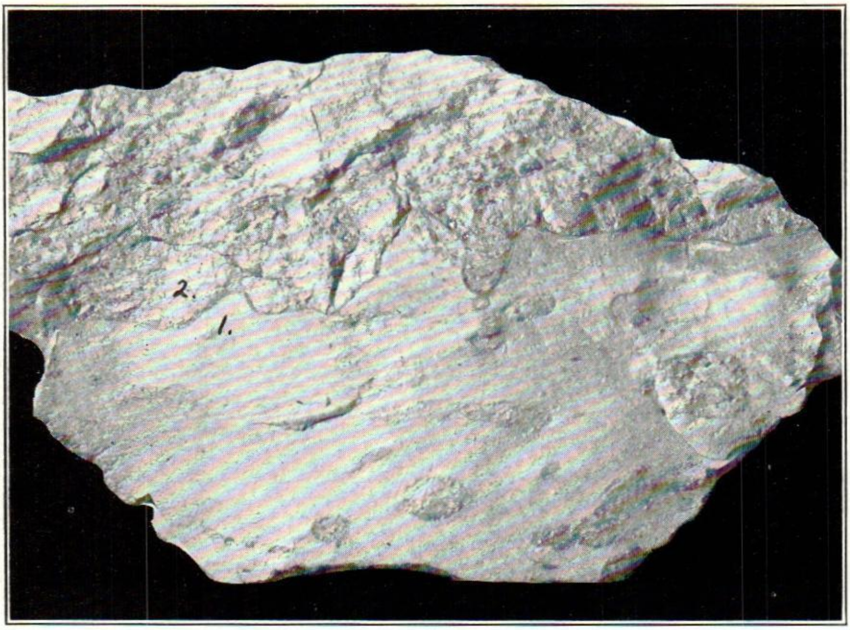
(A) Typical outcrop of the Pierce formation at crossing of Lebanon pike and Stones River, 7 miles north of Murfreesboro. The photograph shows the thin-bedded, platy limestone with shaly partings and the heavy bed of the Pierce formation.

(B) Outcrop of Murfreesboro limestone in its type area at Stones River bridge, just west of Murfreesboro.



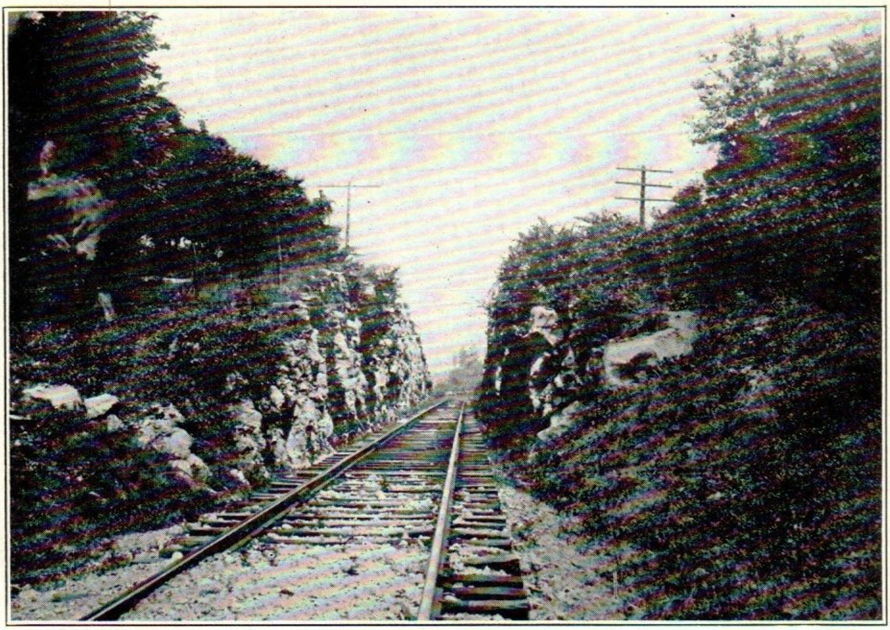
(A) Ridley limestone outcrop along Nashville, Chattanooga & Saint Louis Ry. just west of Murfreesboro, showing massive limestone weathering into chert fragments and deep soil.

(B) View along Nashville pike northwest of Murfreesboro, showing weathered outcrop of Lebanon limestone and illustrating the glade characteristics.

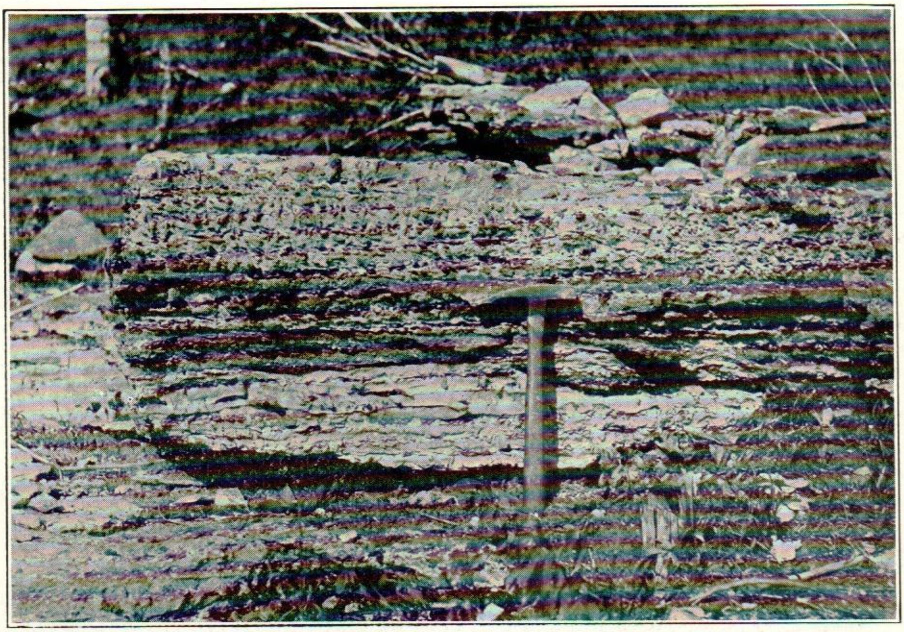


(A) Hand specimen of the limestone layer shown in (B) below, illustrating uneven contact between the smooth Lebanon dove limestone (1) and the more granular Carters limestone (2).

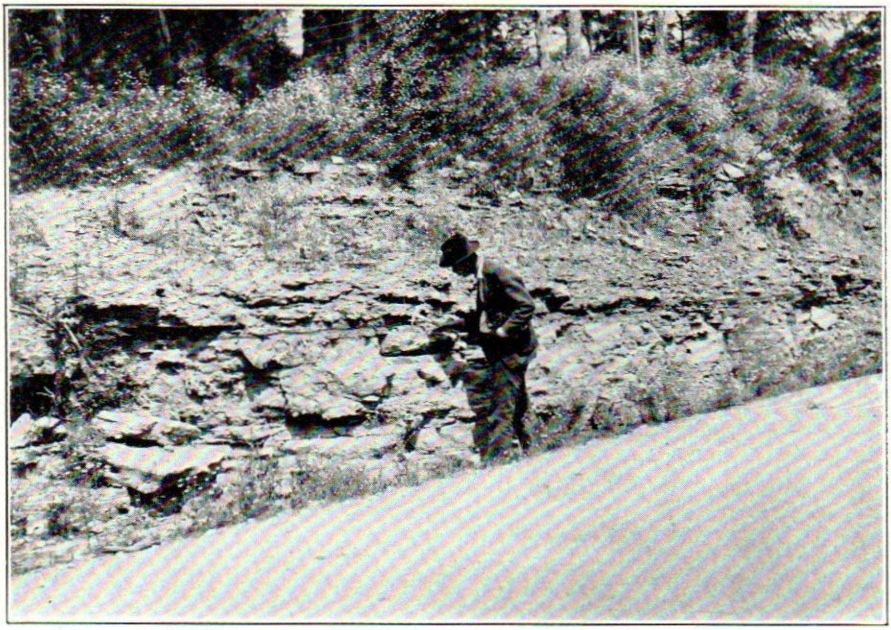
(B) View in bluff along Duck River at Columbia, showing contact between the thin-bedded dove Lebanon limestone below and the massive Carters limestone above. Dr. Ulrich is pointing to the line of unconformity of these geologically widely separated formations, which here are in contact in a single layer.



(A) Black River limestone, possibly of Kimmswick age, exposed along Louisville & Nashville R. R. south of Aspen Hill.

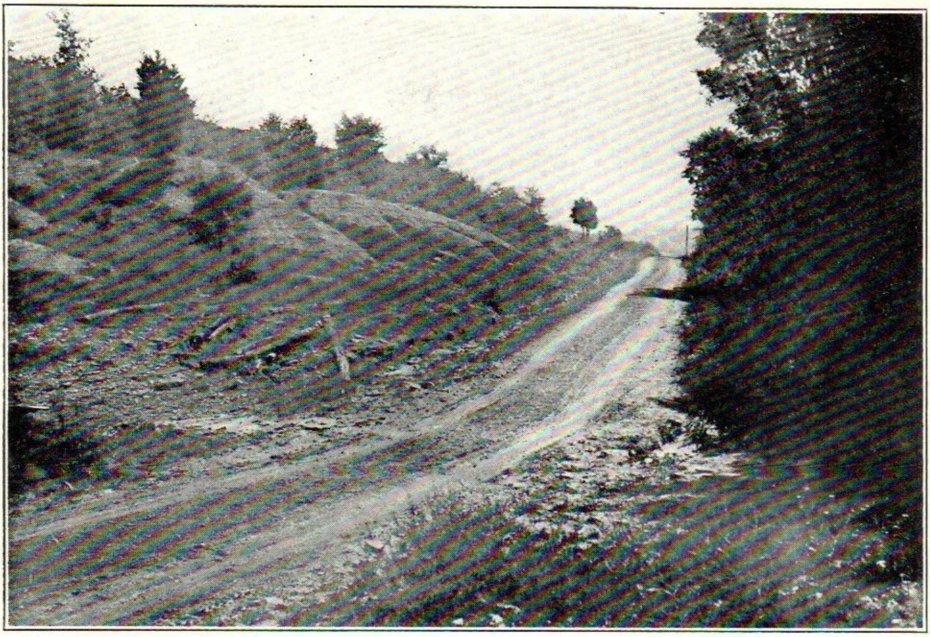


(B) Fucoid bed of Lowville limestone illustrating abundant development of *Buthotrephis inosculata*. Near Hoover Mills, Woodbury quadrangle.



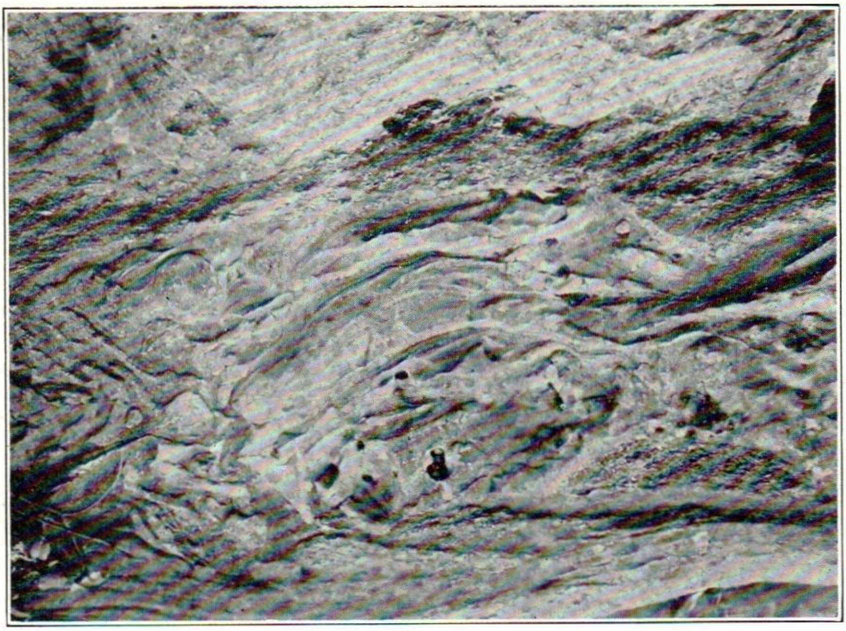
(A) Outcrops of the upper, thin-bedded Tyrone member of the Lowville limestone along the Dixie Highway, 5½ miles southeast of Shelbyville, followed by the thin clay limestones and shales of the Hermitage formation. Mr. Nelson's hammer rests on the silicified top layer of the Lowville limestone.

(B) Quarry near Mount Olivet Cemetery, Nashville, showing the Carters limestone, the bentonite bed (marked by the hammer), and the overlying, thin-bedded Tyrone member of the Lowville formation.

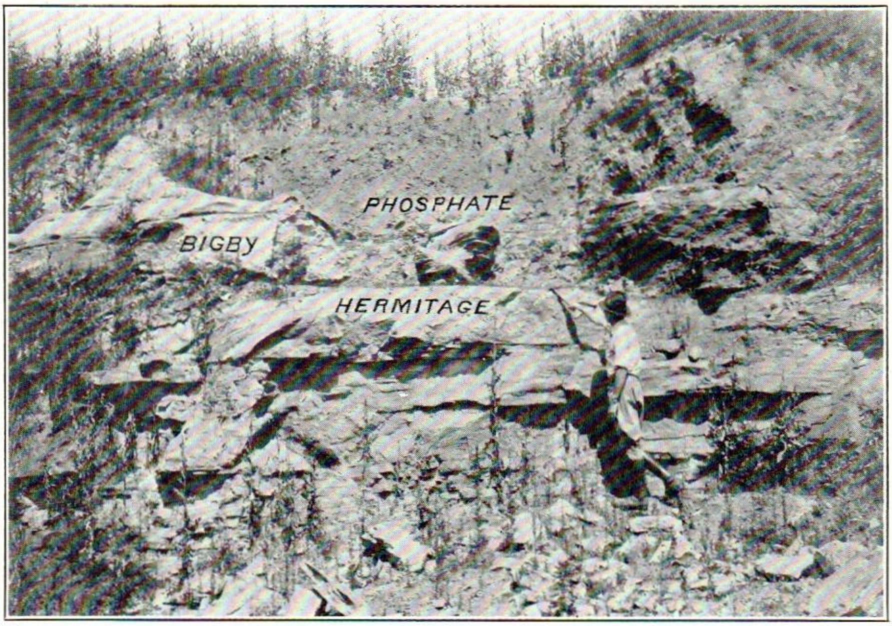


(A) Characteristic view of the Hermitage formation as developed in the eastern part of the Franklin quadrangle, where sandy shales prevail. These rocks weather into bare, much-gullied areas.

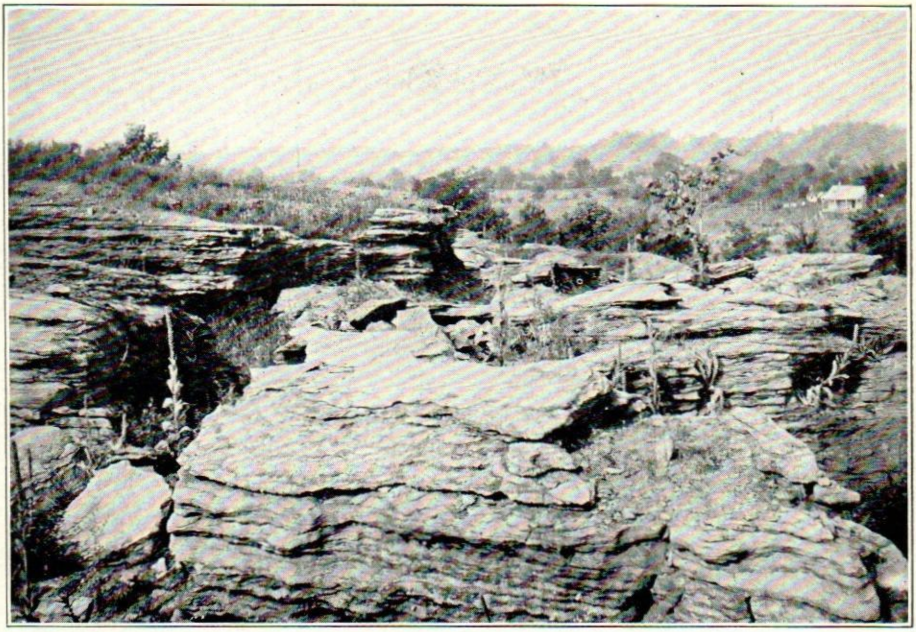
(B) Typical outcrop of the Carters limestone along Carters Creek about 5 miles north of Columbia, illustrating the characteristic erosion into castellated forms and fluted surfaces along joint planes.



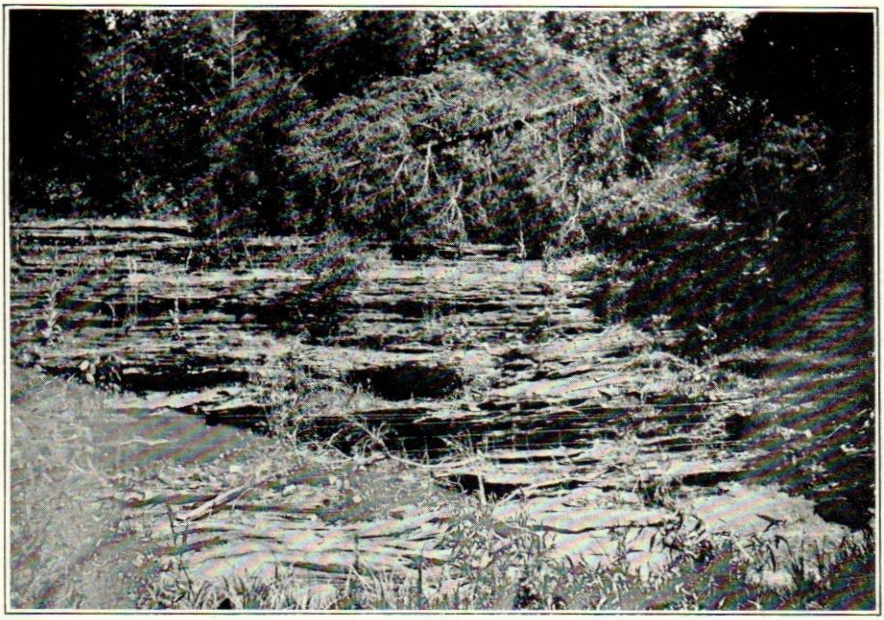
(A) A near view of the Hermitage formation exposed along Harpeth River on northeast edge of Franklin, showing the massive disturbed layers of the upper Hermitage *Modiolodon* beds, with lenses composed almost entirely of the characteristic brachiopod *Dalmanella fertilis* and with the associated contorted layer.



(B) View of the upper Hermitage *Modiolodon* bed and the lower Bigby limestone exposed in old quarry, northeast corner of Franklin, showing the contact between the Hermitage and Bigby and the weathering of the latter formation into phosphate.



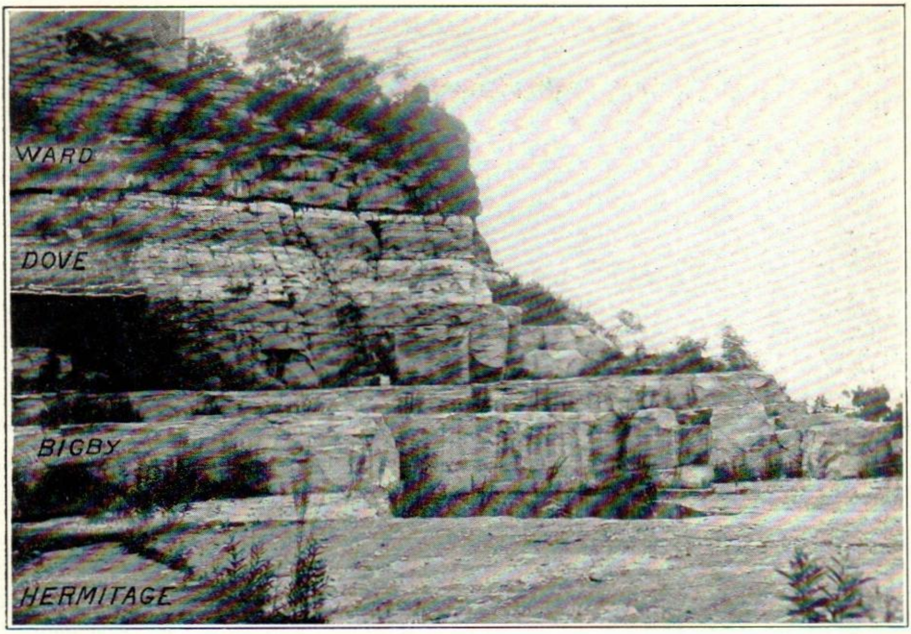
(A) Outcrops of Bigby limestone at phosphate works in southwest corner of Franklin quadrangle. The phosphate, which has been formed along the joint planes or "cutters", has been mined away leaving the unleached strata in large blocks.



(B) Weathered outcrop of Bigby limestone, unchanged to phosphate but exhibiting laminated character. Two miles southwest of Peytonsville.

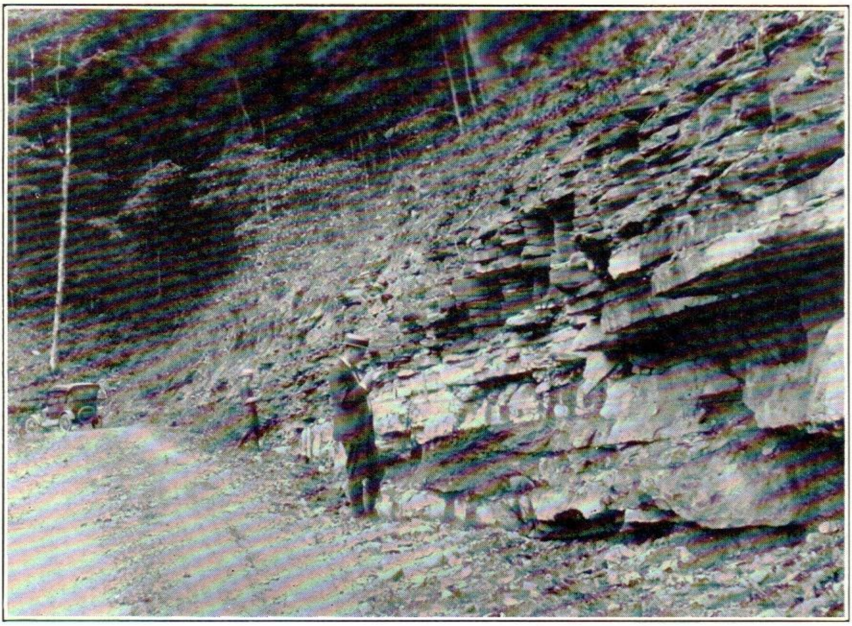
(A) View of a slab of dove limestone (one-tenth natural size), showing the polygons of the upper surface that represent sun-cracking in ancient times and many worm tubes penetrating the rock vertically.

(B) Outcrop along the Louisville & Nashville R. R. half a mile northeast of Thompson station. The typical Bigby limestone is followed by 1 foot or less of the dove beds and 20 feet of the blue crystalline Ward limestone of the Cannon formation and above this comes the usual development of the Catheys.

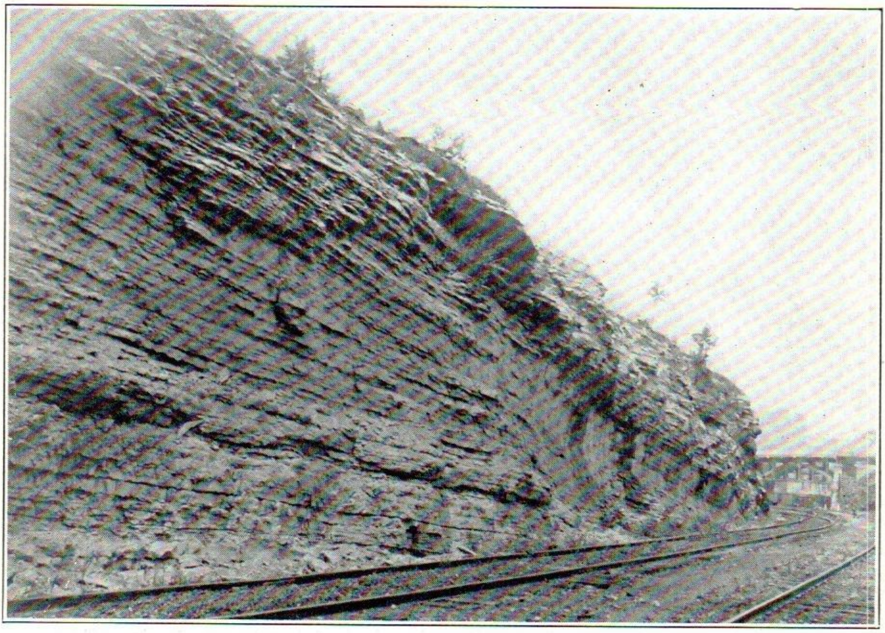


(A) View of the Blind Asylum quarry along the Tennessee Central R. R. at Nashville. The massive upper layers of the Hermitage are followed by the typical massive, gray, granular Bigby (Capitol limestone) and this in turn by the Dove and Ward divisions of the Cannon limestone.

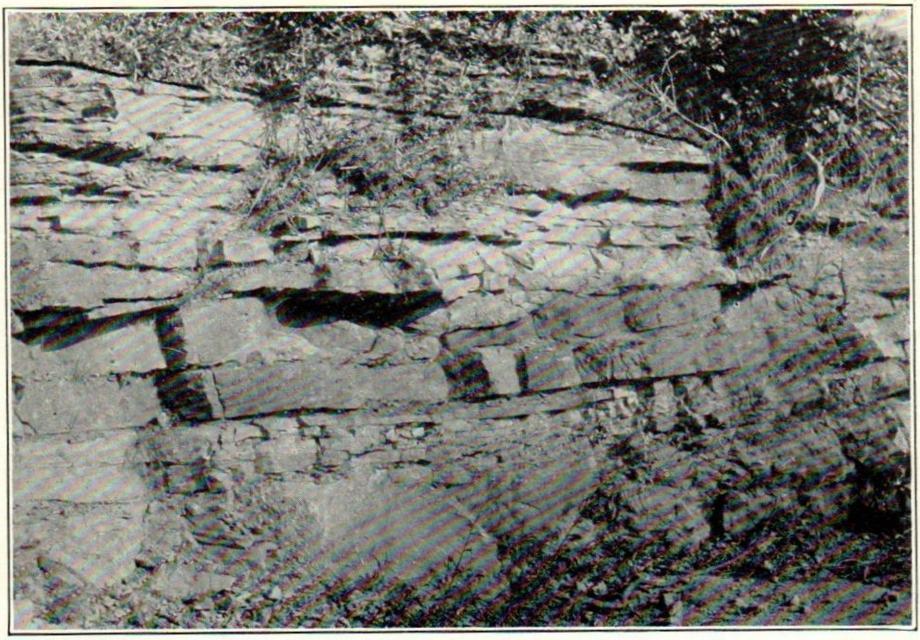
(B) Portion of outcrop of the Cannon limestone along the Tennessee Central R. R. near the Blind Asylum at Nashville.



(A) Contact of Cannon limestone and Chattanooga black shale south of Celina, Tenn., showing appearance in fresh outcrops and usual sequence of strata on the east side of the Basin.



(B) Cannon (Ward) limestone and Catheys formation exposed along Tennessee Central R. R. tracks at Nashville.



(A) View along road north of Celina, showing contact of heavy-bedded Catheys limestone with thin-bedded strata of the Leipers formation.

(B) Leipers phosphate at Twomey near Centerville.

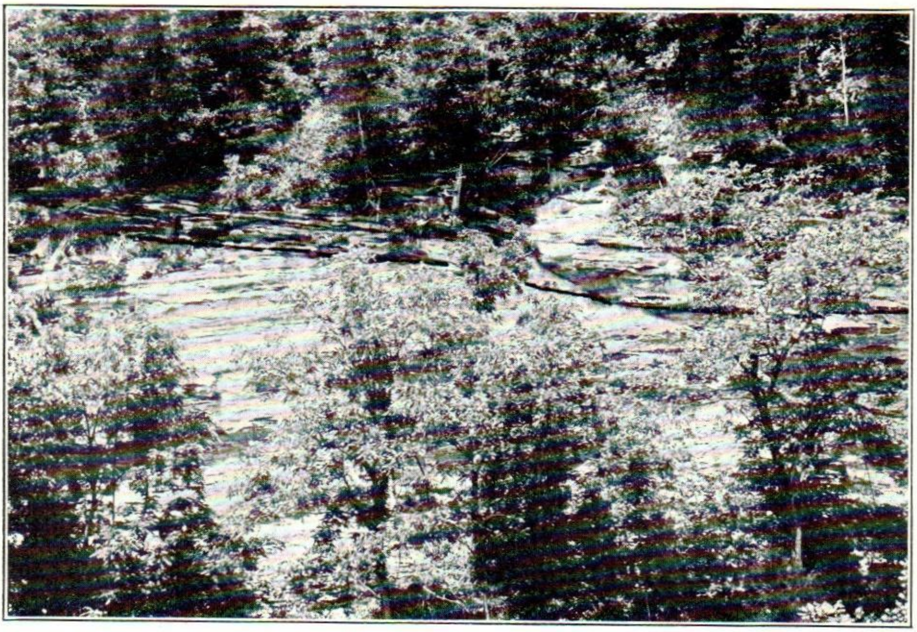
(A) Outcrop of Leipers limestone near Celina, Tenn., showing a portion of one of the many small domes of this area.

(B) Bluff one-fourth of a mile west of Newsom, along Nashville, Chattanooga & St. Louis Ry., showing massive Osgood and Laurel limestone, thin band of Waldron shale and over this the upper Niagaran Brownsport limestone.

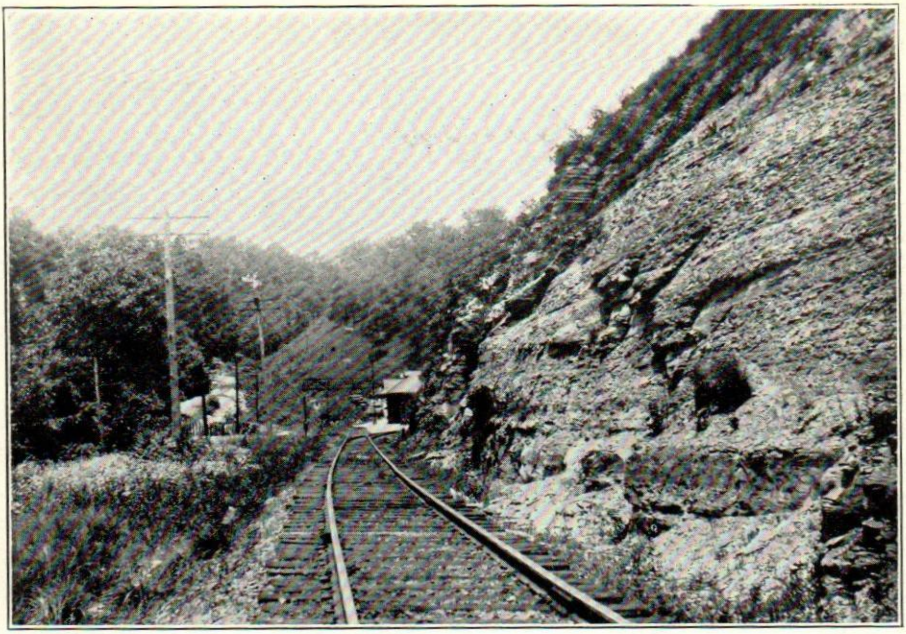
(A) Contact between the Chattanooga black shale and the Ridgetop green shale. The phosphatic nodules in the upper part of the Chattanooga continue through the lower part of the Ridgetop. The latter portion contains in addition to the phosphatic nodules, glauconite (greensand), this being separated long ago as the Maury green shale.

(B) Silurian and Mississippian strata exposed along the Louisville & Nashville R. R. at Bakers. The massive Laurel limestone and the shales and limestones of the Waldron formation are followed by the Chattanooga with a thin layer of Hardin at its base, and the Ridgetop of Mississippian age.

(A) The classic outcrop of the New Providence shale crinoid beds at Whites Creek Springs.



(B) Outcrops along Eagle Creek 8 miles northeast of Livingston, showing overlap of Fort Payne limestone on New Providence shale.

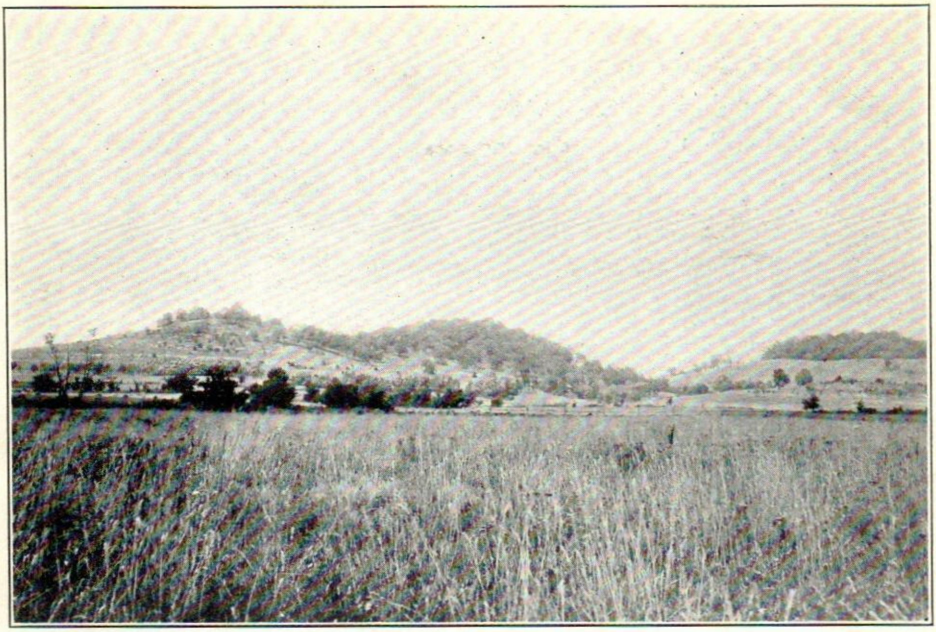


(A) New Providence shale below and Fort Payne shaly limestone outcropping along Louisville & Nashville R. R. at Ridgetop.

(B) Outcrop along road cutting edge of Highland Rim east of Woodbury, showing fissure in Chattanooga shale filled with Fort Payne limestone now changed to chert.

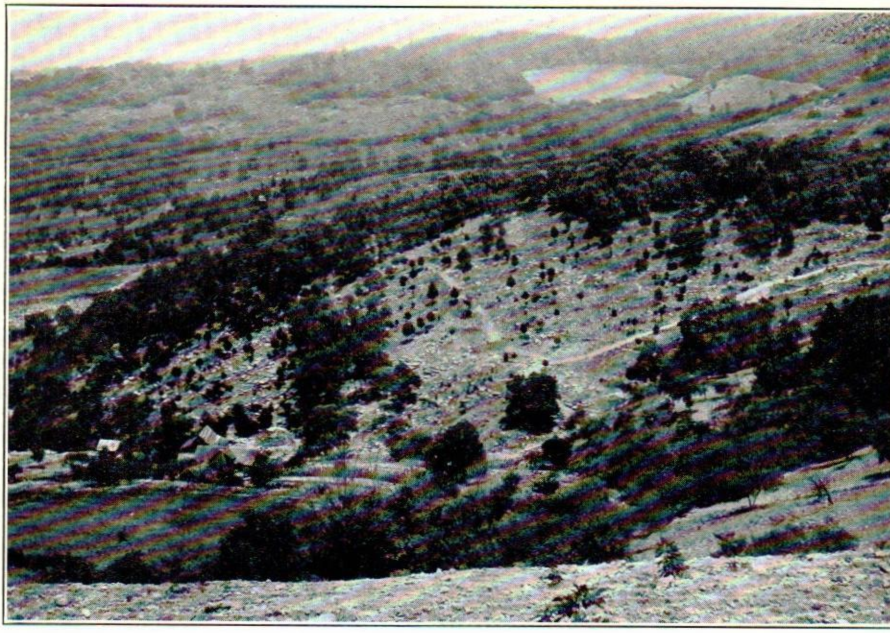
(A) Usual aspect of Fort Payne chert outcrop. Exposures along road crossing Duck River at Manchester.

(B) Outcrop in Tullahoma, Tenn., exhibiting the unconformable relations of the Fort Payne chert and Warsaw limestone.



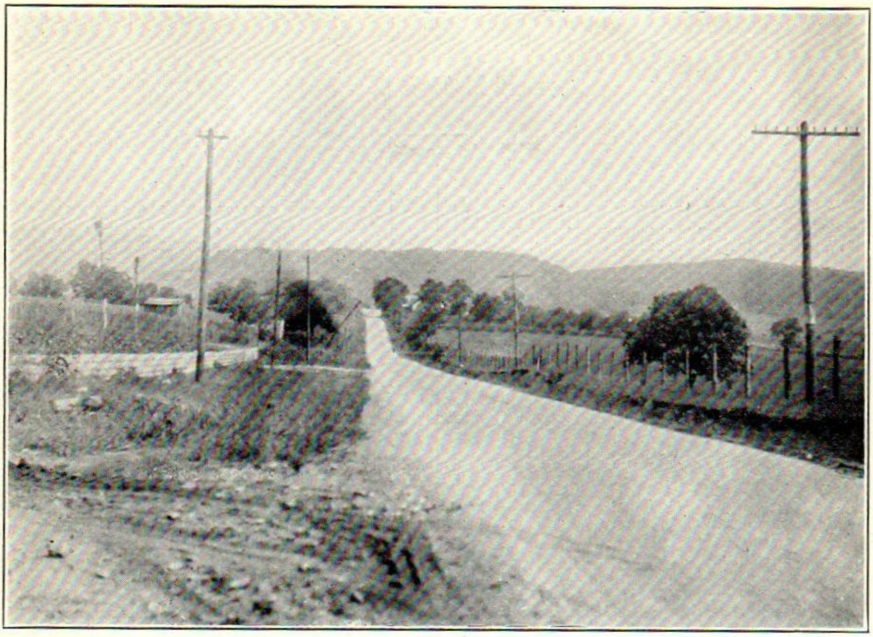
(A) A typical knob of the Central Basin (northeast of Franklin) with a remnant of Chattanooga black shale at the top and middle Ordovician limestones forming the main mass of the knob.

(B) View from the hill above Rhodes quarry, 1½ miles southwest of Franklin, northeast across the Harpeth River plain with Franklin in the middle ground and Roper and other knobs on the east in the distance.



(A) View showing usual aspect of Cannon limestone outcrops along edge of Highland Rim, Hollow Springs quadrangle.

(B) Photograph of dissected Highland Rim at its contact with Central Basin, taken from top of hill just east of junction of Rutherford, Cannon, and Coffee Counties.



(A) Sky line of the Cumberland Plateau as seen from point just east of Sparta.

(B) Falls of Duck River near Manchester, occasioned by the siliceous Fort Payne chert projecting over Chattanooga black shale.

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