The Mississippian and Pennsylvanian (Carboniferous) Systems in the United States— Georgia

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Historical review and summary of areal, stratigraphic, structural, and economic geology of Mississippian and Pennsylvanian rocks in Georgia

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THE MISSISSIPPIAN AND PENNSYLVANIAN (CARBONIFEROUS) SYSTEMS IN THE UNITED STATES—GEORGIA

By WILLIAM A. THOMAS[1] and HOWARD R. CRAMER[2]

ABSTRACT

Mississippian and Pennsylvanian rocks are exposed in the Appalachian fold and thrust belt of northwest Georgia. The Mississippian System includes a carbonate facies on the northwest and a clastic facies on the southeast. The carbonate facies is characterized by high-energy shallow-marine limestones. The clastic facies is composed mainly of prodelta mud and includes minor delta-front sands. Intertonguing of the clastic and carbonate facies indicates that delta progradation alternated with transgression and delta destruction. Both facies of the Mississippian System grade upward through a sequence of fine clastic rocks to massive sandstone that has commonly been considered as Pennsylvanian. However, the Mississippian-Pennsylvanian boundary is not precisely defined. Early Pennsylvanian rocks (Pottsville) are the youngest Paleozoic rocks in northwest Georgia. The Pennsylvanian System is predominantly sandstone and shale, and contains subordinate amounts of conglomerate, coal, and siltstone. The lower coal-bearing rocks appear to have been deposited in a shoreline environment; bar, tidal-delta, and lagoonal deposits have been identified. The upper coal-bearing rocks appear to have been deposited in a lower-delta-plain environment; the sedimentary units are individually more widespread and less variable. Bituminous coal is the major economic resource, although the reserves are uncertain and may be somewhat less than 100 million tons. All the coal is medium- and low-volatile, low sulfur, and for the most part in beds much less than 1 m thick.

INTRODUCTION

Sedimentary rocks of the Mississippian and Pennsylvanian Systems are exposed in the Appalachian fold and thrust belt of northwest Georgia (fig. 1). The maximum thickness is more than 1,000 m. The Mississippian System includes a carbonate facies on the northwest and a clastic facies on the southeast. Both facies of the Mississippian System grade upward into a Pennsylvanian clastic sequence characterized by sandstone, shale, and coal.

In the Appalachian Piedmont of Georgia (fig. 1), some metamorphic and plutonic rocks yield radiometric dates indicating a Mississippian-Pennsylvanian age (Pinson and others, 1957; Smith and others, 1969; Hurst, 1970; Fullagar, 1971; Fullagar and Butler, 1974; Jones and others, 1974; Whitney and others, 1976). None of the metasedimentary rocks in the Appalachian Piedmont of Georgia has yet been shown to represent Mississippian-Pennsylvanian deposition. To the southwest, in the Piedmont of Alabama, metasedimentary rocks in the Talladega Slate belt include sedimentary deposits of Mississippian (Carrington, 1967, p. 26) and Pennsylvanian ages (Butts, 1926, p. 219). Parts of the Talladega have been traced from Alabama into northwest Georgia (Cressler, 1970, p. 51).

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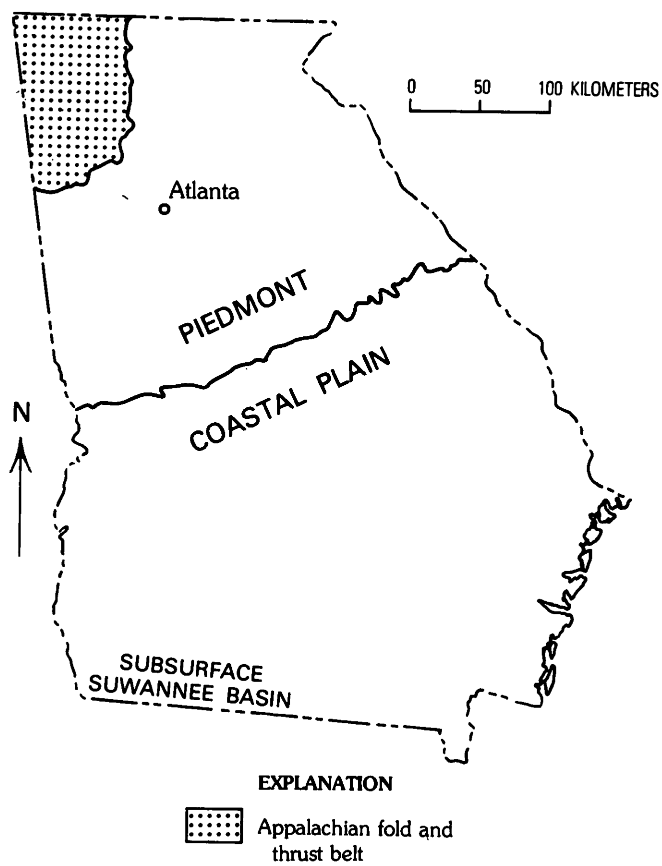

FIGURE 1.—Index map of Georgia.

In south Georgia, beneath the Mesozoic-Cenozoic strata of the Gulf Coastal Plain, the Suwannee basin contains a thick sequence of Paleozoic clastic sedimentary rocks (fig. 1). Palynological studies of samples from one well (Anderson No. 1 Great Northern Paper Co.) indicate a Devonian age (McLaughlin, 1970). Studies of fossils in cores from another well (Warren No. 1 Chandler) yield conflicting results. Ostracodes suggest a Late Ordovician or Early Silurian age (Swartz, 1949, p. 320); however, Pennsylvanian pelecypods have been identified in slightly deeper beds (Palmer, 1970). Possibly Mississippian-Pennsylvanian strata will be documented by future work in the pre-Mesozoic basin.

The purpose of this paper is to review the Mississippian and Pennsylvanian sedimentary rocks in Georgia as they are presently understood. The scope of the paper is limited to consideration of known Mississippian-Pennsylvanian strata in the Appalachian fold and thrust belt of northwest Georgia. To facilitate organization, a twofold subdivision has been used; however, that subdivision is hampered by problems of identification of the Mississippian-Pennsylvanian boundary. In general, Thomas has gathered and interpreted data relative to Mississippian rocks, and Cramer has gathered and interpreted data relative to Pennsylvanian rocks. The Mississippian limestone is a distinct lithostratigraphic entity, but the overlying sequence of shales and sandstones evidently lacks persistent lithostratigraphic markers. Massive sandstone above the base of the shale-sandstone sequence forms a bluff that is topographically distinct; however, the bluff evidently is formed by different sandstone units at different places. In any local stratigraphic column, the top of the limestone and a bluff-forming sandstone are the most readily identified beds. In the following discussions, these beds are used loosely as reference horizons. Available biostratigraphic data suggest that the Mississippian-Pennsylvanian boundary is probably within the shale-sandstone sequence between the top of the limestone and the massive sandstone but may be as high as some of the massive sandstones.

The discussion and interpretations are based on data from publications, unpublished manuscripts, field notes, and core descriptions available for compilation in 1977. We acknowledge the assistance of many geologists in identifying data sources. Cores from the Rocky Mountain area, Floyd County, were described by H. D. Lowe and G. S. Grainger of the Southern Co.; data from cores and outcrops were provided by G. S. Grainger and W. V. Conn of Georgia Power Co. Cores from Pigeon and Lookout Mountains, Walker and Chattooga Counties, were described by Duane Jorgensen of the United States Gypsum Co. Core descriptions and measured section data were provided by Robert Bolding of West Georgia College, R. C. Milici of the Tennessee Division of Geology, B. J. Timmons of Florida Rock Industries, D. H. White, Jr., of the U.S. Bureau of Mines, and R. L. Wilson of the University of Tennessee at Chattanooga. Access to file data of the Georgia Geological Survey was provided by S. M. Pickering, Jr., and J. B. Murray. The manuscript has been read by J. B. Murray, D. E. Ogren, S. M. Pickering, Jr., Mark Rich, J. A. Waters, and E. L. Yochelson, and we appreciate their comments.

The stratigraphic nomenclature used in this paper has not been reviewed by the Geologic Names Committee of the U.S. Geological Survey. The nomenclature used here conforms with the current usage of the Georgia Department of Natural Resources, Geologic and Water Resources Division.

HISTORY OF THE STUDY OF THE CARBONIFEROUS ROCKS

Figure 2 shows the evolution of the classification schemes that have been used for the Carboniferous rocks of Georgia.

The period from 1809 to 1892 includes that time from when geology was first studied in the United States to when the Carboniferous rocks of Georgia were first investigated. During this period, the Carboniferous rocks of Georgia were examined only incidentally, as parts of larger regional studies. The nomenclature used did not originate in Georgia but was introduced from elsewhere. Williams (1891) provided a history of the nomenclature evolution of the Carboniferous rocks of Georgia and elsewhere.

The period from 1892 to 1904 encompasses the time when geologists, mostly from the U.S. Geological Survey, first investigated the rocks of Georgia and proposed names for the subdivisions. The period begins with the works of Hayes (1892; 1894; 1895; 1902) and ends with the summary work on the Carboniferous of the entire Appalachian chain by Stevenson (1903, 1904). Economic studies of the Carboniferous rocks of Georgia were made by Spencer (1893) and McCallie (1904). Many of the stratigraphic concepts developed during this period are in use today.

Between 1904 and 1942, little new information accrued about the Carboniferous of Georgia except that in individual reports on economic geology. In

<table>
<tr><th colspan="8">CARBONIFEROUS ROCKS</th><th>AUTHOR AND DATE</th></tr>
<tr><td colspan="8">Secondary</td><td>U.S. Map Maclure 1809</td></tr>
<tr><td colspan="8">Transition Appalachian Coal Field</td><td>Ga. State Map Williams, in White 1849</td></tr>
<tr><td colspan="8">Carboniferous</td><td rowspan="2">U.S. Map Marcou 1853</td></tr>
<tr><td colspan="5">Carbonifiere Inferiere ou Calcaire du Montagne</td><td colspan="3">Carbonifiere Superieur ou Terrain Houiller</td></tr>
<tr><td colspan="3">Vespertine</td><td colspan="2">Umbral</td><td colspan="3">Seral</td><td>Rogers 1858</td></tr>
<tr><td colspan="8">Carboniferous</td><td>U.S. Map Hitchcock and Blake 1874</td></tr>
<tr><td colspan="8">Carboniferous</td><td rowspan="2">Ga. State Map Little 1876</td></tr>
<tr><td colspan="5">Sub Carboniferous</td><td colspan="3">Coal Measures</td></tr>
<tr><td colspan="3">Lower Sub Carboniferous</td><td colspan="2">Upper Sub Carboniferous</td><td colspan="3">Carboniferous</td><td>U.S. Census Map McCutcheon 1884</td></tr>
<tr><td colspan="8">Carboniferous</td><td rowspan="2">Ga. State Map Spencer 1893</td></tr>
<tr><td>Fort Payne Chert</td><td colspan="2">Floyd Shale</td><td colspan="2">Mountain Limestone</td><td colspan="3">Coal Measures</td></tr>
<tr><td colspan="3">Waverlyan</td><td colspan="2">Tennesseean</td><td colspan="3">Pennsylvanian</td><td>Ulrich 1911</td></tr>
<tr><td colspan="8">Carboniferous (on map)</td><td rowspan="2">Ga. State Map Georgia Div. Mines, Mining, and Geology 1939</td></tr>
<tr><td colspan="5">Mississippian (in legend)</td><td colspan="3">Pennsylvanian (in legend)</td></tr>
<tr><td colspan="5">Mississippian</td><td colspan="3">Pennsylvanian</td><td>Ga. State Map Georgia Geological Survey 1976</td></tr>
<tr><td colspan="2">Tournaisian</td><td colspan="2">Visean</td><td colspan="2">Namurian</td><td>Westphalian</td><td>Stephanian</td><td>European Stages</td></tr>
</table>

FIGURE 2.—Correlation chart showing the evolution of Carboniferous nomenclature in Georgia.

1939, the first modern geologic map of the State was published (Georgia Div. Mines, Mining, and Geology, 1939); this map included a summary of the Carboniferous stratigraphy to that date.

During, and just after the war years, from 1940 to about 1950, the need for mineral-resource development prompted geologists again to investigate the Carboniferous rocks of Georgia. Most of the resulting reports deal with the coal resources. The summary volume of Pennsylvanian stratigraphy of the southern Appalachians (Wanless, 1946) appeared at this time, and also the volume of the geology of northwest Georgia (Butts and Gildersleeve, 1948). Correlation charts prepared by committees of the Geological Society of America (Mississippian, Weller, chairman, 1948; Pennsylvanian, Moore, chairman, 1944) fixed the nomenclature of the Carboniferous of Georgia in relation to that of other States.

After 1950, geological education in Georgia flourished, and much data about the Carboniferous resulted from student research. Authors of theses mainly used the nomenclature recommended by Butts (*in* Butts and Gildersleeve 1948).

Expanded activity in geological mapping took place between 1960 and 1969, and much detail was uncovered by geologists from the U.S. Geological Survey and the Georgia Geological Survey (Cressler, 1963; 1964a, b; 1970; Croft, 1964). The work of Culbertson (1963) summarized the nomenclature of the Pennsylvanian rocks. The concepts of regional stratigraphic analysis emanating from the Northwestern University school of stratigraphy were applied to Georgia (Stearns and Mitchum, 1962). In this report the Pennsylvanian rocks of Georgia are shown on three-dimensional maps in a regional context.

Work by Hobday (1969) initiated another era of stratigraphic studies in the Carboniferous rocks of Georgia. Before this, Ferm and his associates (Ferm and others, 1967; Ferm, 1974) had begun to look at the Carboniferous rocks of the Appalachian region, not as layers as in a cake, but as a sequence of laterally discontinuous, time-transgressive sedimentary units that are a result of changing environments in the coastal, littoral, and deltaic regimes. The work of Hobday (1974) was the first published account of the Carboniferous rocks of Georgia that used such a sedimentologic model as the primary interpretation. Application of this kind of interpretation will require a reevaluation of all of the clastic rocks of the Carboniferous of Georgia.

The U.S. Geological Survey's paleotectonic study of the Pennsylvanian of the United States (McKee and others, 1975) summarizes all the available data. This and the most recently published geologic map of the State (Georgia Geological Survey, 1976) will serve as springboards for the reevaluation and future interpretations.

DISTRIBUTION AND STRUCTURAL SETTING OF THE CARBONIFEROUS ROCKS

Mississippian and Pennsylvanian strata in northwest Georgia are within the Appalachian fold and thrust belt (figs. 1, 3*A*). Pennsylvanian strata, the

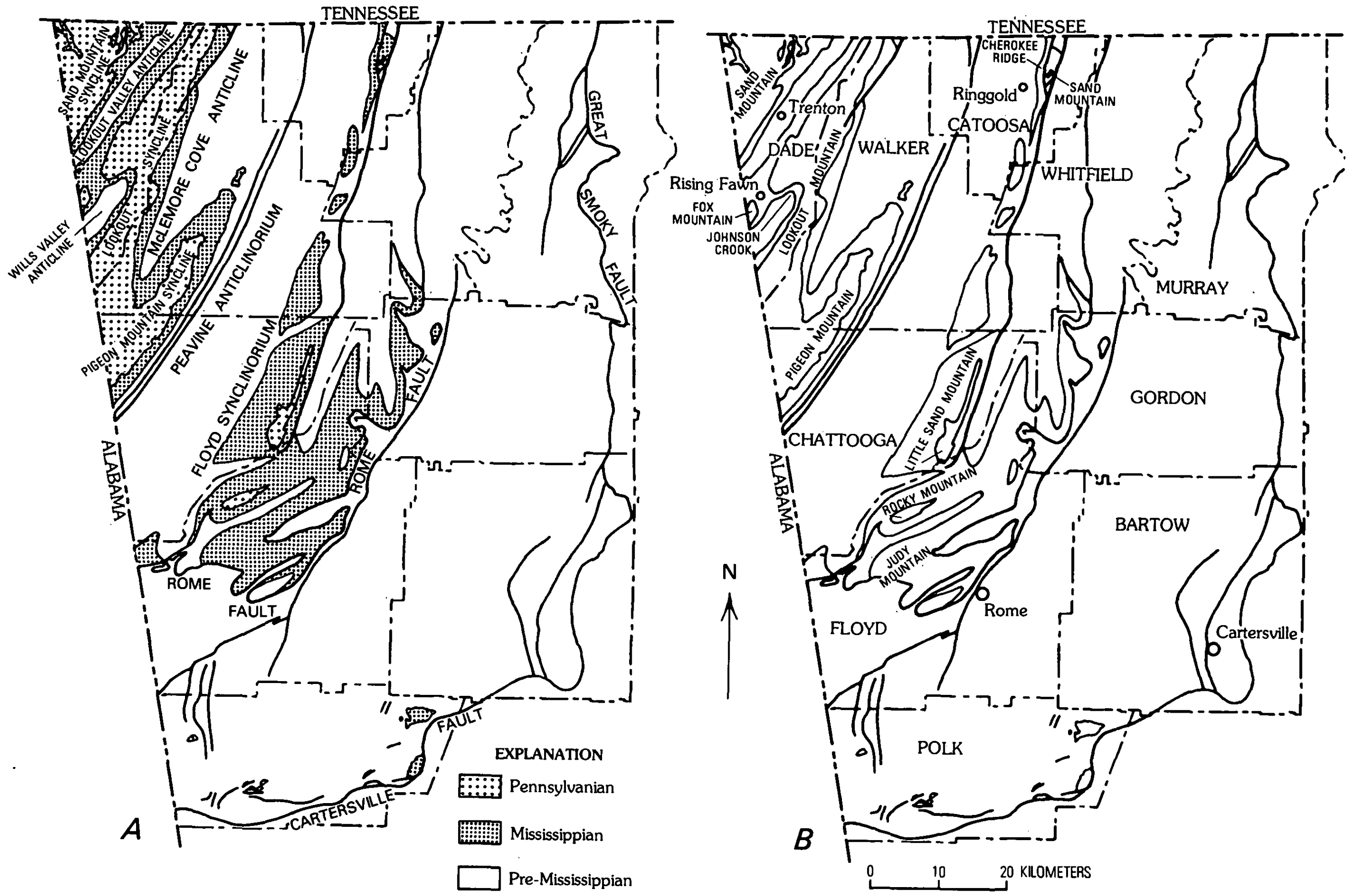

FIGURE 3.—Geologic map (*A*) of northwest Georgia and outline map (*B*) showing localities mentioned in text. Geologic map adapted from the geologic map of Georgia (Georgia Geological Survey, 1976).

youngest rocks exposed in northwest Georgia, cap flat-topped mountains. The Pennsylvanian beds are preserved in the troughs of synclines and commonly have gentle dips. Mississippian rocks are exposed along the mountain slopes and in adjacent valleys.

On the east and south, the Appalachian fold and thrust belt is bordered by metamorphic rocks of the Appalachian Piedmont along the Cartersville (Great Smoky) fault. The next major structure northwest of the Cartersville fault is the Rome fault, the sinuous trace of which reflects low dip and folding of the fault plane (fig. 3*A*). The Rome fault block is internally complicated by folds and faults and is composed of lower Paleozoic formations except for small areas of Mississippian rocks north of the Cartersville fault in Polk County. A regional structural recess in the Appalachian structural system in northwest Georgia is expressed by abrupt curves in strike of both the Cartersville and Rome faults.

Northwest of the Rome fault is the large, complex Floyd synclinorium which plunges into a depression northwest of Rome in Floyd County (fig. 3*B*). North of the depression, a complex south-plunging anticline divides the synclinorium into two branches; a thrust fault along the west limb of the anticline ends southward down the plunge. Southwest of the depression, northeast-trending anticlines plunge northeastward. An abrupt change in strike within the synclinorium at the depression outlines the regional structural recess (fig. 3*A*). Much of the surface area of the depression and synclinal branches of the Floyd synclinorium is formed on Mississippian rocks. Pennsylvanian rocks in synclinal troughs cap three isolated mountains: Rocky Mountain (shown as Rock Mountain on the 7½-min quadrangle map named for the mountain), northwest of Rome; Little Sand Mountain, north of Rome; and Sand Mountain[3], east of Ringgold (fig. 3*B*).

Northwest of the Floyd synclinorium on the Peavine anticlinorium, Cambrian and Ordovician

[3] Two separate topographic features in northwest Georgia are called Sand Mountain: (1) on the east, an areally small mountain east of Ringgold in Catoosa County, and (2) in the northwest corner of Georgia, in Dade County, a broad flat-topped mountain that extends into Alabama and Tennessee.

rocks are exposed, and the anticlinorium separates Mississippian-Pennsylvanian outcrops of northwest Georgia into two major parts (fig. 3*A*). On the southeast is the large outcrop area in the Floyd synclinorium. On the northwest is a large area of Mississippian and Pennsylvanian outcrops on Pigeon, Lookout, and Sand Mountains.

Northwest of the Peavine anticlinorium, the strata are broadly folded in the Pigeon Mountain and Lookout synclines (fig. 3*A*). The two synclines are separated by the southwest-plunging McLemore Cove anticline. The anticline flattens down plunge, and the Pigeon Mountain and Lookout synclines apparently merge southwestward into the more narrow Lookout syncline along Lookout Mountain in Alabama. The northwest limb of the Lookout syncline is formed by the en echelon Wills Valley and Lookout Valley anticlines (fig. 3*A*). Northwest of the en echelon anticlines, the broad flat-bottomed Sand Mountain syncline extends northwestward beyond the northwest corner of Georgia. The most northwesterly Appalachian anticline, the Sequatchie anticline, is farther northwest in Tennessee and Alabama.

Pennsylvanian rocks form a wide outcrop area on the flat mountain tops in the Pigeon Mountain and Lookout synclines. A continuous outcrop extends from the northern end of Lookout Mountain at Chattanooga, Tenn., across northwest Georgia, and southwestward into Alabama. Lower Pennsylvanian sandstones form a prominent bluff, or brow, around the top of Pigeon and Lookout Mountains. Mississippian formations, mainly limestones, are exposed along the slopes of Lookout and Pigeon Mountains. A similar arrangement of outcrops and rock types is found on Sand Mountain in the northwest corner of Georgia (fig. 3*B*).

MISSISSIPPIAN STRATIGRAPHY OF NORTHWEST GEORGIA

By William A. Thomas

LITHOFACIES

The Mississippian System of northwest Georgia includes two geographically and stratigraphically distinct facies. The facies on the northwest is mainly carbonate rock, and that to the southeast is mainly clastic rock (fig. 4). Areas of distribution of the two facies are divided roughly by the Peavine anticlinorium (fig. 3*A*).

The northwestern carbonate facies may be subdivided into three successive units. The lower unit is characterized by bedded chert and cherty carbonate. The middle and thickest unit is mainly noncherty limestone. The upper unit is characterized by maroon, green, and gray mudstones and shales. Boundaries between the three subdivisions are gradational. The shale unit at the top of the Mississippian System grades upward into a sequence of sandstone, shale, and coal that has been assigned to the Pennsylvanian System.

The southeastern clastic facies is mainly shale but also includes sandstone. The lower part of the southeastern clastic facies contains bedded chert similar to that in the bedded chert unit at the base of the northwestern carbonate facies. The clastic facies also contains interbeds of limestone similar to the limestone in the middle unit of the northwestern carbonate facies (fig. 4). The southeastern clastic facies of Mississippian rocks is overlain by sandstone of the Pennsylvanian System.

Limestone tongues within the southeastern clastic facies indicate a lateral transition characterized by intertonguing of the two facies; however, outcrop sections do not show the complete range of intermediate characteristics between the two facies. Along the Peavine anticlinorium, in the probable area of facies transition, Mississippian rocks have been removed by erosion. Interpretation of structure of the anticlinorium (Butts, *in* Butts and Gildersleeve, 1948, geologic map) suggests only minor structural telescoping of the sedimentary facies. Some possible transitional aspects can be seen where the section is mostly limestone on Sand Mountain (Catoosa County) in the western north-trending branch of the Floyd synclinorium (fig. 3*A*). To the south in the Floyd synclinorium, the Mississippian System is represented by the clastic facies. Evidently the clastic facies grades northward to the carbonate facies along the western branch of the Floyd synclinorium, but details are obscure because of poor exposure. Apparently the facies boundary roughly parallels structural strike along the Peavine anticlinorium, but it trends somewhat more easterly and extends into the Floyd synclinorium on the north.

Trends of major facies patterns are paralleled by major thickness trends in the Mississippian System (fig. 4). On the northwest, the carbonate facies ranges in thickness from approximately 360 to 460 m. The system thickens to the southeast, and in the depression of the Floyd synclinorium the clastic facies is as much as 775 m thick. Because of poor exposure, thickness data for the clastic facies are sparse. Complex structure precludes a thickness

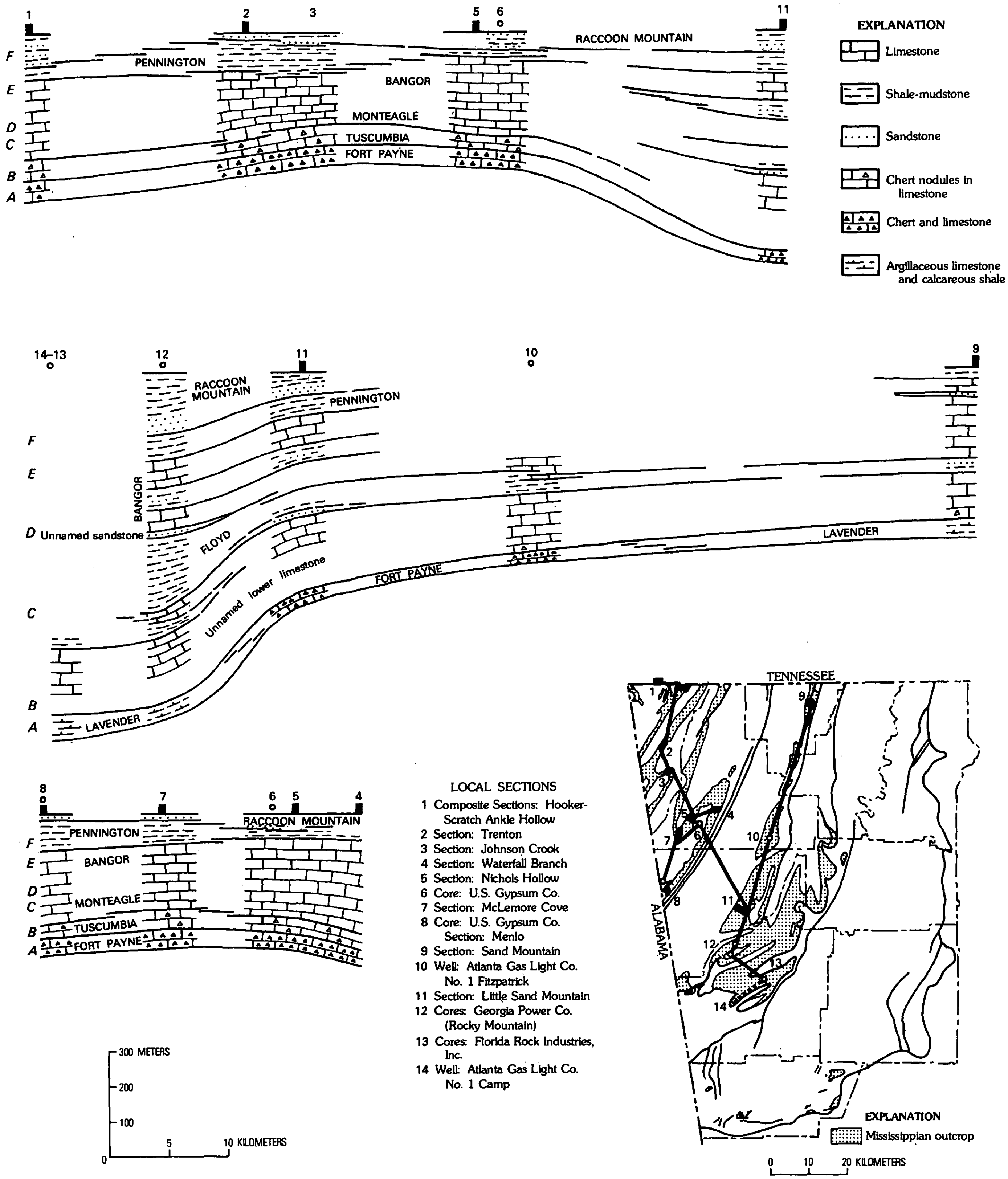

FIGURE 4.—Diagrammatic stratigraphic cross sections of Mississippian rocks in northwest Georgia. Top of each section is base of massive sandstone. Lithologic symbols on cross sections show the part of each local section that is included in available descriptive data. Letters A through F on cross sections show approximate stratigraphic positions of maps in figure 8. Data for local sections from Sullivan (1942) (section 3), Allen (1950) (section 9), Clement (1952) (section 3), Moore (1954) (section 2), Wheeler (1954) (sections 4, 5), Windham (1956) (section 9), Wilson (1965) (section 1), McLemore (1971) (sections 1–5, 7–9, 11), Florida Rock Industries, Inc. (section 13), Georgia Geological Survey (sections 10, 14), Georgia Power Co. (section 12), and U.S. Gypsum Co. (sections 6, 8).

measurement of Mississippian rocks on the Rome fault block.

EVOLUTION OF STRATIGRAPHIC NOMENCLATURE

Pioneer stratigraphic work in Tennessee and Alabama led to the recognition of three major subdivisions of Carboniferous rocks (Safford, 1869; Smith, 1879). The Lower Sub-Carboniferous or Siliceous group included the cherty beds that make up the lower part of the Mississippian in Georgia. The Upper Sub-Carboniferous or Mountain Limestone included the carbonate sequence of northwest Georgia. The Coal Measures apparently included the shale at the top of the Mississippian as well as the overlying sandstone-shale-coal sequence of the Pennsylvanian.

The first identification of formation subdivisions in Georgia apparently is the work of Hayes (1891) who extended the stratigraphic names Fort Payne Chert, Oxmoor Sandstone, and Bangor Limestone from Alabama. Hayes first used the name Floyd Shale for the lower part of the clastic sequence in Georgia (fig. 5).

In quadrangle mapping at Ringgold and Rome, Hayes (1894; 1902) recognized the two geographically distinct sequences of Mississippian rocks in Georgia. He used the name Bangor for all carbonate rocks above the Fort Payne Chert on the northwest, and he used the names Floyd and Oxmoor for the shale and sandstone parts of the clastic sequence on the southeast (fig. 5). The name Bangor was also used for a limestone unit above the Floyd and Oxmoor of the clastic sequence. Hayes (1894) specifically recognized that the clastic facies changes northwestward into the carbonate facies and that the Floyd on the southeast is the same age as the lower part of the Bangor on the northwest.

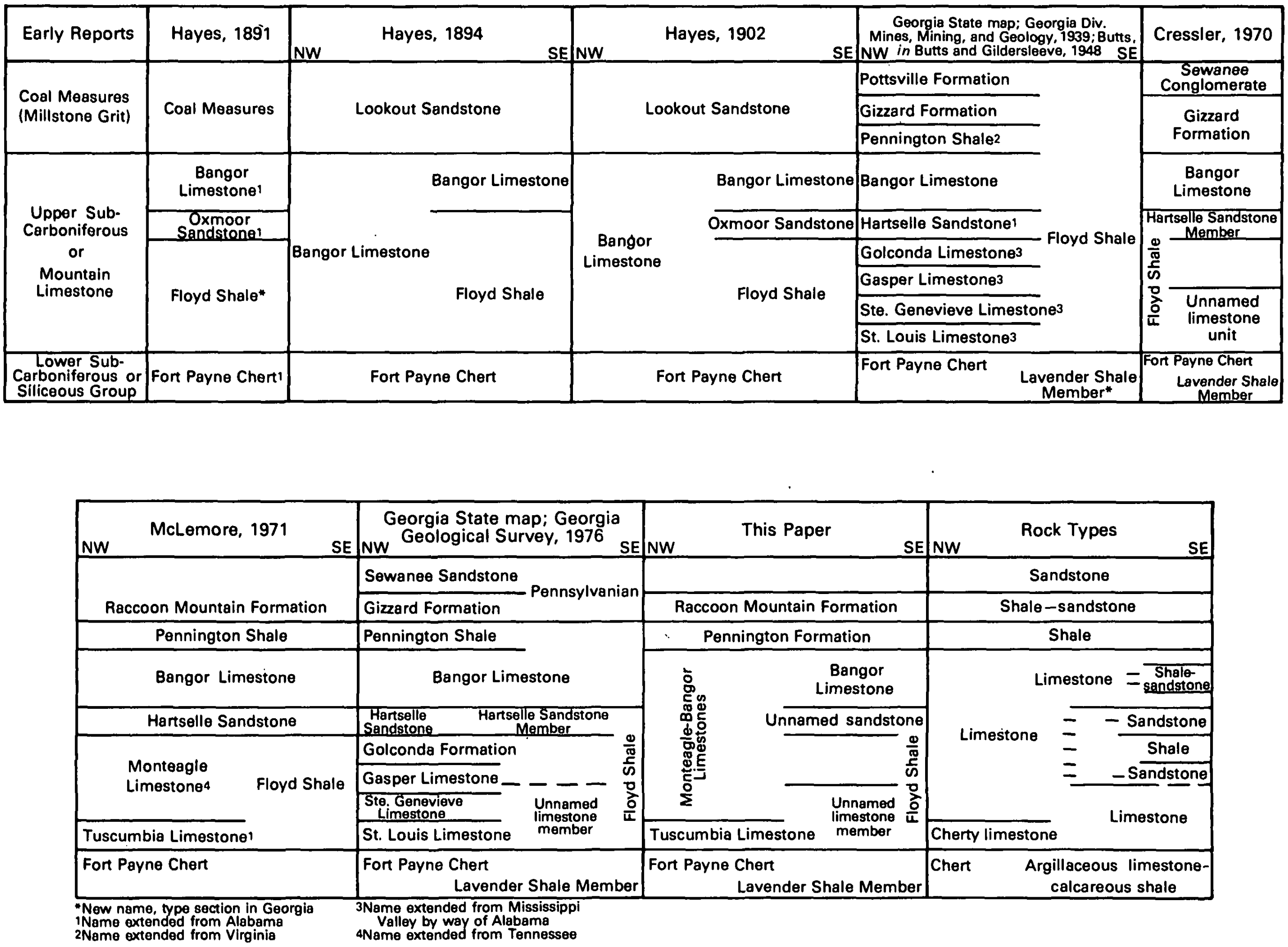

FIGURE 5.—Chart showing the evolution of stratigraphic subdivision and nomenclature of Mississippian rocks in northwest Georgia.

On the 1939 State geologic map of Georgia and in a subsequent report by Butts (*in* Butts and Gildersleeve, 1948, p. 3–79), several formation names were extended into Georgia from the Mississippi Valley section (fig. 5). These subdivisions were based mainly on earlier work, in which Butts (1926) had extended the use of the Mississippi Valley units to Alabama. The same units were subsequently extended to Georgia from Alabama. Recognition of St. Louis, Ste. Genevieve, Gasper, and Golconda was based mainly upon the presence of certain distinctive faunal elements (Butts, *in* Butts and Gildersleeve, 1948, p. 45–48). Above the Golconda (of Butts, 1926) in Alabama is an extensive sandstone unit, the Hartselle Sandstone. Originally the name Bangor Limestone had been used in Alabama for the entire limestone sequence above the Fort Payne Chert (in that sense, Hayes, 1894, extended the use of Bangor into Georgia), and Hartselle Sandstone had been recognized as a member of the Bangor (Thomas, 1972a, fig. 2). Later, Butts (1926) restricted the Bangor to limestone beds above the Hartselle Sandstone and raised Hartselle to formation rank. In the latter sense, Butts (*in* Butts and Gildersleeve, 1948, p. 48). extended the use of Hartselle and Bangor into Georgia.

The Hartselle Sandstone in Alabama is a distinctive sandstone unit locally as much as 50 m thick (Thomas, 1972a, pl. 10), and a sandstone and sandy limestone approximately 3 m thick marks the position of the Hartselle at the north end of Lookout Mountain in Chattanooga, Tenn. (Butts, *in* Butts and Gildersleeve, 1948, p. 48). However, the limestone sequence in Georgia contains no persistent sandstone unit at the stratigraphic position of the Hartselle. Extension of the name Hartselle Sandstone from Alabama has led to a frustrating search for a rock unit to fit the stratigraphic name.

Butts (*in* Butts and Gildersleeve, 1948, p. 49) also extended the name Pennington from Alabama for the shale unit at the top of the Mississippian section (fig. 5). The name Pennington was defined in Virginia (Campbell, 1893, p. 28) and had been extended to Alabama by Butts (1910).

The clastic facies on the southeast in Georgia was assigned to the Floyd Shale (Butts, *in* Butts and Gildersleeve, 1948, p. 49–52). So defined, the Floyd included interbeds of limestone and sandstone, but stratigraphic names were not applied to any of these units (Butts *in* Butts and Gildersleeve, 1948, p. 50). Butts defined the Lavender Shale Member of the Fort Payne Chert as a dark-colored shale member (fig. 5). The Lavender Shale Member is restricted generally to the east of the area of the Fort Payne Chert.

Preparation of county maps by Cressler (1970) led to further subdivision of the clastic facies (fig. 5). A distinctive limestone tongue in the upper part of the clastic facies was identified as Bangor Limestone, following the usage of Hayes (1891). The clastic rocks below the Bangor and above the Fort Payne Chert were called Floyd Shale, and a sandstone unit near the top of the Floyd was designated the Hartselle Sandstone Member (Cressler, 1970, p. 48). The Hartselle Sandstone Member as mapped by Cressler (1970) is the same unit Hayes (1891; 1902) called Oxmoor Sandstone. Both names had been extended from Alabama, and the change introduced by Cressler reflected changes in subdivision and nomenclature of the Alabama section. The Hartselle Sandstone in Alabama occupies a well-defined stratigraphic position, and Cressler's (1970) work extended the use of the name into the clastic facies in Georgia. A limestone unit at the base of the Floyd Shale was mapped locally by Cressler (1970) as an unnamed limestone unit.

In a dissertation, McLemore (1971) proposed revisions of some of the stratigraphic nomenclature to recognize lithologically distinct units (fig. 5). The name Tuscumbia was extended from Alabama for the lower cherty part of the carbonate facies above the Fort Payne Chert. Overlying the Tuscumbia is a noncherty limestone unit for which the name Monteagle Limestone was extended to Georgia from Tennessee. McLemore (1971) continued the use of the name Hartselle for a shaly and locally sandy unit that he identified within the carbonate facies between Monteagle and Bangor. Although the thickness of the complete Monteagle-Bangor interval is relatively constant, the stratigraphic position of the unit assigned to the Hartselle seems to vary abruptly from section to section resulting in abrupt reciprocal changes in thickness of beds assigned to Monteagle and to Bangor. It appears likely that the rocks designated as Hartselle are not a continuous clastic unit but rather are several local clastic lenses at different stratigraphic positions. McLemore (1971) also used the name Hartselle Sandstone for a sandstone unit within the clastic facies.

Many of the formal stratigraphic names applied to Mississippian rocks in northwest Georgia have been extended from other areas, and subdivision of the Georgia succession has been designed to conform to a scheme of subdivision defined elsewhere. Some units have been identified on the basis of rock characteristics, but many of the formation names that have been extended into Georgia were applied to subdivisions that were identified on the basis of their fossil content. Such units are biostratigraphic units in terms of modern concepts and are not necessarily distinct as rock-stratigraphic units. This review of the evolution of stratigraphic nomenclature in Georgia provides the background for recognition of units that are distinct on the basis of rock type, in keeping with a modern definition of rock-stratigraphic units (fig. 5).

The rocks of the carbonate facies are divided herein into the Fort Payne Chert, Tuscumbia Limestone, Monteagle-Bangor Limestones undifferentiated, and Pennington Formation, in ascending order (fig. 5). The Fort Payne is characterized by bedded chert. The Tuscumbia is cherty limestone. The Monteagle-Bangor sequence is characterized by bioclastic and oolitic limestones that contain very little chert. Maroon and green mudstone is characteristic of the Pennington, and the formation grades upward into a sequence of gray shale, sandstone, and coal.

Because no persistent sandstone unit can be identified within the carbonate facies, the rock-stratigraphic unit called Hartselle cannot properly be identified in Georgia. The Hartselle Sandstone is a distinct rock-stratigraphic unit in Alabama, but isopach mapping shows that the Hartselle Sandstone pinches out eastward along an irregular north-trending line more than 65 km west of the Georgia-Alabama State line (Thomas, 1972a, pl. 10). Because the Hartselle Sandstone of Alabama does not continue eastward into Georgia, and because the beds that have been assigned to the Hartselle in Georgia do not constitute a distinct rock-stratigraphic unit, it is inappropriate to continue the use of the name Hartselle in Georgia. Lack of a mappable stratigraphic unit precludes the need for a separate unit between Monteagle and Bangor.

In northeastern Alabama the Monteagle and Bangor Limestones are differentiated because of the Hartselle Sandstone between them (Thomas, 1972a, p. 22). East of the pinch-out of Hartselle Sandstone in Alabama, a contact between Bangor and Monteagle cannot be reliably traced, and the carbonate sequence can be identified best as Monteagle-Bangor undifferentiated (Thomas, 1972a, p. 22). Use of Monteagle-Bangor undifferentiated is a practical approach to the present problem of subdivision of the carbonate facies in northwest Georgia.

On the southeast, the clastic facies contains several stratigraphic units that have not been precisely defined. The lower part of the sequence has been called Floyd Shale, and the Floyd rests on either Fort Payne Chert or its facies equivalent, the Lavender Shale Member. The Lavender does not constitute a single distinctive member within the Fort Payne; rather it appears to be a laterally equivalent facies that intertongues with the entire Fort Payne Chert.

In Floyd County, the Lavender or Fort Payne is overlain by a distinctive limestone unit that has been included within the Floyd Shale (Cressler, 1970, p. 47). Presumably the limestone unit in the lower part of the clastic facies is a tongue of the lower part of the carbonate facies. However, because the limestone unit cannot be traced or precisely correlated to the carbonate sequence, it should be referred to as an unnamed limestone member of the Floyd Shale or as a new formation, rather than as one of the named units of the carbonate sequence (fig. 5).

Above the limestone unit the Floyd Shale is mainly shale and contains a few thin beds of sandstone and limestone. The shale sequence grades upward into a sandstone unit that has been called Hartselle. However, the sandstone is not physically continuous with the Hartselle Sandstone of Alabama but is separated from the Hartselle by a wide area in the carbonate facies of northwest Georgia and northeast Alabama. Therefore, the name Hartselle is inappropriate for the sandstone in the clastic facies in Georgia; however, no formal name is presently available (fig. 5).

The sandstone unit is overlain by a tongue of the Bangor Limestone, and the Bangor is overlain by a shale unit in the stratigraphic position of the Pennington. Thus, the Pennington both on the northwest and southeast overlies Mississippian limestone and is overlain by sandstone and shale that are generally considered to be Pennsylvanian.

LITHOSTRATIGRAPHY

MAURY SHALE

The Maury Shale is a thin, extensive, distinctive unit at the base of the Mississippian System in Alabama, Tennessee, and Georgia (Hass, 1956, p. 23; Conant and Swanson, 1961, p. 66). The Maury consists of partly silty to sandy green and gray shale. The rocks are commonly glauconitic, and the formation characteristically contains phosphatic nodules (Wheeler, 1955; Conant and Swanson, 1961, p. 63). In Georgia, the formation is generally less than 2 m thick.

FORT PAYNE CHERT

In weathered outcrops the Fort Payne Chert typically consists of light-colored chert in nodular beds less than one-fourth meter thick. The formation in northwest Georgia has a maximum thickness of more than 60 m (fig. 4). Much of the bedded chert evidently has been concentrated by the present weathering cycle from siliceous carbonate rocks. Cherty dolostone and cherty limestone (microfacies 5, 6, and 8 of McLemore, 1971, p. 99; fig. 6) make up much of the formation. Parts of the formation include quartz geodes which contain relict anhydrite replaced by quartz and calcite (Chowns, 1972, p. 90). The weathered Fort Payne Chert commonly contains molds of echinoderm columnals and other fossils. The Fort Payne Chert of northwest Georgia is part of a regionally extensive cherty facies that extends westward through the Fort Payne Chert of northern Alabama and Mississippi and is possibly continuous farther west with the upper part of the Arkansas Novaculite of the Ouachita Mountains in Arkansas (Thomas, 1972b, p. 96; 1977a, p. 16). In Georgia, the Fort Payne grades eastward into the Lavender Shale Member.

TUSCUMBIA LIMESTONE

The Tuscumbia Limestone is characterized by bioclastic limestone that contains relatively abundant nodules of chert. Chert appears to be scattered randomly through the formation, and no persistent marker beds have been defined. Beds of lime mudstone and finely crystalline dolostone are common; dolomitic mudstones locally contain calcite pseudomorphs after gypsum (McLemore, 1971, p. 102). Argillaceous limestone and thin beds of calcareous shale are rare. The formation ranges from approximately 35 to 65 m in thickness (fig. 4).

The contacts of the Tuscumbia with the underlying Fort Payne Chert and the overlying Monteagle Limestone are gradational. The bedded chert of the Fort Payne contrasts with the nodular chert of the Tuscumbia. The contact between the Tuscumbia and Monteagle is a regional upward change from cherty limestone to generally noncherty oolitic limestone. The contact is arbitrarily placed above the highest cherty lime mudstone and below the lowest thick oolitic limestone (McLemore, 1971, p. 102). However, the sequence above the arbitrary contact includes some thin cherty limestone, and thin beds of

MICROFACIES DESCRIPTION	DEPOSITIONAL ENVIRONMENT
1 Echinoderm grainstone and sparry echinoderm packstone	Shallow marine, outer platform of carbonate bank High current energy
2 Sparry bryozoan packstone and muddy bryozoan packstone	Protected shallow marine, inside bars (barrier rim) Low current energy
3 Oolitic grainstone and sparry oolitic packstone	Shallow marine, shoals or bars High current energy
4 Skeletal wackestone	Shallow marine, protected lagoon Low current energy
5 Mudstone (lime mudstone)	Shallow marine, lagoon between oolite shoals Low current energy
6 Dolostone	Shallow marine shelf, supratidal
7 Muddy skeletal packstone	Shallow marine, protected lagoon Low current energy
8 Dolomitized limestone	Partial dolomitization of shallow marine limestone

FIGURE 6.—Chart showing microfacies of Mississippian carbonate rocks in George (modified from McLemore, 1971).

oolitic limestone are present in the Tuscumbia. The contact as defined may not be practical for detailed mapping.

MONTEAGLE-BANGOR LIMESTONES

In the absence of a traceable contact between subdivisions, the upper part of the carbonate facies in Georgia is herein considered as Monteagle-Bangor Limestones undifferentiated. The Monteagle-Bangor sequence ranges from 135 to 275 m in thickness (fig. 4) and is mainly oolitic and bioclastic limestone (microfacies 1, 2, and 3 of McLemore, 1971; fig. 6). Thick beds of oolitic limestone are commonly crossbedded. The sequence includes beds of lime mudstone. Thin beds of dolostone and dolomitic limestone make up a small part of the unit, and dolostone locally contains scattered gypsum crystals. Chert nodules in thin intervals are scattered throughout the Monteagle-Bangor. Some cherty zones apparently extend laterally for short distances, but none are so extensive as to provide stratigraphic markers.

The Monteagle-Bangor sequence includes a few beds of argillaceous limestone and calcareous shale. The shaly intervals commonly are no more than 10 m thick and include limestone interbeds. Shale interbeds appear to be randomly distributed throughout the sequence. Two shaly zones in the lower (Monteagle) part of the sequence apparently extend at least 25 km along the Pigeon Mountain syncline. In northeastern Alabama, a shaly zone marks the middle Monteagle (Thomas, 1972a, p. 21), but that zone cannot be traced into Georgia. Locally, east of the pinch-out of the Hartselle Sandstone in Alabama, a thin shale marks the same stratigraphic horizon; but, the shale unit has limited extent (Thomas, 1972a, p. 42). Most of the shaly intervals appear to have limited lateral extent in Georgia. Some shaly zones in the upper part of the succession locally contain thin beds of sandstone.

The upper part of the limestone sequence generally includes beds of gray calcareous shale and maroon and green mudstone, and the Monteagle-Bangor grades upward into the Pennington Formation. In southern Tennessee and northeastern Alabama, a distinctive dolostone unit marks the base of the Pennington (Ferguson and Stearns, 1967, p. 58; Thomas, 1972a, p. 84). Although the upper part of the Bangor in Georgia includes some dolostone beds, the marker unit has not been identified.

PENNINGTON FORMATION AND RACCOON MOUNTAIN FORMATION ABOVE NORTHWESTERN CARBONATE FACIES

Overlying the carbonate facies is a sequence of fine-grained clastic sediments approximately 65 to 130 m thick (fig. 4). The lower part of the sequence, the Pennington Formation, is characterized by maroon and green shale and mudstone. Impressions of fenestrate bryozoans are abundant. The maroon and green mudstone grades up into dark-gray shale. The upper part of the sequence includes beds of siltstone and fine-grained sandstone, but locally the upper part contains maroon mudstone like that of the lower part. The upper, characteristically dark-gray, sandstone-bearing part of the sequence evidently belongs to the Raccoon Mountain Formation as used in Tennessee (Culbertson, 1963, p. E56).

The Pennington-Raccoon Mountain contact is within a gradational sequence that includes a variety of vertical arrangements of rock types. The Tennessee Division of Geology defines the top of the Pennington as the top of the highest limestone or maroon and green mudstone (Milici, 1974, p. 118). The Raccoon Mountain Formation contains gray shale, sandstone, and coal. Sandstone units in the Raccoon Mountain appear to be laterally discontinuous. Siderite nodules are common in the shale units. On Sand Mountain (Dade County), the formation contains several coal beds. The overlying massive bluff-forming sandstone is formed by different stratigraphic units in different places (Wilson, 1965, p. 28).

LAVENDER SHALE MEMBER OF FORT PAYNE CHERT

The Lavender Shale Member of the Fort Payne Chert consists of dark-gray calcareous shale and dark-gray argillaceous lime mudstone. The calcareous rocks weather to light-gray, greenish-gray, and yellowish-gray shale and mudstone, and the type section of the member consists of weathered shale (Butts, *in* Butts and Gildersleeve, 1948, p. 44; Cressler, 1970, p. 45). Petrographic work shows that the typical rock of the Lavender, where unweathered, is as much as 75 percent carbonate (Hurst, 1953, p. 218).

The Lavender does not constitute a single unit within the Fort Payne, and beds of Lavender rock types are distributed randomly within the Fort Payne Chert interval (Cressler, 1970, p. 47). The Lavender includes discontinuous beds of chert. Thickness of the argillaceous rocks increases toward the east as the thickness of rocks typical of the Fort Payne Chert decreases. Beds of argillaceous rocks are rare in the Fort Payne west of the Peavine anticlinorium, but farther east, the Lavender replaces most of the Fort Payne. The facies boundary between Lavender and Fort Payne apparently is a very irregular north-trending line through the Floyd synclinorium. On the Rome fault block in Polk County, thin intervals of Fort Payne Chert are found in scattered small thrust slices, and the Fort Payne is replaced eastward across Polk County by the Lavender Shale Member (Cressler, 1970, p. 41).

Near the depression of the Floyd synclinorium, the Lavender Shale Member apparently is nearly 80 m thick (fig. 4). It is not clear whether the top of the Lavender is equivalent to the top of the Fort Payne or whether the Lavender also includes equivalents of some younger beds.

UNNAMED LOWER LIMESTONE OF CLASTIC FACIES

The lower part of the interval that commonly has been mapped as Floyd Shale is a limestone unit in the depression of the Floyd synclinorium. The limestone may be more than 180 m thick (fig. 4). The lower limestone unit is characterized by bioclastic limestone, some of which contains coarse bioclasts. The unit also includes gray-black, very argillaceous lime mudstones that are similar to the Lavender Shale Member. Some of the bioclastic limestone contains black nodular chert. The very argillaceous lime mudstone within the sequence of bioclastic limestones suggests intertonguing with the clastic facies. Farther south, on the Rome fault block in Polk County, the lower part of the Floyd is shale (slate), and evidently the limestone grades southward to shale.

FLOYD SHALE

The Floyd is characteristically dark-gray to black shale, part of which is calcareous and part of which is carbonaceous. The Floyd Shale above the unnamed lower limestone apparently is as much as 290 m thick (fig. 4). Locally the shale contains siderite nodules, and at one locality in northwestern Polk County pyritic nodules in the shale contain fossils (Cressler, 1970, p. 48). The Floyd includes thin beds of siltstone, sandstone, and limestone. Around Rocky Mountain, the unnamed lower limestone is overlain by calcareous shale; but, around Little Sand Mountain north of Rocky Mountain, the unnamed lower limestone member of the Floyd is overlain by a sandstone unit approximately 11 m thick (fig. 4). The sandstone is characteristically fine grained but the lower part commonly is very fine grained and argillaceous. The lower part of the sandstone consists of thin ripple-laminated sandstones that have thin clay partings. Small unidentified plant fragments lie on bed surfaces.

UNNAMED SANDSTONE AT TOP OF FLOYD SHALE

Most of the Floyd Shale sequence contains relatively little sandstone, but the shale grades upward into a sandstone unit. The sandstone is fine to very fine grained and commonly is interlaminated with clay. The sandstone unit throughout most of its extent appears to be less than 20 m thick (fig. 4); however, it is reported to be about 90 m thick on Judy Mountain west of Rome (Cressler, 1970, p. 48). Because the outcrop on Judy Mountain is isolated by erosion from other exposures of the sandstone, correlation of the much thicker sandstone on Judy Mountain with the thinner sandstone elsewhere is uncertain.

BANGOR LIMESTONE TONGUE OF SOUTHEASTERN CLASTIC FACIES

The limestone interval within the southeastern clastic facies is as much as 200 m thick, but that interval includes beds of shale and sandstone (fig. 4). The Bangor tongue includes bioclastic limestone and argillaceous lime mudstone. Part of the bioclastic limestone contains nodules of dark-colored chert. The argillaceous lime mudstone weathers to massive clay that contains numerous impressions of fenestrate bryozoans. Clastic beds within the Bangor tongue consist of dark-gray clay shale and fine-grained sandstone, generally in thin wavy beds having partings of shale. The limestone interval and the sandstone-shale interbeds indicate repeated intertonguing of the clastic and carbonate facies.

PENNINGTON FORMATION OF SOUTHEASTERN CLASTIC FACIES

Above the Bangor Limestone tongue is a dark-colored shale in the stratigraphic position of the Pennington Formation (fig. 4). The lower part of the Pennington includes thin beds of brown-weathered claystone which contains molds of brachiopods; the claystone may be weathered from argillaceous limestone. The upper part of the Pennington includes thinly bedded sandstone and shale in which sandstone generally increases in abundance upward. Some sandstone beds have micaceous, carbonaceous laminae on top. Siderite nodules are common in parts of the shale sequence. The Pennington Formation interval generally coarsens upward and grades upward into a sandstone unit. Although correlation of the sandstone unit above the shale is uncertain, it may be considered to mark the base of the Raccoon Mountain Formation.

RACCOON MOUNTAIN FORMATION OF SOUTHEASTERN CLASTIC FACIES

The sandstone at the base of the Raccoon Mountain Formation forms a prominent ledge on Rocky Mountain and Little Sand Mountain in Floyd and Chattooga Counties. The sandstone unit is locally more than 50 m thick (fig. 4) and consists of very fine to fine-grained slightly argillaceous sandstone. The beds are characteristically thin; some are ripple laminated. Carbonaceous, micaceous laminae mark the tops of sandstone beds, and clay partings are common. Toward the top of the unit, the sandstone is more quartzose. Echinoderm columnals, bryozoan fragments, and possible brachiopod fragments are preserved in one sandstone bed. The sandstone is overlain by dark-colored shale, similar to the dark-colored shale below the sandstone unit. The upper shale interval is as much as 120 m thick (fig. 4) and includes thin beds of sandstone and a few thin beds of limestone. Thin coaly beds are found in the lower part; siderite nodules are common in the upper part of the shale. The shale at the top of the Raccoon Mountain Formation is overlain by massive bluff-forming sandstone, part of which contains quartz pebbles.

POSSIBLE FACIES TRANSITION

The carbonate and clastic facies in Georgia are distinct, but details of the facies transition are obscure. However, a section exposed around Sand Mountain in Catoosa County east of Ringgold shows features that suggest the nature of the facies transition. Because of complicated structure in the area, different authors have reported different thicknesses and stratigraphic sequences for Mississippian rocks (Allen, 1950; Windham, 1956; McLemore, 1971). The problem is mainly one of recognizing stratigraphic units, particularly the sandstone or sandstones.

The section is mainly limestone, but the lower part is dominated by the Lavender Shale facies rather than the Fort Payne Chert (fig. 4). Above the Mississippian limestone sequence is a thin interval of maroon, green, and gray shale of the Pennington Formation. The Pennington is overlain by massive bluff-forming sandstone that contains quartz pebbles and that is considered to be Pennsylvanian. Between the Lavender and Pennington, most outcrops are limestone. On Sand Mountain, a sandstone unit is exposed within the east-dipping limestone sequence; and west of Sand Mountain on Cherokee Ridge, a sandstone is exposed within the east-dipping limestone sequence. On the assumption that the Hartselle Sandstone is the only sandstone within the limestone sequence in northwest Georgia, both the sandstone on Cherokee Ridge and the sandstone on Sand Mountain have been called Hartselle. That correlation requires that a thrust fault has duplicated the section between Sand Mountain and Cherokee Ridge and that the Mississippian section is 300 to 350 m thick (Windham, 1956; McLemore, 1971, p. 239).

The sandstone on Cherokee Ridge is a distinctive light-gray fine-grained quartzose sandstone that is thick bedded to massive. Where exposed on Cherokee Ridge, this sandstone appears to be at least 15 m thick. The sandstone on Cherokee Ridge is associated with an interval of shale and sandstone which is more than 30 m thick (Allen, 1950, p. 150). In contrast, the sandstone on Sand Mountain is a brown slightly argillaceous fine-grained sandstone characterized by thin, irregular beds, some of which are ripple laminated. Clay partings are common. The contacts between the sandstone on Sand Mountain and the adjacent limestones are not exposed, but the interval that contains the sandstone apparently is not more than 12 m thick.

Both lithologic characteristics and thickness distinguish the sandstone on Sand Mountain from that on Cherokee Ridge. Evidently the two sandstones are not the same but represent two different sandstone tongues within the carbonate facies. Following that interpretation, the amount of implied structural duplication is reduced. The thickness of Mississippian rocks may be nearly 500 m (fig. 4). Whereas a thickness of 300 to 350 m is anomalously thin for the Mississippian in Georgia, a thickness of 500 m is intermediate between that of the carbonate facies and the maximum for the clastic facies.

The possible relationship of the two clastic tongues in the limestone sequence to the Floyd Shale farther south in the Floyd synclinorium has not been established. The section on Sand Mountain east of Ringgold has some characteristics of the southeastern clastic facies but it is dominated (above the Lavender at least) by carbonate rocks similar to those of the northwestern carbonate facies. Regardless of interpretation of details, the section on Sand Mountain contains a large amount of carbonate rock and is more like the northwestern carbonate facies than the southeastern clastic facies. Facies strike, therefore, crosses structural strike along the western north-trending branch of the Floyd synclinorium where the clastic sequence of the depression grades northward into the intermediate or carbonate sequence on Sand Mountain.

PALEONTOLOGY

BIOSTRATIGRAPHY

The oldest formation in the Mississippian of northwest Georgia is the Maury Shale which overlies the Late Devonian Chattanooga Shale. Regional correlations based on conodont studies show that the Maury is of Kinderhook age and that the upper beds are probably Osage (Hass, 1956).

The Fort Payne Chert contains a fauna of corals and brachiopods characteristic of the Keokuk and Burlington Formations of the standard Mississippian section of the Mississippi Valley (Butts, *in* Butts and Gildersleeve, 1948, p. 44). Among the typical fossils reported from the Fort Payne are "*Hadrophyllum ovale, Zaphrentis* cf. *Z cliffordana, Z. compressa,* large crinoid stems, one-half inch or more in diameter, *Athyris lamellosa, Chonetes shumardanus, Linoproductus ovatus, Dictyoclostus* (*Productus*) cf. *D. crawfordsvillensis, D.* cf. *D. inflatus, D.* cf. *D. viminalis, Spirifer, leidyi* type, *Spirifer rostellatus*" (Butts, *in* Butts and Gildersleeve, 1948, p. 44). Cressler (1970, p. 42) collected *Torynifer* cf. *T. pseudolineata, Leptogonia* cf. *L. analoga Brachythyris* cf. *B. suborbicularis, Spirifer* sp., *Cleiothyridina*? sp., echinoderms, and corals from the Fort Payne of Polk County.

The Lavender Shale Member of the Fort Payne Chert contains a bryozoan and brachiopod fauna which also demonstrates equivalence to the Burlington-Keokuk (Butts, *in* Butts and Gildersleeve, 1948, p. 44). From the Lavender Shale Member, Butts (*in* Butts and Gildersleeve, 1948, p. 44) tentatively identified "*Dictyonema* sp., *Cystodictya linearis, Hemitrypa* near *H. nodosa, Fenestrellina burlingtonensis, Fenestralina* near *funicula, F. multispinosa, F. regalis, F.* near *F. rudis, Brachythyris subcardiformis*?, *Cleiothyridina glenparkensis, Dictyoclostus* (*Productus*) *burlingtonensis, Phaethonides spinosus.*" The Lavender Shale Member in Polk County has yielded *Brachythyris* sp., other brachiopods, *Cypricardella* or *Cypricardinia* sp., other pelecypods, *Sinuitina*? sp., other gastropods, and echinoderms (Cressler, 1970, p. 43). The trilobite, *Australosutura georgiana,* has been described from the Lavender Shale Member near Ringgold (Rich, 1966) and has been collected from the Fort Payne Chert in Alabama (McKinney, 1969).

The name Tuscumbia Limestone is now applied to the cherty limestone beds which Butts (*in* Butts and Gildersleeve, 1948, p. 45) referred to the St. Louis Limestone. Like most of the other formation names that Butts extended from the Mississippi Valley section into Alabama and Georgia, the St. Louis was recognized mainly on the basis of its fossil fauna. Thus, the unit was traced as a biostratigraphic zone rather than as a lithostratigraphic formation. The Tuscumbia (St. Louis) in Georgia is characterized by the presence of two species of corals, *Lithostrotionella castelnaui* and *Lithostrotion proliferum* (Butts, *in* Butts and Gildersleeve, 1948, p. 46). No fossils diagnostic of Warsaw and Salem have been reported from the section in Georgia, and Butts (*in* Butts and Gildersleeve, 1948, p. 42) concluded that a hiatus separates Fort Payne and St. Louis. However, the lower Tuscumbia in Alabama contains a Warsaw-Salem fauna (Drahovzal, 1967, p. 14). The lithologic succession in Georgia does not require an unconformity, and possibly the lack of Warsaw-Salem fossils is a result of factors other than a hiatus.

The Monteagle-Bangor Limestones contain a characteristic Genevievian-Chesterian fauna. Butts (*in* Butts and Gildersleeve, 1948, p. 3–79) listed fossils representative of the Ste. Genevieve, Gasper, Golconda, and Glen Dean from the sequence now assigned to the Monteagle-Bangor. The units Butts understood as formations are now defined as time-stratigraphic units in Illinois (Swann, 1963). The succession is divided into Genevievian (Ste. Genevieve), Gasperian (Gasper), Hombergian (Golconda-Glen Dean), and Elviran (post-Glen Dean) Stages (Swann, 1963, fig. 1). Because the definition of a formation used by Butts and others of his time was based on index fossils, the formations are directly comparable with time-stratigraphic subdivisions. Thus, Butts' work provides a time-stratigraphic correlation with the Mississippi Valley section.

The Monteagle contains the Ste. Genevieve guide fossil, *Platycrinus penicillus* (Butts, *in* Butts and Gildersleeve, 1948, p. 46; McLemore, 1971, p. 115). Gasper forms reported from Georgia include *Talarocrinus, Campophyllum gasperense, Pentremites pyriformis, P. godoni,* and *Agassizocrinus ovalis* (Butts, *in* Butts and Gildersleeve, 1948, p. 47). Lithostrotionoid corals, similar to the characteristic forms of the St. Louis, are found in association with Gasper faunas in the limestone sequence in northwest Georgia (Butts, *in* Butts and Gildersleeve, 1948, p. 47) and in the Floyd Shale (Broadhead, 1975, p. 33). The value of lithostrotionoids as guides to the Meramec may be questioned in light of these associations. Beds equivalent to the Golconda are marked by *Pterotocrinus capitalis* (Butts, *in* Butts and Gildersleeve, 1948, p. 47).

The Bangor contains a distinctive Glen Dean fauna including *Pentremites cherokeeus, P. spicatus, Archimedes communis, A. meekanus, A. swallovanus, Fenestrellina cestriensis, F. serrulata, F. tenax, Prismopora serrulata, Septopora subquadrans, Polypora cestriensis, Composita subquadrata,* and *Spiriferina transversa* (Butts, *in* Butts and Gildersleeve, 1948, p. 48). A collection from an outcrop of the Bangor Limestone and Pennington Formation northwest of Rising Fawn includes *Pterotocrinus tridecibrachiatus, P. edestus,* and *Pentremites gutschicki*; these forms indicate age equivalence of the upper Bangor to the Kinkaid Limestone of the Illinois basin (Waters and Chowns, 1977).

Fossils from the Floyd Shale include an age range of Meramec to Chester; index fossils are listed by Broadhead (1975, p. 30–31) as:

Chester undifferentiated
- *Cleiothyridina sublamellosa*
- *Reticulariina spinosa*
- *Spirifer leidyi*
- *Pentremites* (*godoni* and *pyriformis* groups)
- *Agassizocrinus*
- *Zeacrinites*

Middle Chester
- *Cravenoceras*
- *Tylonautilus*

Lower Chester
- *Talarocrinus*
- *Lyrogoniatites*
- *Neoglyphioceras*

Meramec
- *Cystelasma*
- *Lithostrotionella*
- *Lithostrotion proliferum*
- *Perditocardinia dubia*
- *Forbesiocrinus*

Some assemblages from the Floyd contain forms characteristic of two successive stages; for example, one assemblage contains both the Lower Chesterian goniatite *Lyrogoniatites* and the Middle Chesterian goniatite *Cravenoceras* (Broadhead, 1975, p. 32). Broadhead (p. 32) concludes that these assemblages are from beds very near the stage boundary. The oldest fauna in the Floyd Shale includes both *Cystelasma* and *Perditocardinia dubia* which have been reported from the Salem Limestone (Broadhead, 1975, p. 34). The limestone unit within the lower Floyd contains *Talarocrinus* which is distinctive of the Gasper (Butts, *in* Butts and Gildersleeve, 1948, p. 51). Butts (*in* Butts and Gildersleeve, 1948, p. 51) reported fossils distinctive of St. Louis and Gasper from the Floyd east of Ringgold; however, the section at that locality is mainly limestone like the Tuscumbia and Monteagle. Fossils collected from the Floyd Shale in western Polk County include *Lyrogoniatites newsomi georgiensis, Goniatites* cf. *G. kentuckiensis,* and *Neoglyphioceras georgiensis* which indicate an Early Chester age (Crawford, 1957, p. 46; Cressler, 1970, p. 49).

The youngest fossils from the Floyd are compatible with an age assignment that is equivalent to the Haney (upper Golconda) Limestone (Broadhead, 1975, p. 35). Within the clastic sequence, the sandstone at the top of the Floyd Shale has been assumed to be equivalent to the Hartselle Sandstone of Alabama, and the sandstone is overlain by a limestone that has been considered to be a tongue of the Bangor Limestone. The Bangor Limestone in the carbonate facies of northwest Georgia and Alabama contains a Glen Dean fauna; and, because of its position below the Bangor, the Hartselle Sandstone of Alabama has been assumed to be equivalent to the Hardinsburg Sandstone of the Mississippi Valley (Butts, 1926, p. 195). Limestone within the clastic sequence in northeastern Chattooga County has yielded specimens of *Pentremites robustus* which indicates age equivalence to Haney or Glen Dean (J. A. Waters, written commun., 1978).

PALEOECOLOGY

Fossil faunas indicate marine environments for Mississippian sediments in northwest Georgia. The carbonate facies of northwest Georgia is characterized by a brachiopod-bryozoan-echinoderm-coral fauna that indicates an open-marine-shelf environment. Echinoderm fragments are associated with rock types that denote high current energy. (McLemore, 1971, p. 49). Rock types that suggest low current energy contain relatively large concentrations of bryozoans (McLemore, 1971, p. 104). Reeflike clusters of corals are less than 1 m in height and width (Owen, 1955).

Broadhead (1975, 1976) has defined and characterized five communities of marine benthic organisms within the Floyd Shale (fig. 7). Definition of the communities has been based on the recognition of a few groups of animals, and each of the communities may show much faunal diversity (Broadhead, 1975, p. 42; 1976, p. 268). Communi-

COMMUNITY	CHARACTERISTICS	ROCK TYPES	INTERPRETATION
(1) *Lingula*	Low faunal diversity; *Lingula*; bryozoans, articulate brachiopods; fragments of terrestrial plants	Bioturbated sandy siltstone and silty shale	Prodelta or distal delta front
(2) Bivalvia-Spiriferida-Productidina	High faunal diversity; *Inflatia, Spirifer, Phestia, Aviculopecten*; bryozoans, echinoderms, gastropods; fragments of terrestrial plants	Silty shale to argillaceous limestone	Restricted bays
(3) Fenestellidae	Low faunal diversity; *Fenestella, Archimedes*; brachiopods	Calcareous shale to siltstone	Bay, distal prodelta, mudbank
(4) *Pentremites*-Spiriferida-Fenestellidae	High faunal diversity; *Pentremites, Composita, Cleiothyridina, Spirifer, Reticulariina, Inflatia, Michelinia*; crinoids, gastropods, pelecypods, bryozoans	Calcareous shale to lime mudstone	Open marine shelf
(5) *Michelinia*-Rugosa	Low faunal diversity; *Michelinia, Pentremites*; crinoids, brachiopods	Lime mudstone to bioclastic and oolitic limestone	Carbonate bank

FIGURE 7.—Chart showing marine benthic communities in the Floyd Shale (modified from Broadhead, 1975, 1976).

ties 1, 2, and 3 reflect various components of a prograding delta, whereas communities 4 and 5 are associated with transgressive carbonate units that suggest delta destruction. Although understanding of the distribution of communities is complicated by complex structure and some uncertainty in stratigraphic position, communities 1 and 2 are most common on the south and east, and community 5 is restricted to the north and west (Broadhead, 1976, p. 272). Community 4 is widely distributed, but community 3 is relatively uncommon (Broadhead, 1976, p. 272). The evident distribution pattern suggests that a delta system prograded northward and (or) westward onto a marine shelf and that episodically delta lobes were abandoned and reworked. At a locality in Catoosa County, east of Ringgold, an oolitic and skeletal limestone containing community 5 is overlain by about 1 m of silty limestone and siltstone that contains fragments of a terrestrial plant (Broadhead, 1975, p. 60; 1976, p. 271). The plant-bearing beds are overlain by calcareous shale and limestone containing community 4. This locality is in the probable area of facies transition and apparently is indicative of numerous, abruptly bounded tongues of the southeastern clastic facies within the carbonate facies.

DEPOSITIONAL AND TECTONIC FRAMEWORK

The major facies of Mississippian rocks in northwest Georgia were deposited in two different depositional regimes. On the northwest is a carbonate-shelf sequence and on the southeast is a fine-clastic sequence of prodelta and delta-front sediments. Intertonguing of the carbonate and clastic facies results from migration of the prograding delta front and episodic transgression of the carbonate shelf facies over the deltaic sediments (fig. 4). The northwestern corner of Georgia remained in the carbonate-shelf regime throughout most of the Mississippian. In latest Mississippian an extensive complex of clastic sediments prograded over the carbonate facies.

The thinness and mineralogy of the Maury Shale suggest very slow accumulation of clastic sediments (McLemore, 1971, p. 99), and the Fort Payne Chert indicates the initial deposition of Mississippian carbonate sediments on the shallow-marine shelf. The association of dolostone and relict evaporites in the Fort Payne reflects a sabkha environment (Chowns, 1972, p. 90). On the east, the argillaceous limestone and calcareous shale of the Lavender Shale Member are evidently the most distal part of a sediment dispersal system and probably were deposited in deeper water off the shallow shelf (fig. 8*A*). The broad area of mixing of carbonate and clastic sediments in the Lavender suggests that no abrupt shelf edge had formed.

The Tuscumbia cherty limestones were deposited in an open-marine-shelf environment (fig. 8*B*). The Tuscumbia probably is correlative with at least the lower part of the lower limestone member of the Floyd Shale. If we assume that correlation, the Tuscumbia and related limestones extend farther east than part of the Fort Payne Chert and represent a

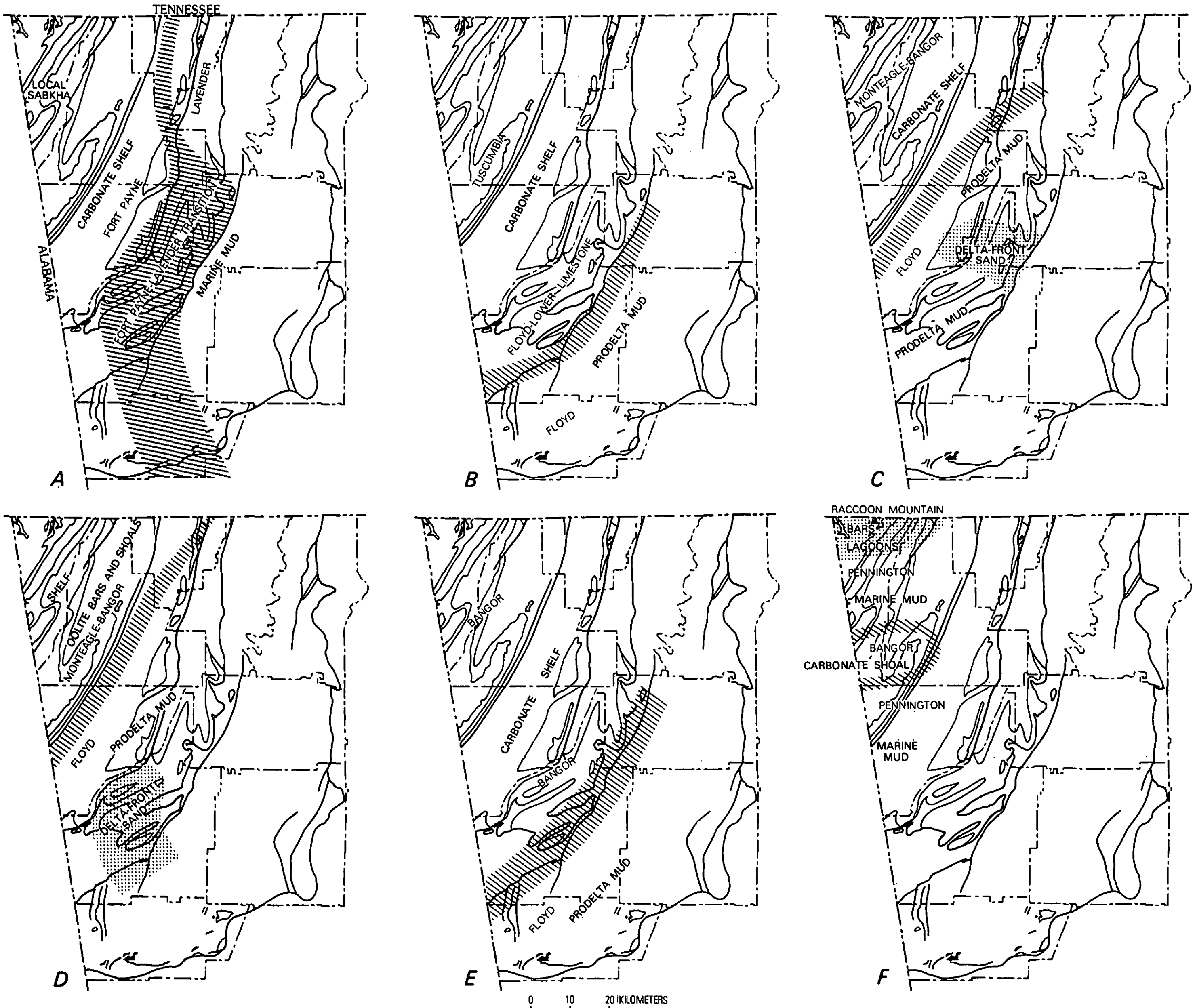

FIGURE 8.—Generalized lithofacies and paleogeographic maps of Mississippian rocks in northwest Georgia. Approximate stratigraphic position of each map is shown by letter on cross sections in figure 4. Line pattern indicates approximate area of facies transition. *A*. Fort Payne Chert/Lavender Shale Member. *B*. Tuscumbia Limestone/unnamed lower limestone/Floyd Shale. *C*. Lower part of Monteagle-Bangor Limestones/Floyd Shale. *D*. Middle part of Monteagle-Bangor Limestones/unnamed sandstone/Floyd Shale. *E*. Upper part of Monteagle-Bangor Limestones/Bangor Limestone tongue in clastic facies/Floyd Shale. *F*. Pennington Formation/Raccoon Mountain Formation/top of Bangor Limestone.

transgression of the shallow-marine shelf over the muddy sediments of the Lavender.

The Monteagle-Bangor sequence demonstrates persistence of the carbonate shelf (fig. 8*C*, 8*D*, and 8*E*). The sequence is mainly composed of oolitic and bioclastic limestones that indicate high-current energy on shoals and bars of a carbonate bank (McLemore, 1971; fig. 6). Lime mudstones and muddy bioclastic limestones indicate deposition on the shelf in protected lagoons between oolite shoals. Rare dolostones suggest local supratidal areas on the shelf. Rare beds of shale represent the most distal outwash from laterally equivalent clastic facies.

On the southeast, the fine clastic sequence of the Floyd Shale consists mainly of prodelta muds (fig. 8*C*). Benthic faunal communities in the Floyd suggest distal prodelta, delta front, and marine-bay environments (Broadhead, 1975; 1976; fig. 7). On the Rome fault block, prodelta shales rest directly on Fort Payne Chert (compare fig. 8*A* with fig. 8*B*). Farther northwest, the prodelta shales overlie the lower limestone member of the Floyd (compare fig. 8*B* with fig. 8*C*). The lower limestone is evidently equivalent to the lower part of the carbonate facies, presumably Tuscumbia and part or all of Monteagle. These relations indicate northwestward progradation of the prodelta sediments onto the carbonate shelf. Argillaceous zones within the lower limestone indicate pulses in the general progradation.

Sandstone units in the Floyd Shale are delta-front sands (fig. 8*C* and 8*D*). The sequence locally coarsens upward from shale into sand through a fine-grained ripple-laminated sand. The upper part of each sand unit is generally more thick bedded and quartzose. At least two different sandstone units are present: one just above the lower limestone unit, the other at the top of the Floyd (fig. 4).

Because of the small outcrop area and poor exposures, insufficient data are available to define the extent of the sandstone units, and details of geometry of the delta-front facies are unknown. The deltaic sediments locally prograded northwestward, and distribution of facies demonstrates that clastic sediment was transported into the area south and east of the carbonate facies. Presumably the preserved delta-front sediments were supplied through a fluvial system, but the orientation of the fluvial system and the location of the source of the sediment presently cannot be defined.

Other Mississippian clastic facies in the region indicate similar deltaic deposition, and for some of these the directions of progradation are better defined. On the west in Alabama, a deltaic sandstone-shale sequence in the Parkwood Formation progrades northeastward onto the western part of the Bangor Limestone (Thomas, 1972a, p. 81; 1974, p. 196). Along Appalachian synclines in Alabama the Parkwood deltaic sandstones reach their maximum eastward extent but apparently are limited to the west of the Georgia-Alabama State line. Thus, the sandstone units in the Floyd Shale of Georgia evidently are not continuous with the Parkwood sandstones presently exposed in Alabama. Furthermore, the most extensive Parkwood sandstones are in the upper part of the Mississippian section in Alabama, and the most extensive sandstones in the section in Georgia appear to be older.

To the north in Tennessee, a clastic sequence of Pennington, Raccoon Mountain, and younger units progrades southwestward over the Mississippian carbonate facies (Ferm and others, 1972, fig. 3). However, that clastic wedge progrades over the Bangor Limestone in Georgia and is younger than the deltaic sandstones of the Floyd (fig. 4). Older Mississippian clastic rocks are preserved locally in the Greasy Cove Formation in eastern Tennessee (Neuman and Wilson, 1960); but, because of limited exposure, the original extent of that unit is unknown.

Possibly the fluvial system that fed the deltaic facies in Georgia originated in the same provenance as did the Parkwood system of Alabama or in the same provenance as did the Greasy Cove clastic rocks on the north in Tennessee. Either source requires a long fluvial system outside (on the south or east) the limits of presently preserved Mississippian strata in Georgia. Alternatively, the sandstones in Georgia may have had local sources to the south or east. Regardless of the location of the sediment source, preserved rocks in Georgia are in the prodelta and delta-front facies (fig. 8*C* and 8*D*). No sediments of the delta plain have been recognized.

An extensive tongue of Bangor Limestone indicates marine transgression over the deltaic sandstone facies (fig. 8*E*). The contact between the sandstone and overlying transgressive limestone is not exposed, and details of destructional reworking of the abandoned delta lobe cannot be defined on the basis of available data. Within the limestone tongue another shale-sandstone unit indicates another pulse of delta progradation that was followed by delta destruction and deposition of the upper part of the limestone.

The Bangor grades upward into marine shale of the Pennington, and the Pennington grades upward from maroon and green mudstone to gray shale. The upper part of the shale sequence contains siderite nodules and carbonaceous beds as well as sandstone interbeds. The Pennington-Raccoon Mountain sequence represents the transition from marginal marine to bay and lagoonal sediments (fig. 8*F*). A few local bar sands are included. The fine-grained clastic sequence is overlain by massive sandstone of a barrier complex (Ferm and others, 1972). The clastic sediments in the upper part of the Mississippian in Georgia are part of a large-scale clastic wedge that prograded southwestward over the Mississippian carbonate facies (Thomas, 1974, p. 205; 1977b, p. 1258).

PENNSYLVANIAN STRATIGRAPHY OF NORTHWEST GEORGIA

By Howard R. Cramer

LITHOFACIES

Pennsylvanian sedimentary rocks are confined to Chattooga, Dade, Walker, Catoosa, and Floyd Counties (figs. 3 and 9), and have been summarized in three major regional studies (Wanless, 1946; Stearns and Mitchum, 1962; McKee and others, 1975). The rocks are almost entirely clastic and are, in approximate order of abundance: sandstone, siltstone, shale, coal, clay (as underclay), and siderite (also called ironstone). Some of the clastic rocks are cemented by carbonate. Very little limestone is known.

Coal is the major economic resource of the Pennsylvanian rocks, and has been the subject of many reports. The works of McCallie (1904) and Johnson (1946) remain the most comprehensive studies of the coal and enclosing rocks to date, although much detail can be gleaned from the publications of the U.S. Geological Survey and the U.S. Bureau of Mines.

EVOLUTION OF STRATIGRAPHIC NOMENCLATURE

Coal-bearing rocks have long been known from Georgia. Maclure's map (1809) showed the rocks to be Secondary in age (following the Wernerian scheme), and his text alluded to coal. Williams' map (*in* White, 1849) showed the rocks to be Transition in age (still following the Wernerian scheme) and outlined two distinct coal terranes, one in Dade County and the other in Walker County. Hayes (1892) was the first to subdivide the Pennsylvanian rocks of Georgia. He recognized two distinct units, the Lookout Sandstone below and the Walden Sandstone above.

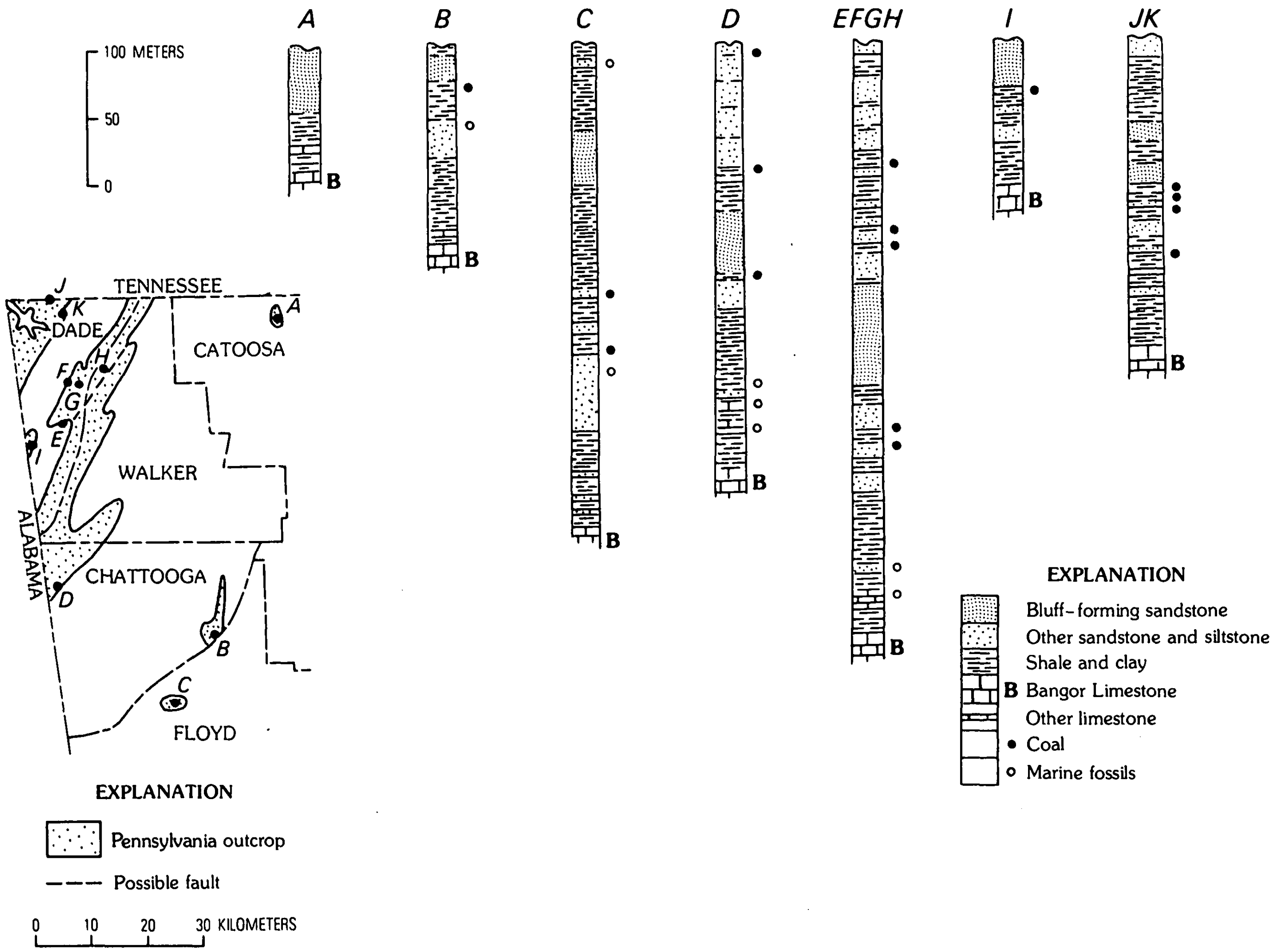

FIGURE 9.—Generalized columnar sections showing Pennsylvanian and Mississippian rocks above the Bangor Limestone.

Other studies of Pennsylvanian rocks in nearby States, notably Alabama and Tennessee, have resulted in nomenclature which has been later introduced for the rocks of Georgia. Culbertson (1963) summarized the history of Pennsylvanian nomenclature in Georgia.

More recently, the U.S. Geological Survey Pennsylvanian paleotectonic study (McKee and others, 1975) included much data about the Pennsylvanian of Georgia; the rocks are included in the stratigraphic category of Interval A. The stratigraphic nomenclature has been deliberately simplified for regional comprehension.

Most recently, the geologic map of Georgia (Georgia Geological Survey, 1976) has been revised, and the twofold subdivision of the rocks proposed by Hayes (1892) has been retained. Figure 10 shows the nomenclature that has been used for the Pennsylvanian rocks of Georgia. Because the rock succession consists of alternating units of sandstones and gray shales and siltstones, the identification and tracing of a common reference unit is difficult, causing much confusion in the nomenclature. The figure shows: (a) That there have been numerous interpretations for the same rocks, (b) that uncertainties exist even in the most recent interpretations, and (c) why the nomenclature used in this report has been simplified.

In order to avoid introducing any new names into what is intended to be a summary, no formal stratigraphic nomenclature is used in this report; all of the rocks are Early Pennsylvanian, or Pottsvillian in age.

Generally, the Pennsylvanian of Georgia is exposed in sandstone-capped plateaus and mountain tops, and these topographic features can be used for reference. Three categories of Pennsylvanian rocks can be recognized: (a) Massive bluff-forming sandstone on the brow of the plateaus at the top of steep slopes. Massive sandstone may be found in the rocks below the bluff-forming sandstone, giving the impression of two sandstone bluffs. In these places, notably near Cloudland, the upper one is considered the bluff-forming sandstone. (b) Rocks stratigraphically, and general topographically, above the bluff-forming sandstone. (c) Rocks below the bluff-forming sandstone exposed in the steep slopes of the plateaus and above the Mississippian Monteagle-Bangor Limestones.

This threefold subdivision is used entirely for reference, and no stratigraphic correlation is intended. For instance, the bluff-forming sandstone is probably not everywhere the same continuous stratigraphic unit. It has been called by different researchers in different places, the Flat Rock Sandstone, the Warren Point Sandstone, the Sewanee Conglomerate, the Lookout Sandstone, or the Bon Air Sandstone.

LITHOSTRATIGRAPHY

Correlation problems result from many factors, economic, topographic, and stratigraphic.

During the years when the stratigraphy of the area was being defined, coal mining was not extensive, and was entirely underground, providing few or no maps of value to the modern stratigrapher. Now strip mining is taking place, although only in very limited areas.

Topographically, problems result from the generally poor exposures on the talus-covered steep slopes of the plateaus and on the flat terrane of the plateau surfaces. Sandstone or conglomerate forms the brow of the plateaus, and as many similar-appearing sandstones and conglomerates are in the section, visual tracing is the only way to correlate one rock unit with another.

Stratigraphically, correlation is difficult because: (a) Measured sections taken from the literature are often incomplete because of the topographic difficulties cited, or are very old and not sufficiently detailed for modern stratigraphic interpretation. (b) Sections often encompass several miles of horizontal traverse to include but a few hundred feet of vertical section. In view of the rapid horizontal facies changes known, such sections, if presented vertically, would be misleading. (c) Almost all of the previous correlations have been based upon the assumption that the rocks are in continuous blankets, especially the coal seams. The rocks are now suspected to be of deltaic or littoral origin, and as such would have very limited horizontal continuation. (d) The common occurrence of sedimentation features such as pebble beds and zones, crossbedding, flaser bedding, and so on, both in horizontal and vertical context, make the use of these features extremely sensitive for correlation over any but immediate outcrop distances. (e) Almost no paleontological data are available except for a few floral lists from uncertain stratigraphic and geographic localities (just enough to show the rock to be Early Pennsylvanian). (f) Uncertain, but probable, structural complexities in the region may have juxtaposed distinctly different stratigraphic or sedimentologic units.

Another correlation problem relates to the base of the Pennsylvanian System, at its contact with the

UNDERLYING ROCKS	PENNSYLVANIAN ROCKS	AUTHOR AND DATE
Upper Sub-Carboniferous	Coal Measures	Little 1876
Bangor Limestone	Lookout Sandstone; Walden Sandstone	Hayes 1892
Pennington Formation	Pottsville Formation	Georgia Div. of Mines, Mining and Geology 1939
Pennington Formation	Lookout Formation (Unnamed; Lower Conglomerate; Unnamed; Upper Conglomerate); Walden Formation	Moore and others 1944
Pennington Formation	Lookout Formation (Gizzard Member; Sewanee Member); Whitwell Shale; Bonair Sandstone; Vandever Shale; Rockcastle Sandstone	Johnson 1946
Pennington Formation	Lee Group (Unnamed; Warren Point Sandstone; Gizzard Formation; Sewanee Conglomerate; Whitwell Shale; Eastland Sandstone; Newton Sandstone)	Wanless 1946
Pennington Formation	Carboniferous (on map); Pennsylvanian (in legend); Pottsville Formation (in text)	Butts and Gildersleeve 1948
Pennington Formation	Pottsville Series; New River Group	Stearns and Mitchum 1962
Pennington Formation	Gizzard Formation (Raccoon Mountain Formation; Warren Point Sandstone; Signal Point Shale); Crab Orchard Mountains Group (Sewanee Conglomerate; Whitwell Shale; Newton Sandstone; Vandever Shale; Rockcastle Sandstone)	Culbertson 1963
Pennington Formation	Gizzard Group (Norwood Cove Formation; Flat Rock; Warren Point Sandstone; Signal Point Shale); Crab Orchard Mountains Group (Sewanee Conglomerate)	Wilson 1965
Pennington Formation	Interval A_2	McKee and others 1975
Pennington Formation	Lookout Sandstone (Gizzard Formation; Sewanee Conglomerate); Pennsylvanian undifferentiated	Georgia Geological Survey 1976
Rocks below bluff-forming sandstone	Bluff-forming sandstone; Rocks above bluff-forming sandstone	This paper

FIGURE 10.—Correlation chart showing the evolution of Pennsylvanian nomenclature in Georgia.

underlying Mississippian System. The actual level of the contact in the succession of rocks below the bluff-forming sandstone is unclear, and has been much discussed in the literature; in some places the bluff-forming sandstone may be Mississippian.

The rocks below the bluff-forming sandstone are predominantly shale containing bedded sandstone and coal (fig. 9). The sandstones may be well developed and several meters thick. A small amount of nodular and laminar siderite is found in some localities. The paleobotanical data are sparse; only a few plants and no palynomorphs have been described. Only recently have marine invertebrates been discovered in these rocks immediately below the bluff-forming sandstone, and these have not yet been evaluated. These rocks have been called the Raccoon Mountain Formation, the Gizzard Formation, and the lower part of the Lookout Sandstone.

Underlying this sandstone and shale sequence is another sequence of clastic rocks, mainly shale, but including limestone, a little sandstone, and a small amount of coal and siderite. These clastic beds contain, in some localities, unquestioned Mississippian marine fossils, and are generally included in the Pennington Formation. These rest upon unquestioned marine limestones of the Monteagle-Bangor sequence.

The contact between the clastic Pennington rocks and the clastic rocks overlying them is not obvious in the field. Some geologists separate the two sequences on the basis of unconformity, but because of the nature of the sedimentation, there are several unconformities within them. Other geologists separate the two sequences on the basis of lithology, but it can be shown that the lithology of each formation is not unique, and the exposures are generally poor. Still other geologists would separate the two sequences on the basis of fossils, but fossils are sparse.

Accordingly, in the following discussion, and on figure 9, these rocks are not separated, but are included together in the clastic sequence known as the "rocks below the bluff-forming sandstone" and above the Monteagle-Bangor Limestones.

For the above reasons, it seems prudent to describe the Pennsylvanian rocks of Georgia purely as vertical lithologic successions and to avoid any horizontal correlation. Cores are important because they show the true vertical sequence and lithology of the sediments. Unfortunately, some of the more important sedimentary characteristics needed for correlation are not recovered from cores, particularly sedimentary structures and their orientation. Core data are used wherever possible in the following discussions, and are supplemented by data from nearby outcrops where possible.

The following discussions of Pennsylvanian rocks are taken from the most recently-published geologic map of Georgia (Georgia Geological Survey, 1976), from the published accounts from which the map was prepared, and from fieldwork by the authors.

PENNSYLVANIAN ROCKS ON SAND MOUNTAIN, CATOOSA COUNTY

Sand Mountain in Catoosa County (fig. 9, locality A) contains a small outlier of Pennsylvanian rocks preserved in a syncline at the northern part of the Floyd synclinorium. Pennsylvanian rocks underlie only a few hundred square meters at the crest of the mountain.

No cores are known. The section illustrated in figure 9 is taken from two sources. The upper part, the bluff-forming sandstone, is taken from Allen (1950, p. 158), and the lower part, rocks below the bluff-forming sandstone, are from McLemore (1971, p. 239). The section is at the crest of the mountain.

The bluff-forming sandstone consists entirely of massively bedded, crossbedded, conglomeratic quartz sandstone, 46 m thick. It has been called the Pottsville by Allen (1950), the Lookout Sandstone by Hayes (1894) and Cressler (1963), and on the present geologic map of the State (Georgia Geological Survey, 1976). McLemore (1971) called these rocks the Raccoon Mountain Formation.

The rocks below the bluff-forming sandstone are poorly exposed, but are entirely shale, 29 m thick. In this area, the rocks were called the Pennington Formation by Allen (1950) and Mc Lemore (1971) and were considered Mississippian in age.

No coals are known, and the basis for considering the bluff-forming sandstone Pennsylvanian is entirely its stratigraphic position. No fossils are reported from the Pennington Formation at this locality, and its age is considered Mississippian on the basis of its regional distribution and stratigraphic position.

PENNSYLVANIAN ROCKS ON LITTLE SAND MOUNTAIN, CHATTOOGA COUNTY

Pennsylvanian rocks are mapped as constituting the entire mountain, and are preserved in the Floyd synclinorium (fig. 9, locality B). These are among the least known Pennsylvanian rocks in Georgia, and to this date, no measured section has been published. A brief description by Spencer (1893, p. 127) is the only published account:

> a remnant of the Coal Measures occurs on Little Sand Mountain, which rises from 300 to 500 feet above the valley.

The lower part of the mountain consists of shale succeeded by sandstone, which are massive, but in layers of moderate thickness. The surface of the southern end of the mountain forms a basin, drained by Mill Creek, which cascades over a ledge of sandstone 15 or 20 feet thick. Descending the little chasm of the horse-shoe falls, there is a layer of rock, more or less shaly, having a thickness of 15 inches, through which a dozen seams of coal are scattered, each with a thickness of a quarter or half an inch. From this plateau a ridge extends some miles northward, composed of the same rock. No other coal is known upon it other than that just described.

The section illustrated in figure 9 has been compiled from field reconnaissance, topographic maps and aerial photographs, and from a generalized description of part of it given by Mc Lemore (1971, p. 246). All the rocks described are from the southern part of the mountain.

The beds overlying the Monteagle-Bangor Limestones and below the bluff-forming sandstone consist of about 121 m of clastic rocks, the lower 56 m of which are mainly gray and green shale containing siderite nodules and fenestrate bryozoans. Overlying this shale sequence is about 30 m of thin-bedded, flaggy, fine-grained sandstone which contains a marine fauna of fenestrate bryozoans, echinoderm columnals, and possibly brachiopods; this fauna has not yet been evaluated.

Overlying this sandstone is a poorly exposed section of about 35 m of gray shale.

The bluff-forming sandstone apparently rests unconformably upon the gray shale, is about 15 m thick, is massively bedded at the base, and more thinly bedded toward the top. The quartz sandstone contains discrete beds of conglomerate containing quartz pebbles as much as 1 cm in diameter.

The bluff-forming sandstone is overlain by an unknown thickness of gray shale that fills the bowl of the basin at the southern end of the mountain; the sandstone forms the rim. The shale is at least 10 m thick.

Mc Lemore (1971, p. 246) considered the clastic rocks above the Bangor Limestone and below the thin-bedded, fine-grained sandstone to be the Mississippian Pennington Formation, and the thin-bedded, fine-grained sandstone to be the basal sandstone in the Raccoon Mountain Formation. The 1939 geologic map of the State (Georgia Div. Mines, Mining, and Geology, 1939) showed all the rocks above the shale to be Pottsville as did Cressler (1970). The most recent geologic map of the State (Georgia Geological Survey, 1976) has the rocks mapped as Pennsylvanian undifferentiated.

For this report, the lowermost clastic rocks are considered Mississippian on the basis of regional facies considerations and paleontology. The bluff-forming sandstone is considered Pennsylvanian only on the basis of its stratigraphic position.

PENNSYLVANIAN ROCKS ON ROCKY [ROCK] MOUNTAIN, FLOYD COUNTY

Rocky Mountain, called Rock Mountain on the 7½-minute quadrangle, contains an outlier of Pennsylvanian rocks preserved in a syncline within the Floyd synclinorium (fig. 9, locality C).

Natural exposures on the rugged slopes are extremely poor, resulting in very limited and incomplete knowledge of the section from surface exposures. Recently, however, the Georgia Power Co. has investigated the mountain in regard to construction of a pump-storage facility, and has taken numerous cores. The section illustrated in figure 9 is prepared from several of these cores which overlap to form a complete section. The top of the section is within a few feet of the top of the mountain, both topographically and stratigraphically.

The lowermost 75 m of rocks, those above the Bangor Limestone, are mainly shale containing beds of limestone and carbonatic sandstone, with a few thin seams of coal near the top. Above these beds are about 55 m of thin-bedded, fine-grained sandstone which forms ledges or steps on the slope of the mountain, and which contains marine fossils.

This ledge-forming, thin-bedded, fine-grained sandstone is overlain by 120 m of gray shale containing a few beds of sandstone, some of which are fossiliferous.

Above this shaly sequence is about 40 m of bluff-forming sandstone which is massively bedded, cross-bedded, channeled, and medium to coarse grained; it is somewhat thinner bedded toward the top, and conglomeratic throughout. This unit forms the prominent scarp around the top of the mountain.

Over the bluff-forming sandstone is a gray shale sequence, 63 m thick, which contains a few beds of carbonatic, medium-grained, arkosic sandstone, and a marine fauna of gastropods, pelecypods, orthoconic nautiloids, fenestrate bryozoans and brachiopods.

Published accounts of the rocks on Rocky Mountain are unclear about the nomenclature used for the rocks below the bluff-forming sandstone. The lower, shaly part regionally resembles the Pennington Formation of Mississippian age, but no basis exists for an age assignment for the fine-grained sandstone nor for the bluff-forming sandstone and the rocks above it except for the marine fossils which have not yet been evaluated. No coals other than the thin seams mentioned are known. The bluff-forming sandstone is generally considered to be Pottsville on the basis of its lithology and stratigraphic position.

PENNSYLVANIAN ROCKS ON PIGEON MOUNTAIN AND ON THE SOUTHERN PART OF LOOKOUT MOUNTAIN, CHATTOOGA, DADE, AND WALKER COUNTIES

Lookout Mountain and Pigeon Mountain together form a sigmoidal-shaped, flat-topped plateau west of the Peavine anticlinorium. Because the section on the southern part of Lookout Mountain is different from the section on the northern part, and because a structural discontinuity may be between them, it seems practical to discuss the two parts of the mountain separately; the rocks on Pigeon Mountain are continuous with the rocks on the southern part of Lookout Mountain. The line of distinction between the northern and southern parts of Lookout Mountain appears to trend northeastward (figs. 3 and 9) from the narrow constriction between the two to the place where the fault intersects the eastern brow of the mountain.

The well-known coal deposits on Lookout Mountain have been much studied in the past, and numerous sections have been measured, but none is complete because of the poor exposures everywhere except on the brow of the plateau. Fortunately the U.S. Gypsum Co. has drilled some cores on the mountain for the purpose of finding evaporites in the underlying Mississippian limestone, and these holes pass through the entire Pennsylvanian section in that locality.

The most complete of these cores, and the one used for figure 9, locality D, is near the community of Cloudland, at an altitude of 443 m.

The beds between the Monteagle-Bangor Limestones and the bluff-forming sandstone are 150 m thick. The lower 110 m are mainly shale containing some fossiliferous limestone beds near the base. The upper 40 m are mainly quartz sandstones with interbedded shale; the sandstones form ledges, some very pronounced on the steep slopes, so that two bluffs are present. Coal is associated with the uppermost sandstone and shale.

Hobday (1974, p. 217–218) provided a measured section of some of these strata from the brow of the plateau nearby. He described the bluff-forming sandstone and the sandstone-shale interval immediately below, and provided an interpretation of the sedimentary environment. From his description, the presence of two potential bluff-forming sandstones can be deduced:

*** The lower 300 feet of this outcrop consists of upward coarsening sequences, between 8 and 40 feet thick, composed of shale and siltstones with minor sandstones. Overlying these is a vertical sequence of eight orthoquartzite bodies averaging 10 feet in thickness, separated by siltstone averaging one foot in thickness. The sandstones are both massive and low-angle planar cross-bedded and are cut into their upper part by channels up to 15 feet deep, which contain bedding types similar to those in the unchanneled portions. . . . Separated from the top of these sandstones by 50 feet of silty shale are two superimposed orthoquartzite complexes which clearly illustrate the mutually perpendicular relation between the trough cross beds and the long, low-angle planar cross beds. The overlying upward-coarsening "bay-fill" sequence of siltstone, with horizontally bedded sandstones and a highly carbonaceous shale on top, is capped by low-angle planar cross-bedded sandstones ***

The bluff-forming sandstone, at the top of the steep slope, is 47 m thick, massive conglomeratic, crossbedded, and contains a few thin shale lenses.

The rocks over the bluff-forming sandstone are mainly sandstone containing shale beds and are about 110 m thick. Immediately over the bluff-forming sandstone one of the shale sequences is about 12 m thick.

The beds below the bluff-forming sandstone, and immediately above the Bangor Limestone, are generally mapped as the Pennington Formation, and the beds above these, but still below the bluff-forming sandstone, are mapped as the Gizzard Formation or the lower part of the Lookout Formation.

The bluff-forming sandstone has been mapped as the Sewanee Conglomerate and the Lookout Sandstone; it has been mapped as Pennsylvanian undifferentiated on the present State geologic map, and the rocks above the bluff-forming sandstone have been mapped as Walden Sandstone or as Pennsylvanian undifferentiated.

Several well-developed coal seams are in this section; two are above the bluff-forming sandstone, called the Tatum and Sewanee seams. The one below the bluff-forming sandstone is known as the Cliff seam. All have been mined sporadically, but all are discontinuous.

PENNSYLVANIAN ROCKS ON THE NORTHERN PART OF LOOKOUT MOUNTAIN. DADE AND WALKER COUNTIES

This part of Lookout Mountain is northwest of the line running northeastward from the narrow constriction of Lookout Mountain (figs. 3 and 9). These rocks contain immense reserves of coal and have been extensively investigated. Because of the incomplete exposures, however, no continuous section is known; the section in figure 9 is a composite, from four different localities.

The lowermost rocks were described by Sullivan (1942, p. 26) from Johnson Crook (fig. 9, locality E); they rest upon Bangor Limestone, are mainly shale, are 123 m thick, and contain some limestone beds. They are generally mapped as the Pennington Formation.

Above these are some rocks described by Wanless (1946, p. 24) from the west brow of Lookout Mountain just east of Trenton (fig. 9, locality F). They are 43 m thick, are mainly gray shales containing, ledge-forming sandstone beds, some very pronounced, and have a discontinuous coal seam near the top. These have been mapped as the Gizzard Formation, as part of the Lookout Sandstone, and as Pennsylvanian undifferentiated on the current State geologic map.

The bluff-forming sandstone rests upon these. Part of this section described above (Wanless, 1946, p. 24) fig. 9, locality F) can be seen in the core described by Johnson (1946) from nearby. The bluff-forming sandstone is very massive, crossbedded, channeled, conglomeratic, and coarse-grained quartzose; it is 70 m thick. It has been mapped as the Warren Point Sandstone, the Sewanee Conglomerate, the Lookout Sandstone, the Bon Air Sandstone, and as Pennsylvanian undifferentiated on the current State geologic map.

Above the bluff-forming sandstone are 182 m of shale containing beds of sandstone and coal. The sandstones are finer grained and are more evenly bedded and widespread than those below. The illustrated section is from a core described by Johnson (1946) and from a section measured by Wanless (1946, p. 31). The individual sandstone and shale units have been given different names by different workers, but they have been collectively called the Walden Formation or Pennsylvanian undifferentiated (fig. 9, localities G and H).

The rocks above the bluff-forming sandstone have been dated as Medial Pottsville on the basis of paleobotany. No fossils are known from the bluff-forming sandstone nor from the beds immediately below; the beds called the Pennington Formation have been dated as Late Mississippian on the basis of marine fossils and regional considerations.

PENNSYLVANIAN ROCKS ON FOX MOUNTAIN, DADE COUNTY

Fox Mountain, the northeastern part of which is in Dade County, is a small outlier of the much larger Sand or Raccoon Mountain. The rocks are preserved in the trough of a syncline, and are the least known of the Pennsylvanian rocks of northwest Georgia.

The section illustrated (fig. 9, locality I), is taken from McCallie (1904, p. 73) and from a field reconnaissance. The rocks above the Monteagle-Bangor Limestones are poorly exposed, but appear to be about 69 m of varicolored shale at the base and gray shale toward the top. Limestones are interbedded toward the base, and sandstones are interbedded toward the top. A thin, relatively persistent coal seam is at the top, immediately under the bluff-forming sandstone.

The bluff-forming sandstone forms the top of the plateau. It is medium to coarse grained, very conglomeratic, massive to thin bedded, channeled, and crossbedded. It is at least 33 m thick, though the top is nowhere exposed.

No fossils are known. The age of the rocks below the bluff-forming sandstone are probably Mississippian on the basis of regional considerations and stratigraphic position. The bluff-forming sandstone is probably Pennsylvanian.

PENNSYLVANIAN ROCKS ON SAND MOUNTAIN, DADE COUNTY

Sand Mountain in Georgia is a part of a much larger feature known as Sand or Raccoon Mountain in Alabama and Tennessee. The rocks are preserved as the trough of a broad syncline, forming a plateau, into which obsequent streams have incised deep valleys.

The section in figure 9 is composite, from two different localities. Most of the section is from Scratch Ankle Hollow (fig. 9, locality J), actually in Tennessee, measured by Wilson (1965, p. 36–38), and the lowermost part of the section is from an uncertain location identified only as Hooker (fig. 9, locality K) by McLemore (1971, p. 221). The Scratch Ankle Hollow section contains the type sec-much resemble the upper beds of the Bangor Lime-tion of the Raccoon Mountain Formation as identified by Wilson, Jewell, and Luther (1956).

The lowermost 32 m of gray shale in the composite section rests upon Bangor Limestone, and McLemore referred to these beds as being within what he called the Pennington Formation. What McLemore considered to be the lower part of the Pennington Formation contains beds which very much resemble the upper beds of the Bangor limestone of this report.

Above the 32 m of gray shale are shale and sandstone beds 106 m thick (Wilson, 1965, p. 36–38) which contain several commercial coal seams. Mc-

Lemore (1971) included some of these rocks within what he called the upper part of the Pennington Formation in the section which he measured. These rocks have been called by others the Lookout Sandstone, Gizzard Formation, Raccoon Mountain Formation (the type section), and the Norwood Cove and Flat Rock Formations. One of the sandstones in this part of the section thickens and becomes the bluff-forming sandstone elsewhere on Sand Mountain (Wilson, 1965, p. 28).

The composite nature of this part of the section results in uncertainty about the thickness; the Hooker section has an uncertain top, and the Scratch Ankle Hollow section has an uncertain base. This results in an uncertain amount of overlap in the two measurements. Reference to other published sections from nearby (McCallie, 1904; Spencer, 1893; Troxell 1946) show the irregularity of deposition of the beds and why the correlations have been so chaotic. Ferm and others (1972) described the sedimentary circumstances under which these beds could have been deposited, if true, would explain why the problems are present.

The bluff-forming sandstone is 39 m thick, massively bedded, conglomeratic, crossbedded, quartz sandstone. This has been called the Flat Rock Sandstone, part of the Gizzard Formation, the Warren Point Sandstone, the Lookout Sandstone, the Sewanee Conglomerate, and Pennsylvanian undifferentiated.

The beds above the bluff-forming sandstone constitute a shale sequence about 30 m thick, overlain by a conglomeratic sandstone about 3 m thick. The sandstone caps the highest hills on Sand Mountain, and is the youngest formation on the mountain in Georgia. These rocks have been called the Walden Formation, the Signal Point Shale, and the Sewanee Conglomerate, respectively.

Paleobotanically, the coal beds below the bluff-forming sandstone contain a flora that is Medial Pottsville in age; the beds below these, which rest upon the Bangor Limestone, contain Mississippian fossils. No fossils are in the rocks above the bluff-forming sandstone.

The coal resources on Sand Mountain are in beds below the bluff-forming sandstone, whereas the coals on the northern part of Lookout Mountain are in beds above the bluff-forming sandstone, yet the coals are the same age, Medial Pottsville.

CORRELATION OF PENNSYLVANIAN ROCKS

It is easy to understand how the twofold subdivision of Pennsylvanian rocks originated (fig. 10). Everywhere a similar-appearing, conglomeratic, bluff-forming sandstone can be seen at the edges of the plateaus, with shale, sandstone and coal underneath, with a distinctly irregular sedimentation pattern, whereas the rocks over the bluff-forming sandstone are clearly more widespread and continuous in distribution, and can be traced with more assurance.

The bluff-forming sandstone and the irregularly disposed rocks below were called the Lookout Sandstone, and the more uniform rocks above the bluff-forming sandstone were called the Walden Sandstone. Later, the rocks below the bluff-forming sandstones were identified as the Gizzard Formation, which contained one sandstone known as the Warren Point; the bluff-forming sandstone was called the Sewanee Conglomerate. The Walden Sandstone was subdivided into three shale and three sandstone formations.

As more data were gathered, the bluff-forming sandstone was found not to be the same unit everywhere; the bluffs were being formed by whichever sandstone happened to be at the level of erosion. Therefore, if different sandstones were found to be the bluff-forming sandstone, then the correlations of the rocks above and below would have to be altered; this accounts for the plethora of terms which have been used for the same rocks. An appreciation of the lateral variation in the rocks below the bluff-forming sandstone would also influence any decision about the correlation of these rocks over long distances.

Furthermore, correlations in the past have been predicated upon the "layer cake" philosophy of stratigraphy, that the units are formed as widespread blankets and can be correlated on the basis of superposition. Results of modern studies show that this concept, particularly for the Pennsylvanian of Georgia, is not valid, for the rocks are distinctly interfingered and not blanketlike.

Correlations in the past have been based partly on the assumption that the coal beds are widespread and that correlation by superposition and (or) lithology was possible. Detailed studies show that the coal beds are very irregularly disposed and distributed. Caution should be exercised when correlating the coal seams.

BIOSTRATIGRAPHY

Little paleontological investigation of the Pennsylvanian rocks of Georgia has been carried out because most of the rocks are nonmarine and fossils are sparse. Most investigations have been paleobotanical.

The first published report of fossil plants was by Lesquereux (1880–84, p. 852) who listed a flora of 27 species from an uncertain locality and stratigraphic position in Dade County. Inasmuch as mining activity at that time was confined to the Etna and Dade coal seams, the flora was probably from the rocks below the bluff-forming sandstone. He correlated this flora with that of the No. XI zone in Pennsylvania, which is now called the Mauch Chunk Formation, of Late Mississippian age.

White (1900, p. 817), on the other hand, noted that the flora of the roof shale of the Dade coal (below the bluff-forming sandstone, and from where Lesquereux's flora may have come) was similar to the flora of the *Mariopteris pottsvillea* zone of elsewhere in the Appalachians; he considered the age of this zone to be Early Pottsville, but not the earliest.

White later (1943), identified *Mariopteris pottsvillea* from rocks over the Castle Rock coal seam (also known as the Etna seam), immediately below the bluff-forming sandstone in Dade County; the Castle Rock seam is a few tens of feet above the Dade coal seam, which also contains the *M. pottsvillea* zone flora in the roof shale.

In the same reference, White (1943) noted *Aneimites tenuifolia difoliatis* and *A. pottsvillensis* var. *intermedia* in the roof shale over the Durham No. 5 coal seam, above the bluff-forming sandstone on the northern part of Lookout Mountain in Walker County. These are also Early Pottsville in age, although not the earliest.

Allen and Lester (1954, p. 131–149) listed and illustrated a curious flora of 23 species from coal-mine dumps of uncertain stratigraphic and geographic position, although clearly in rocks above the bluff-forming sandstone. This flora contains species that have much older and much younger ages than the Early Pottsville.

Read and Mamay (1964), in their work on the floral zones of the upper Paleozoic, identified the *Mariopteris pottsvillea-Aneimites* spp. zone as the No. 5 zone in their classification. Zone 5 was according to them, Medial Pottsville, or Early New River in the terms of Appalachian stratigraphers.

Wilson (1965, p. 49) suggested that a coal seam at the base of the Norwood Cove Formation, the base of which he was calling Pennsylvanian, in rocks below the bluff-forming sandstone, contained spores having definite Chesterian (Late Mississippian) affinities.

Wanless (1975, p. 32) concluded that the Pennsylvanian rocks in Georgia are entirely within zones 5 and 6 of Read and Mamay. He noted the presence of elements of floral zone 6 from shale "just above the Sewanee coal on Lookout Mountain". Which coal he meant by the Sewanee is not clear, although in an earlier report (Wanless, 1946), he meant that coal which is in the shale immediately over the bluff-forming sandstone on the southern part of Lookout Mountain. In a later report (Wanless, 1961), he implied that all of the coals above the bluff-forming sandstone in the northern part of Lookout Mountain are the Sewanee, in the sense of the Sewanee coal basin. If this is so, it would include the Durham No. 5 seam, the same seam which contained the species of *Aneimites* noted by White (1943) which were included in floral zone 5 by Read and Mamay (1964).

Detailed biostratigraphic correlations based on paleobotany cannot be made with certainty at this time, but generally the presence of zone 5 and possibly of zone 6 of Read and Mamay seems reasonable. Zones 5 and 6 are entirely in the Pottsville Series, Lower Pennsylvanian, although not the lowest. These correlate with rocks of Morrowan age of the midcontinent region and with rocks of Westphalian-A age of Europe.

Invertebrates from the Pennsylvanian rocks of Georgia are rare. Wanless (1946, p. 32–33) reported a *Lingula*-bearing shale from the rocks overlying the bluff-forming sandstone on the northern part of Lookout Mountain.

Molds of imbricated pelecypod shapes are found in one of the sandstones exposed in a strip mine on Sand Mountain, Dade County, but identification other than the suggestion of beach-environment deposition is not possible.

Brachiopods, fenestrate bryozoans, and crinoid columnals have been found in the thin-bedded, fine-grained sandstone unit below the bluff-forming sandstone on Little Sand Mountain in Chattooga County, above beds commonly considered Pennington Formation, but these fossils have not yet been analyzed.

Brachiopods, pelecypods, gastropods, orthoconic cephalopods, and fenestrate bryozoans have been found in a carbonatic, arkosic sandstone from rocks above the bluff-forming sandstone on Rocky Mountain, but these are not well enough preserved for positive identification.

Limestones, which, if present, would not only be a potential source of marine invertebrates, but would make splendid marker beds for the maps in this otherwise clastic-rock terrane, are rare. Only two have been identified, and neither investigated; both are thin and apparently not widespread. Spencer (1893, p. 252) noted a seam of limestone in the shale unit 3.07 to 5.2 m above a coal bed, later to be known as the No. 4 coal, on Lookout Mountain, Walker County. McCallie (1904, p. 41) failed to find this rock, and Wanless (1946, p. 32) reported a covered interval which included the limestone at that part of his measured section.

Another limestone, at least 0.6 m thick, was reported in one of the cores made by the Georgia Power Co. on Rocky Mountain. It is in the rocks above the bluff-forming sandstone; this has not been investigated.

DEPOSITIONAL AND TECTONIC FRAMEWORK

PAST INTERPRETATIONS

The first comprehensive study of Pennsylvanian rocks in Georgia, that of McCallie (1904), does not contain any geological background for the origin of the rocks or of the coals.

The first discussions of the rocks and coals were included in the report of Wanless (1946, p. 129) in which the Pennsylvanian rocks of the entire southern Appalachian Mountains were described. He speculated upon cyclothemic deposition, so common in the rocks of the midcontinent area, and concluded that:

> *** a sort of rhythmic sequence is frequently repeated *** This begins with a massive basal siltstone or sandstone, unconformable on underlying strata. The sandstone grades up into siltstone or sandy shale, and the shale may contain sandstone partings and fossil plants. The siltstone is followed by an underclay which is often divided by shale or siltstone and may have siltstone or sandstone at the top. The coal zone follows, and often includes several benches of coal spread through an interval of as much as 20 feet. The coal zone is overlain by shale which is generally plant bearing in the immediate roof and which may contain ironstone or occasionally impure limestone bands or concretions and may yield fresh- or brackish water fauna and rarely a marine fauna. This may grade up into sandy shale and siltstone to the next higher sandstone, or the sandstone may cut out part or all of the shale and rest on the coal, or even cut out the coal.
>
> There are many resemblances between the rhythms *** here and the cyclothems *** the differences being the obvious results of differences in environment and rates of sedimentation.
>
> *** The Warren Point, Sewanee, Herbert, Newton, Rockcastle *** sandstones are all basal members of such sequences *** at least a considerable part of the sediment was derived from the east or southeast.
>
> Certain districts seem to have been near the points of discharge of large rivers carrying sandy or gravelly sediment.

He further noted (Wanless, 1946, p. 131):

> The sediments all seem to have formed in aqueous environments which include piedmont, valley flat, marsh, lake, delta, lagoon, and shallow sea-floor environments. Even the coarsest sediments are too well sorted with too nearly horizontal bedding surfaces and are too extensive to suggest a piedmont environment adjacent to high uplands *** The coals are evidently of a marsh environment ***
>
> *** A widespread delta plain fronting the sea, with a network of delta lakes, marshes, and lagoons and shifting channels of discharge for the streams seems the most likely type of environment.

As regards the tectonic setting, Wanless concluded (1946, p. 132):

> Adequate sedimentation prevailed during the deposition of the coal measures of the southern Appalachian field. *** [excess sediment was bypassed to a more distant locality] *** If this assumption is correct, the amount of sediment deposited during a particular interval is a measure of the amount of downwarping. The southeastern border of the coal field [including northwest Georgia] was downwarped several thousand feet more than the region of Ohio *** and the rate of downwarping increased southeastward at a uniform rate.

He showed that the basins of deposition formed during the Pottsville, and that great changes in thickness take place within short distances, such as that between the rocks under the bluff-forming sandstone in Sand Mountain and the northern part of Lookout Mountain. Milici (1974) named the Raccoon Mountain basin as the depositional center for the thick section of rocks under the bluff-forming sandstone on Sand Mountain.

Wanless' pioneer work was followed by many studies and interpretations of the sedimentary petrology of the sandstones, mostly of those on the northern part of Lookout Mountain. Renshaw (1951) recognized deltaic and beach sedimentation, and Allen (1955) and Albritton (1955) identified tidal-flat sediments. The latter writer also speculated upon a southeastern source for the sediments. Shotts (1957) showed that the coals on the southern part of Lookout Mountain are in discrete basins, and that they are separated from one another by what he called deltaic variations in sedimentation.

Tanner (1959) first noted, from crossbedding studies, that Pennsylvanian rocks were deposited by currents that were more toward the south than toward the north; he suggested a shoreline toward the north-northeast. Schlee (1963), also, after crossbedding studies, concluded that the Pennsylvanian sandstones are mainly from a fluviatile environment and that the predominant transport direction was toward the southwest. He suggested that the sandstones are from sands deposited on flood plains or in estuaries, and that they are the result of sheets of anastomosing linear sand bodies.

Chen and Goodell (1964) studied the petrography of the bluff-forming sandstone on both parts of Lookout Mountain. They found provenance to have been mainly a crystalline-rock terrane, and the direction of regional transport to have been to the southwest. They suggested a paludal or marginal-continental environment for the sandstones.

Wilson (1965) believed that the Pennsylvanian rocks on Sand Mountain were of terrestrial origin, and saw no clear evidence for the marine origin suggested by Wilson and Stearns (1960). He interpreted provenance as having been highlands to the east or northeast, with small amounts of the sediments possibly having come from as far away as the Canadian Shield. The coals are from freshwater swamps. Boron-trace studies support this interpretation.

The volume on Pennsylvanian paleotectonics of the United States (McKee and others, 1975), the summation of Pennsylvanian stratigraphy to that date, includes much data about the rocks in Georgia. They were deposited in a basin with the source of the sediments having been to the east and northeast, and with the provenance having been a series of welts of mountainous islands, like those which flank the Pacific basin today. The conglomerates, sandstones, and mudstones form a series of detrital wedges. In some areas, sand and mud accumulated without much interruption, but elsewhere, deposition of detritus ceased periodically, and coal beds resulted. The sea is believed to have transgressed periodically from the southwest. Cyclic sedimentation is plainly evident, but cyclothemic conditions are less uniform regionally.

Coarse sediment entered the Appalachian basin, including Georgia, several times during the deposition of Pottsville sediments, a result of erosion and sedimentation caused by contemporaneous tectonism. Whether the alternations between the coarse, conglomeratic sandstones, clay, and coal beds resulted from intermittant renewal of tectonism or from climatic changes cannot be determined from the exposures in Georgia.

The above review of the data and the interpretation shows no unequivocable explanation for the sedimentary environment or tectonic setting for the Pennsylvanian rocks of Georgia. The rocks are neither unquestionably marine nor unquestionably terrestrial.

CURRENT INTERPRETATIONS

More recent investigations of the Pennsylvanian rocks in the Appalachian Mountains in general, and in Alabama and Tennessee in particular, have allowed for interpretations which take into account the uncertainties outlined above—an environment between the marine and the terrestrial, that of the littoral zone, the barrier-island complex, and the lower-delta plain.

During the time that the Pennsylvanian paleotectonics volume was being prepared, new ideas regarding the interpretations of the Appalachians around Georgia were fermenting. John Ferm and his associates and students identified possible depositional environments for the Pennsylvanian rocks of Georgia and vicinity.

The current interpretations were initiated by Stearns and Mitchum (1962) who applied isopach and lithofacies studies to a regional stratigraphic analysis of the Pennsylvanian of the southeastern United States. They noted a belt of high-sand ratios which passed through Georgia, subparallel to the present outcrop patterns, and trended northeast. They suggested no explanation, but it is possible that these belts of high-sand ratios were roughly parallel to the paleoshorelines and that they could have resulted from barrier-island complexes. Considerable evidence now supports this interpretation.

In many places, particularly along the western brow of the northern part of Lookout Mountain, the bluff-forming sandstone is massively bedded, crossbedded, conglomeratic, channeled, and quartzose. The crossbedding is in channels, planar, and trough-like, such as would be expected in a barrier-island complex environment.

In other places, the bluff-forming sandstones are not as massive or conglomeratic; these could be preserved from other parts of the barrier-island complex, such as tidal deltas, washover fans, or dunes. The dark-gray shales and bedded sandstones which accompany the more massive sandstones could be from barrier-island marshes, which were occasionally invaded by the sea or from washover fans or tidal fans from the seaward side, or from terrestrially-derived detritus from the landward side, such as flood plains. Coal could form when these marshes were filled to sea level and a soil could form; if the environment would not support vegetation, ironstone could precipitate. An environment such as this would explain the irregular distribution of the coal and the sandstones, and the frequent intimate mixing of them.

Milici (1974) and Ferm and others (1972) recognized, for instance, from nearby Tennessee and Alabama, rocks from the littoral environment. The coal-bearing sandstone and shale (the Racoon Mountain Formation), from beneath the bluff-forming sandstone are from lagoon complexes that formed behind barrier bars. Tidal deltas, washover fans, and beach deposits are also part of this complex, and the sandstones from these features are interdigitated with the coal-bearing, shaly, lagoon deposits. The shifting of the strand line, whether tectonic or eustatic, resulted in blanket-sandstone deposits (the bluff-forming sandstone) as the bars migrated over the marsh deposits to follow the strand line.

The interpretation that these rocks were deposited in a littoral environment provides an explanation for the correlation chaos; the various units, sandstone, conglomerate, shale, coal, and others, are all interfingered rather than being superimposed. The coals and siderite layers result from a stillstand of the sea when the lagoons were filled to sea level so that they could support the coal-producing vegetation or ironstone-forming conditions.

Thomas (1972a), in a report on the Mississippian rocks of Alabama, recognized that the rocks lying athwart the Mississippian-Pennsylvanian boundary, in part those below the bluff-forming sandstone, are the result of similar depositional environments. The littoral environment prograded southwestward, bringing clastic sediments into and onto the carbonate shelf. Although his discussion does not include Georgia, it could clearly be extrapolated to include the State. Marine rocks are overlain by intercalated clastic rocks of marine and littoral origin. The alternation of marine and littoral environments resulted from strand-line fluctuations throughout the interval.

Thomas' thesis, of a southwestward-prograding clastic lithosome, was supported by the observations of Ferm (1974) who, in speculating about the sedimentary similarities between the Carboniferous rocks of eastern North America, western Europe and Africa, suggested that a landmass somewhere in the North Carolina area shed sediments outward in all directions. Sediments coming to the Georgia area would have been from a metamorphic terrane, as indicated by the petrologic studies, and from the northeast, as suggested by the textural and structural studies.

Hobday (1974) believed that some of the Pennsylvanian rocks of Georgia were deposited in a littoral environment. His studies of one of the orthoquartzite bodies in the section near Cloudland, the one forming the lower bluffs (fig. 9, locality D) on the southern part of Lookout Mountain, show it to be a deposit of a barrier island. The associated shale and coal originated in relation to this feature.

The sedimentary features that distinguish the rocks over the bluff-forming sandstone from those under it on the northern part of Lookout Mountain and on Sand Mountain, Dade County, were noted as early as 1892 by Hayes (1892, p. 50) who used this distinction to create the first subdivision of the Pennsylvanian rocks of Georgia. He noted:

"These upper rocks [those over the bluff-forming sandstone], embraced under the name Walden, are more homogeneous than the Lookout [the bluff-forming sandstone and the rocks under it] and show marks of fewer abrupt changes in conditions of sedimentation."

This same difference was noted by Wanless (1961) when he discussed what he called the Sewanee coal basin. Although his text did not clearly indicate which coal he meant, the environment of deposition that he discussed for the basin was clearly for rocks overlying the bluff-forming sandstone on the northern part of Lookout Mountain. He noted the persistency of these units over large areas, and showed the relations of these deposits to deltaic sedimentation. The regional correlations were based on the flora of the roof shales of some of the coals. He suggested that the basin persisted for the time that several of the coals were deposited, and not just one of them.

The coal deposits on the northern part of Lookout Mountain, those above the bluff-forming sandstone, seem to have a different character from those below the bluff-forming sandstone elsewhere. The coal seams themselves, and the enclosing shales and sandstones, are much more laterally continuous, reflecting a greater geographic area for the depositional environment, and one which was more stable over a longer time than one closer to sea level, where strand-line fluctuations would be reflected in the changes in sedimentation. The thickness of the coals also support the interpretation of a more stable long-lived environment. Such an environment would be found on the delta plain, behind and inland to the littoral, offshore-bar environment.

Therefore, if the tectonic-sedimentation regime which began in the Mississippian, of deltaic progradation over a carbonate sequence, were to have continued into the Pennsylvanian, the resulting vertical sequence of rocks to be expected over the open-marine rocks would be prodelta and delta-front clastic rocks, which in turn would be overlain by deposits of barrier-bar complexes and barmarsh deposits, which in turn would be overlain by delta-plain deposits in which the coal seams would be thicker and more widespread.

As this appears to be true in Georgia, the systemic boundary between the Mississippian and Pennsylvanian must be in the complex of clastic rocks between the Monteagle-Bangor Limestones of unquestioned Mississippian age and the overlying clastic rocks that contain a Pennsylvanian flora.

MISSISSIPPIAN-PENNSYLVANIAN BOUNDARY PROBLEM

The boundary between Mississippian and Pennsylvanian rocks in Georgia has commonly been assigned to designated marker beds of some description such as at the top of the highest maroon mudstone, below the lowest coal bed, at the base of the massive bluff-forming sandstone, or at the base of the lowest quartz-pebble-bearing sandstone. Although the Mississippian-Pennsylvanian systemic boundary is by definition a time-stratigraphic horizon, the criteria by which it has been identified in Georgia have been rock-stratigraphic.

Fossils in the limestone sequence establish a Mississippian age, and plant fossils demonstrate a Pennsylvanian age in the coal above the massive sandstone. The horizon of the Mississippian-Pennsylvanian boundary must be within the lithofacies transition beds between the limestone and the coal-bearing sequence, and the systemic boundary has commonly been placed at the contact between the Pennington and Raccoon Mountain Formations (Culbertson, 1963; Wilson, 1965, p. 47; Milici, 1974, p. 118). That contact traditionally has been considered to be a regional unconformity (Culbertson, 1963, p. E56), but recent work indicates that the succession is gradational except locally where sandstone at the base of the Raccoon Mountain rests on a scoured surface (Milici, 1974, p. 121). Lack of detailed biostratigraphic data from this part of the section precludes precise identification of the boundary. Spores from a coal bed in the Raccoon Mountain Formation of Alabama have "definite Chesterian affinities" (Wilson, 1965, p. 49), and invertebrate fossils from Raccoon Mountain equivalents in Alabama are Mississippian (Milici, 1974, p. 118). Possibly the systemic boundary is within the Raccoon Mountain Formation.

The rock succession in Georgia suggests continuous sedimentation during deposition of a prograding clastic sequence (fig. 11). The succession above the Mississippian carbonate sequence grades upward from marine and near-shore mudstone to massive barrier and (or) delta-front sandstones. The interpretation that the strata reflect prograding sedimentation implies the identification of time-stratigraphic planes across temporally equivalent facies (fig. 11). Identification of the systemic boundary awaits resolution of a maze of biostratigraphic and lithostratigraphic details.

MINERAL RESOURCES OF THE CARBONIFEROUS ROCKS

COAL

The most valuable mineral deposit in the Carboniferous rocks of Georgia is bituminous coal; it is still being mined after more than 100 years. The first mining took place in Dade County in 1854. In 1891, the first coal was taken from Walker County on Lookout Mountain, and after 1892, when the railroad arrived at Durham, production increased dramatically. By 1900, all of the coal from Georgia was coming from the Lookout Mountain field in Walker County except for one mine still operating on Sand Mountain, in Dade County. The peak year of production was 1903, when 417,000 short tons were taken, mostly from the Durham No. 5 coal.

In 1920, strip mining was introduced to Georgia, and sporadic production continued. Production again increased during World War II, but declined steadily after that, and has been negligible for many years. Currently, production has again increased dramatically.

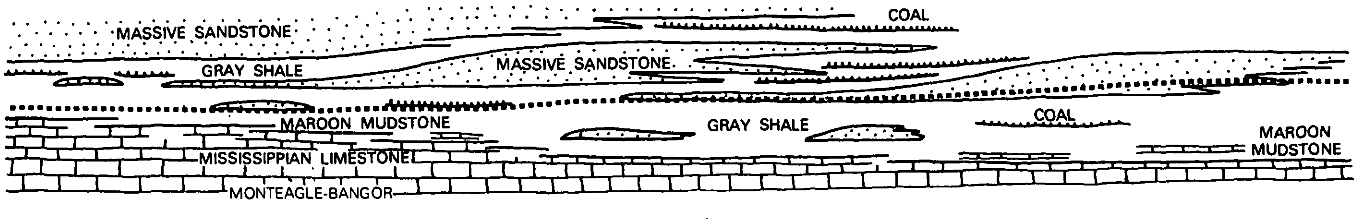

FIGURE 11.—Hypothetical stratigraphic cross section of rocks near the Mississippian-Pennsylvanian boundary in northwest Georgia. Heavy dashed line shows interpreted position of a time-stratigraphic line.

Production of coal from Georgia, by quintade, is shown in figure 12, and the reports of McCallie (1904) and Johnson (1946) remain the most complete sources of information to date.

Coal seams.—Many seams of coal have been mined, and there is much confusion about the correlation of the various seams. The same name has been given to clearly different seams, and the same seam has been given different names. As a result, the information derived from the literature is hard to evaluate.

On Sand Mountain, all of the coals from Georgia are in the rocks below the bluff-forming sandstone; those above have not yet been developed if they exist. Two well-known seams are the Castle Rock, or Etna seam, and the Dade seam. The name Etna is generally used for the coal immediately under the bluff-forming sandstone and the Dade seam is about 10 m below the Etna. The other seams—Rattlesnake, Red Ash, Mill Creek, Cliff, and New England, are irregular and discontinuous, and all are subject to miscorrelation. The seams reach thicknesses of more than 2 m, but most are much thinner than 1 m.

The coals on the northern part of Lookout Mountain are much better known and have been more fully exploited than those on Sand Mountain. Three prominent coal seams are an uppermost A seam,

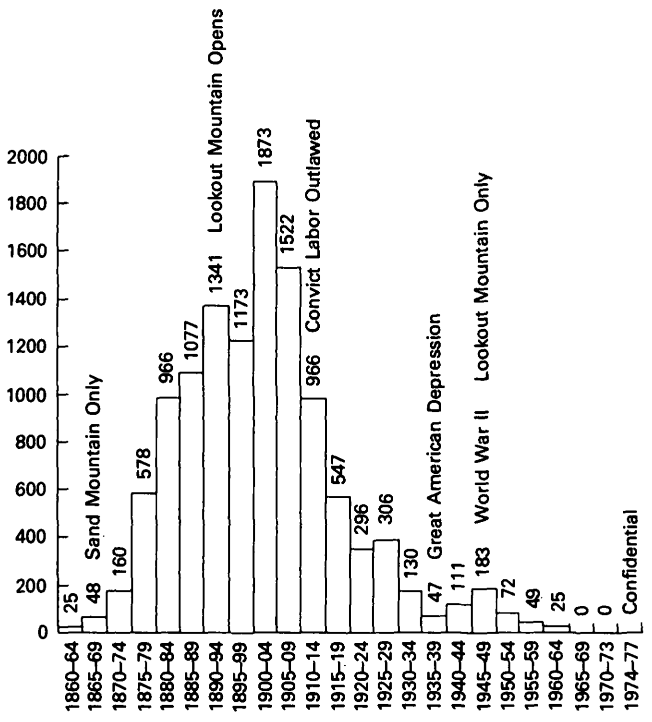

FIGURE 12.—Graph showing coal production (given in thousands of short tons) in Georgia for 5-year intervals from 1860 to 1977.

the Durham No. 5 seam a few tens of meters below the A seam, and the Durham No. 4, or Tatum seam, about 15 m below the Durham No. 5. All are above the bluff-forming sandstone. A thin, discontinuous coal seam is immediately below the bluff-forming sandstone called the Cliff, or Castle Rock seam. All the coals have been mined at one time or another, with the No. 5 being the biggest single producer. All have been called the Sewanee coal seam in the literature.

On the southern part of Lookout Mountain above the bluff-forming sandstone are two coals seams which have been extensively mined. The uppermost one is the Tatum seam, with the Sewanee seam a few tens of meters below it. The Sewanee seam is known to be as much as 2 m thick, but is usually less than a meter. A thin, discontinuous zone of coals is immediately below the bluff-forming sandstone. These coals are called the Cliff seams No. 1 and No. 2, or the upper and lower Cliff coals. They have also been called the Etna and (or) Castle Rock seams. All of the coals on the southern part of Lookout Mountain are being mined today in one place or another; none is everywhere present, however.

Coal reserves.—The figures for the reserves of coal in Georgia have varied considerably. The differences in the figures reflect not only changes in the techniques of reserve calculations, but differing interpretations of the correlations of the coals. Table 1 shows the reserves as calculated in different years.

TABLE 1.—*Coal reserves, Georgia, 1907–74*

Date	Source	Original reserves (millions of short tons)	Remaining reserves (millions of short tons)	Remarks
1907	Campbell, 1908	933	921	
1942	Peyton, 1942	---	400	Unpublished data.
1942	Sullivan, 1942	188	184	Sand Mountain only.
1946	Johnson, 1946	24	---	
1948	Gildersleeve, 1948	206	120	*In* Butts and Gildersleeve, 1948.
1948	Peyton, 1948	---	115	Unpublished data.
1960	Averitt, 1961	100	76	Average of others.
1967	Averitt, 1969	24	18	
1974	Averitt, 1975	84	78	Includes hypothetical possibilities.
1974	Averitt, 1975	---	1	Demonstrated reserve base.

The figure of 1 million tons, currently quoted, is a product of a conservative formula, the Demonstrated Reserve Base, designed to allow comparison of coal reserves from different areas. It is based upon the reserves in beds 24 or more inches thick, less than 1,000 feet deep, and economically exploitable in 1974. Not much Georgia coal falls into this tightly restricted category, hence the low figure.

Coal rank and chemistry.—Table 2 shows published cumulative analyses of Georgia coals. All the coals are medium-volatile bituminous on the table, but individual coal analyses include much low-volatile bituminous coal.

Because of the problems of coal-seam correlation, much confusion probably exists in the identity of the coals cited in the table. Also, the variation in the analytical quality is considerable. Some are the averages of a few tens of analyses, and some are average for as few as three.

All the coals, except for a few that have very distinctly different analyses, are low in sulfur. Many other trace-element studies have been made on Georgia coals, the results of which may be found in Stadnichenko and others (1961), Walker and Hartner (1966), and in Zubovic and others (1966).

CLAY AND SHALE

Clay and shale are actual and potential mineral resources from the Carboniferous rocks of Georgia. The underclays of the Pennsylvanian terrane have been tested for their fire-brick potential, and none is useful for that, although they test well for general ceramic properties. Inaccessibility prevents their being developed at this time.

Shale in the Pennington and Floyd formations of Mississippian age is being used for ceramic products and portland cement; most comes from the Floyd formation. None that has been tested is suitable for whitewear or bloating. Smith (1931) and McLemore (1971) provide numerous analyses and descriptions of clay and shale deposits from the Carboniferous rocks of Georgia.

TABLE 2.—*Proximate analyses and sulfur content of Georgia coals, in percent*

Coal	H_2O	Volatile matter	Fixed carbon	Ash	Sulfur
Cliff	1.7	21.1	70.5	8.1	2.0
Dade	2.5	23.9	63.4	11.4	.9
Red Ash	4.8	23.9	70.2	4.4	1.3
Etna	2.6	26.3	66.8	5.3	1.8
Rattlesnake	3.8	24.6	65.0	9.3	1.1
Durham 4	2.8	20.2	72.1	5.4	.7
Durham 5	2.4	20.0	72.5	5.5	.9
A	2.6	20.2	61.6	18.1	2.1
Sewanee	2.9	18.1	65.6	13.5	1.0

BUILDING STONE

Some crossbedded sandstones in the Pennsylvanian have been used for flagstone (Sullivan, 1942), as has the so-called Hartselle Sandstone on Lookout Mountain (U.S. Geol. Survey and U.S. Bur. Mines, 1968, p. 200–201). This latter unit is more likely a Pennsylvanian sandstone.

Burns (1892, p. 899) wrote of the Millstone Grit on Lookout Mountain, presumably the bluff-forming sandstone, and pointed out its value as a potential source of millstones. The market for these is depressed at the moment.

LIMESTONE AND DOLOSTONE

All the limestone and dolostone resources of the Carboniferous rocks of Georgia are from the Mississippian. Cement limestone is taken from parts of the Monteagle-Bangor facies and from one of the limestone tongues in the Floyd Shale. Numerous other quarries provide limestone for aggregate, most of which also comes from the Monteagle-Bangor; a little comes from the cherty Tuscumbia Limestone. A small amount of Mississippian limestone is used for aglime, and one quarry provides fluxstone. McLemore (1971) provides a review of the limestone and dolostone resources of the Mississippian rocks.

CHERT

Chert is found in great abundance in the weathered parts of the Fort Payne and Tuscumbia terranes, and is used for aggregate and road metal locally.

SLATE

In Polk County, the Floyd Shale has been metamorphosed to slate and is exposed in a few of the slices in the overthrust belt. It has been taken in the past along with the much more abundant Rockmart Slate, of Ordovician age. Cressler (1970) gives the details.

GROUND WATER

Northwest Georgia in general has a good supply of ground water, sufficient for most domestic needs, but the rugged topography of the Carboniferous terrane precludes the possibility of obtaining large supplies for commercial development (Schneider and others, 1965). Precipitation is between 132 and

152 cm per year, and Wyrick (1968) shows groundwater flows of 0–73,000 liters per day per square kilometer. The maximum yield of ground water, in liters per minute per day is 379 to 1,137 for Sand Mountain, and 1,137 to 2,274 for Lookout and Pigeon Mountains. Croft (1964) and Cressler (1963; 1964a b; 1970) provide the details about the ground water, of the Carboniferous terrane.

SCENIC FEATURES

Many scenic features have already been set aside for public enjoyment and recreation on the Carboniferous terrane, and even more are possible candidates for such development. The sandstone-capped plateaus have deep canyons cut into them by the obsequent streams draining them. Cloudland Canyon State Park is one such feature (just north of locality G, fig. 9). DeSoto Falls State Park, southward on the same mountain in Alabama, is a similar feature, and many others could also be developed as parks and scenic areas.

Rock City is an attraction formed from joint-separated blocks of the bluff-forming sandstone on the northeastern bluff of Lookout Mountain.

Many caves have been formed in the Mississippian limestone below the bluff-forming sandstone that forms the cap rock of the plateaus; some of the caves may be developed commercially. Included in these is Ellison's Cave, on the eastern flank of Pigeon Mountain; this cave is the largest in Georgia and contains one of the largest vertical pits in the world.

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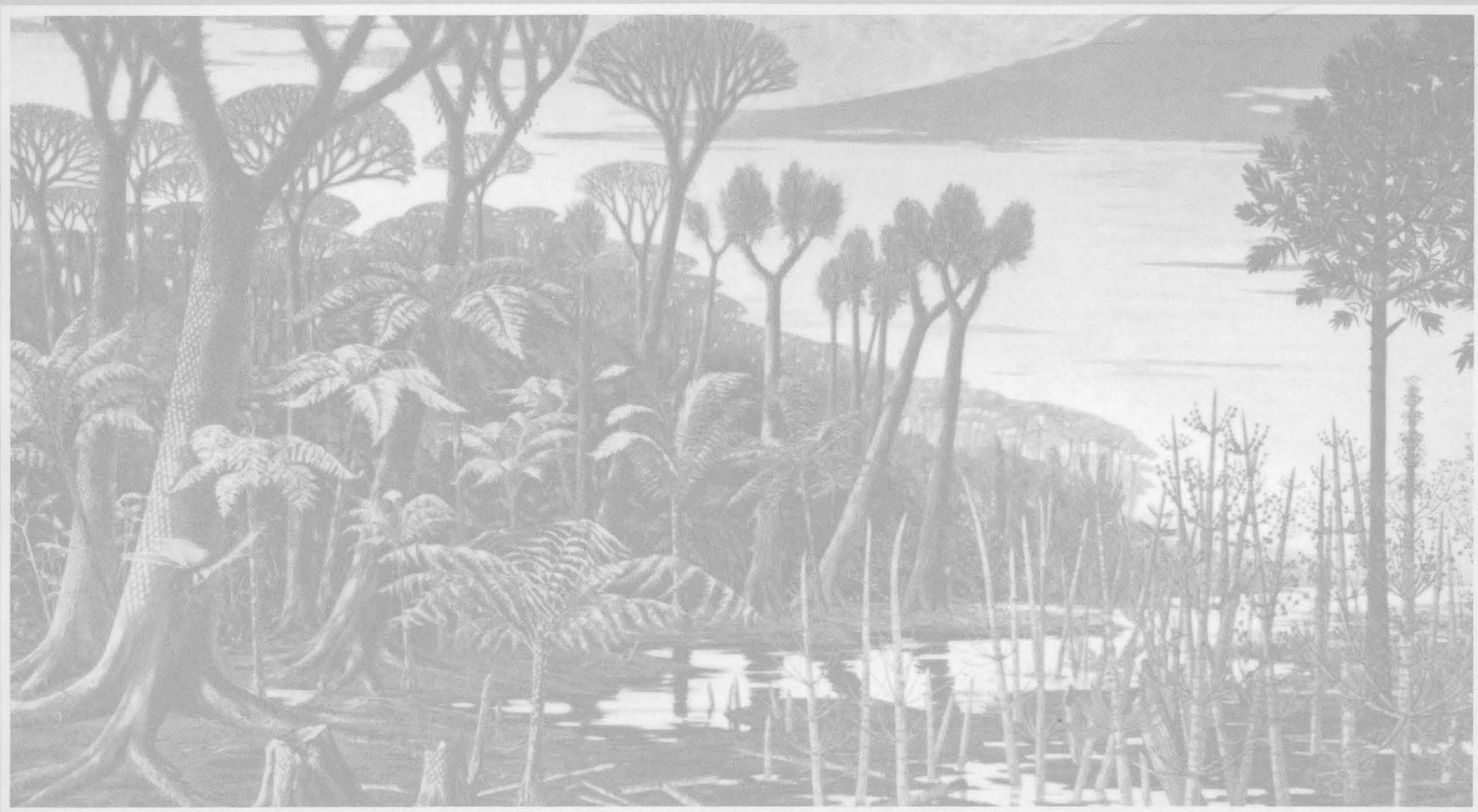
The Mississippian and Pennsylvanian (Carboniferous) Systems in the United States



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ON THE COVER

Swamp-forest landscape at time of coal formation: lepidodendrons (left), sigillarias (in the center), calamites, and cordaites (right), in addition to tree ferns and other ferns. Near the base of the largest *Lepidodendron* (left) is a large dragonfly (70-cm wingspread). (Reproduced from frontispiece in Kukuk, Paul (1938), "Geologie des Niederrheinisch-Westfälischen Steinkohlengebietes" by permission of Springer-Verlag, New York, Inc.)

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A. Massachusetts, Rhode Island, and Maine, by James W. Skehan, S.J., Daniel P. Murray, J. Christopher Hepburn, Marland P. Billings, Paul C. Lyons, and Robert G. Doyle

B. Pennsylvania and New York, by William E. Edmunds, Thomas M. Berg, William D. Sevon, Robert C. Piotrowski, Louis Heyman, and Lawrence V. Rickard

C. Virginia, by Kenneth J. Englund

D. West Virginia and Maryland, by Thomas Arkle, Jr., Dennis R. Beissell, Richard E. Larese, Edward B. Nuhfer, Douglas G. Patchen, Richard A. Smosna, William H. Gillespie, Richard Lund, Warren Norton, and Herman W. Pfefferkorn

E. Ohio, by Horace R. Collins

F. Kentucky, by Charles L. Rice, Edward G. Sable, Garland R. Dever, Jr., and Thomas M. Kehn

G. Tennessee, by Robert C. Milici, Garrett Briggs, Larry M. Knox, Preston D. Sitterly, and Anthony T. Statler

H. Georgia, by William A. Thomas and Howard R. Cramer

I. Alabama and Mississippi
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FOREWORD

The year 1979 is not only the Centennial of the U.S. Geological Survey—it is also the year for the quadrennial meeting of the International Congress on Carboniferous Stratigraphy and Geology, which meets in the United States for its ninth session. This session is the first time that the major international congress, first organized in 1927, has met outside Europe. For this reason it is particularly appropriate that the Carboniferous Congress closely consider the Mississippian and Pennsylvanian Systems; American usage of these terms does not conform with the more traditional European usage of the term "Carboniferous."

In the spring of 1976, shortly after accepting the invitation to meet in the United States, the Permanent Committee for the Congress requested that a summary of American Carboniferous geology be prepared. The Geological Survey had already prepared Professional Paper 853, "Paleotectonic Investigations of the Pennsylvanian System in the United States," and was preparing Professional Paper 1010, "Paleotectonic Investigations of the Mississippian System in the United States." These major works emphasize geologic structures and draw heavily on subsurface data. The Permanent Committee also hoped for a report that would emphasize surface outcrops and provide more information on historical development, economic products, and other matters not considered in detail in Professional Papers 853 and 1010.

Because the U.S. Geological Survey did not possess all the information necessary to prepare such a work, the Chief Geologist turned to the Association of American State Geologists. An enthusiastic agreement was reached that those States in which Mississippian or Pennsylvanian rocks are exposed would provide the requested summaries; each State Geologist would be responsible for the preparation of the chapter on his State. In some States, the State Geologist himself became the sole author or wrote in conjunction with his colleagues; in others, the work was done by those in academic or commercial fields. A few State Geologists invited individuals within the U.S. Geological Survey to prepare the summaries for their States.

Although the authors followed guidelines closely, a diversity in outlook and approach may be found among these papers, for each has its own unique geographic view. In general, the papers conform to U.S. Geological Survey format. Most geologists have given measurements in metric units, following current practice; several authors, however, have used both metric and inch-pound measurements in indicating thickness of strata, isopach intervals, and similar data.

This series of contributions differs from typical U.S. Geological Survey stratigraphic studies in that these manuscripts have not been examined by the Geologic Names Committee of the Survey. This committee is charged with insuring consistent usage of formational and other stratigraphic names in U.S. Geological Survey publications. Because the names in these papers on the Carboniferous are those used by the State agencies, it would have been inappropriate for the Geologic Names Committee to take any action.

The Geological Survey has had a long tradition of warm cooperation with the State geological agencies. Cooperative projects are well known and mutually appreciated. The Carboniferous Congress has provided yet another opportunity for State and Federal scientific cooperation. This series of reports has incorporated much new geologic information and for many years will aid man's wise utilization of the resources of the Earth.

H William Menard

H. William Menard
Director, U.S. Geological Survey

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