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

Mississippian Stratigraphy of Alabama
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Pennsylvanian Stratigraphy of Alabama
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Carboniferous Outcrops of Mississippi
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Historical review and summary of areal, stratigraphic, structural, and economic geology of Mississippian and Pennsylvanian rocks in Alabama and Mississippi

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MISSISSIPPIAN STRATIGRAPHY OF ALABAMA

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MISSISSIPPIAN STRATIGRAPHY OF ALABAMA

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ABSTRACT

Mississippian rocks in Alabama are exposed along the Appalachian fold and thrust belt and extend through the Black Warrior basin and East Warrior platform northwest of the Appalachians. The lower part of the Mississippian System is an extensive unit of chert and cherty carbonate (Fort Payne and Tuscumbia); the upper part includes three different facies. In north-central Alabama, the upper part of the Mississippian is a shallow-marine limestone facies (Monteagle and Bangor). On the southwest, the carbonate facies is bordered by a northeast-prograding sequence of prodelta mud and deltaic sand and mud (Floyd and Parkwood). Tongues of the clastic facies pinch out northeastward into the carbonate facies. The most extensive tongue of shale and sandstone (Pride Mountain and Hartselle) extends from the lower part of the clastic facies and grades northeastward into the Monteagle Limestone on the East Warrior platform. The upper part of the clastic facies grades northeastward into the Bangor Limestone near the southwest edge of the East Warrior platform. The Mississippian System thickens southwestward in the clastic facies off the East Warrior platform and is thicker in Appalachian synclines southeast of the platform. Where the section is thick in Appalachian synclines, the clastic facies (Floyd and Parkwood) progrades over the Bangor Limestone and extends much farther northeast than on the East Warrior platform. In northeastern Alabama, a southwest-prograding clastic facies (Pennington) grades southwestward into the upper part of the Bangor Limestone. Both the northeast-prograding Floyd-Parkwood clastic facies and the southwest-prograding Pennington Formation grade upward into massive sandstones of the Pottsville Formation, and the Pottsville extends over the Bangor Limestone in north-central Alabama. Although the Mississippian-Pennsylvanian boundary is not precisely defined, the Pottsville is commonly considered to be Pennsylvanian.

Distribution of thickness and facies of Mississippian rocks in Alabama define the Black Warrior basin and East Warrior platform. Greater thickness and extent of the northeast-prograding clastic facies indicate contemporaneous Appalachian synclines southeast of the East Warrior platform. On a more regional scale, the northeast-prograding Floyd-Parkwood sequence is at the eastern limit of a major clastic wedge centered on the Ouachita structural salient, and the southwest-prograding Pennington sequence is at the southwestern fringe of a clastic wedge centered on the Tennessee Appalachian structural salient. The large-scale clastic wedges converged on the Mississippian carbonate facies in the Alabama Appalachian structural recess.

INTRODUCTION

In northern Alabama, Mississippian rocks are exposed in a wide outcrop area along the north limb of the Black Warrior basin and have been drilled in the subsurface beneath Pennsylvanian rocks throughout the basin (fig. 1). The north limb of the Black Warrior basin is a homocline of low dip, and the basin is bordered on the southeast by the Appalachian fold and thrust belt. The eastern part of the Black Warrior basin is defined as the East Warrior platform (Thomas, 1972a, p. 5).

In the Appalachian fold and thrust belt, Mississippian rocks are exposed in narrow linear outcrops along Appalachian structures, including both limbs of the Sequatchie anticline; the northwest limbs of the Birmingham anticlinorium, Murphree Valley anticline, and Wills Valley anticline; both limbs of the Blount Mountain and Lookout synclines; the northwest limb of the Cahaba syncline (southeast limb of Birmingham anticlinorium); the northwest limb of the Coosa synclinorium; and the Coosa deformed belt along the southeast limb of the Coosa synclinorium (fig. 1). Farther southeast in the Piedmont province of Alabama, some metasedimentary rocks are of Mississippian age (Carrington, 1967, p. 26; 1972, p. 1–18).

Toward the west and southwest both in the Black Warrior basin and along Appalachian structures, Paleozoic rocks plunge southwest beneath the cover of Mesozoic strata in the Gulf Coastal Plain (fig. 1). In the subsurface (below Mesozoic coastal-plain beds) of western Alabama, the northwesternmost

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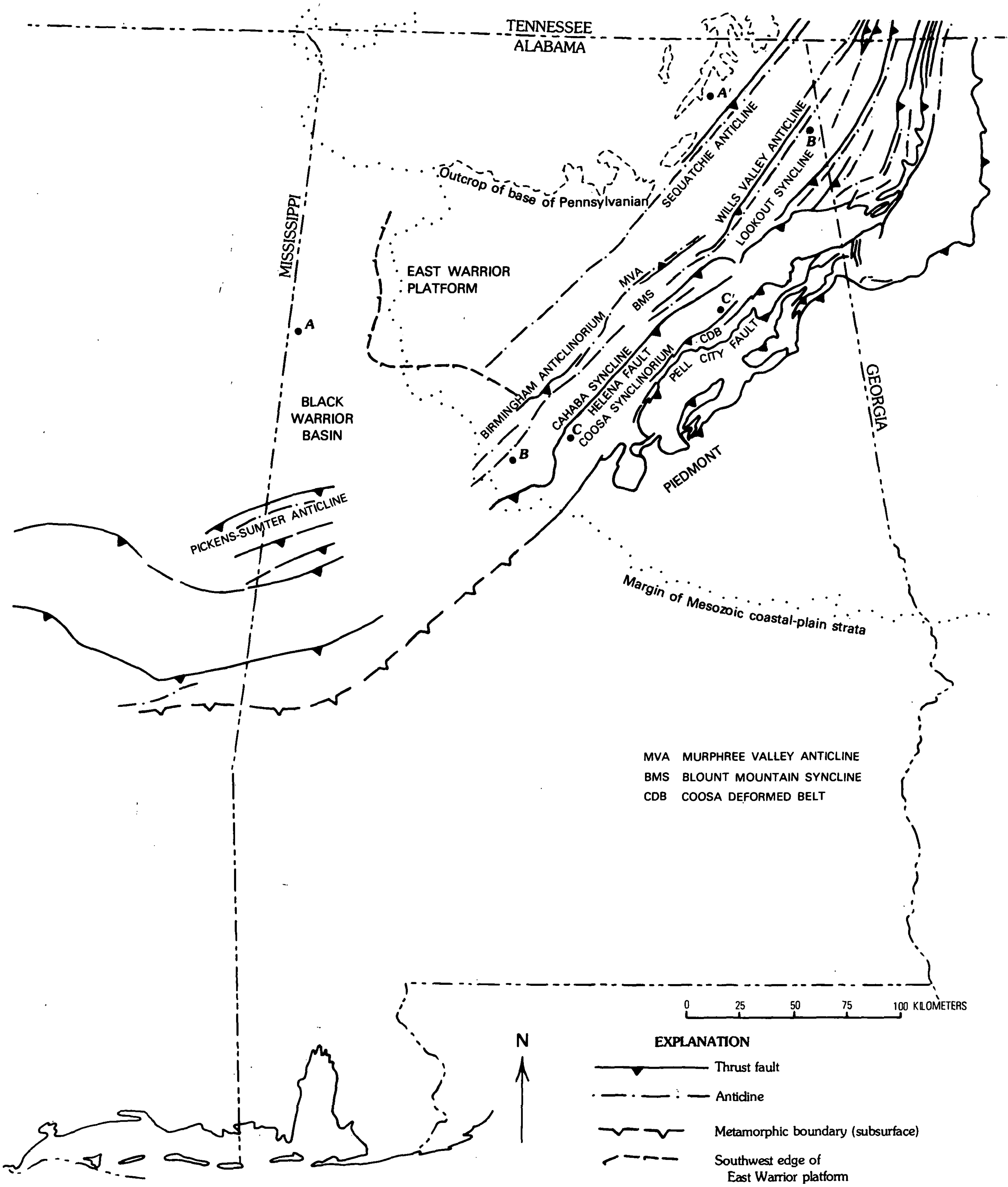


FIGURE 1.—Outline geologic map of Alabama. End points of cross sections of figure 2 are indicated by dots (*A–A′*, *B–B′*, *C–C′*). Outcrop of base of Pennsylvanian is shown only in area northwest of Appalachian fold and thrust belt.

Appalachian structure is the Pickens-Sumter anticline (fig. 1), and the subsurface fold and thrust belt includes at least two other major structures (Thomas, 1973).

The descriptions and interpretations summarized here are based on measured outcrop sections from each of the outcrop belts and on data (sample descriptions and geophysical logs) from wells in the Black Warrior basin (Thomas, 1972a). More detailed descriptions, as well as detailed stratigraphic cross sections and maps, have been published in Monograph 12 of the Geological Survey of Alabama (Thomas, 1972a). The regional setting of Mississippian rocks in Alabama has been discussed in the context of stratigraphic cross sections and maps (Thomas, 1974).

This paper summarizes published descriptive data available in 1977 and reviews the evolution of stratigraphic subdivision and correlation in Alabama. The data and conclusions are summarized in a discussion of depositional and tectonic framework. The manuscript has been reviewed by J. A. Drahovzal and G. H. Mack.

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 Geological Survey of Alabama.

MISSISSIPPIAN LITHOFACIES

The Mississippian System of Alabama may be divided into two general units (fig. 2). The lower unit is a regionally extensive interval of cherty limestone and chert (Fort Payne and Tuscumbia formations). The Fort Payne Chert is underlain by a thin widespread green shale (Maury Shale) that marks the base of the Mississippian System in Alabama. The upper part of the Mississippian (above Tuscumbia) encompasses three different laterally equivalent facies. In north-central Alabama, the upper part of the Mississippian is almost entirely limestone (Monteagle and Bangor Limestones). The carbonate facies grades southwestward into a succession of shale and sandstone (Floyd and Parkwood formations). Toward the northeast, the upper part of the carbonate facies grades into another succession of shale and sandstone (Pennington Formation). All three facies of the upper part of the Mississippian are overlain by massive sandstone and quartz-pebble conglomerate of the Pennsylvanian Pottsville Formation.

The Fort Payne-Tuscumbia interval is more than 100 m thick in north-central Alabama on the East Warrior platform, but toward the southwest, the cherty carbonate interval thins gradually to less than 50 m in the Black Warrior basin (figs. 2, 3). Similarly, toward the southeast in Appalachian synclines, the Fort Payne-Tuscumbia interval thins to less than 50 m and pinches out locally.

The thickness of Mississippian rocks between the top of the Tuscumbia and the base of the Pottsville ranges from a minimum of about 200 m on the East Warrior platform in north-central Alabama to more than 1,000 m in the Coosa synclinorium (figs. 2, 3). The thickness of the upper part of the Mississippian is less than 300 m across the East Warrior platform, which encompasses the eastern end of the Black Warrior basin and the northwestern part of the Appalachian fold and thrust belt, including the Sequatchie anticline. The southwestern edge of the East Warrior platform is marked by an abrupt southwestward increase in thickness of the upper part of the Mississippian; in the Black Warrior basin, the thickness increases to more than 500 m. The East Warrior platform is bounded on the southeast by thicker sections in Appalachian synclines. Maximum thickness is more than 400 m in the Blount Mountain and Lookout synclines, more than 800 m in the Cahaba syncline, and more than 1,000 m in the Coosa synclinorium.

The Floyd-Parkwood clastic facies thickens southwestward in the Black Warrior basin and is also relatively thick in the Cahaba and Coosa synclines (fig. 2). The clastic facies grades northeastward into the carbonate facies along a boundary that trends southeastward across the Black Warrior basin, diagonally across the East Warrior platform, and into the northwestern part of the Appalachian fold and thrust belt, where the facies boundary is approximately perpendicular to Appalachian structural strike. Tongues of clastic rocks extend northeastward from the clastic facies and pinch out toward the northeast within the carbonate facies on the East Warrior platform. The most extensive tongue of the clastic facies (Pride Mountain Formation and Hartselle Sandstone) extends from the lower part of the Floyd Shale and underlies the Bangor Limestone in north-central Alabama (fig. 2). Farther northeast, the Pride Mountain-Hartselle clastic tongue grades northeastward into the Monteagle Limestone and pinches out between the Monteagle and Bangor Limestones (figs. 2, 3). The upper part of the clastic facies grades northeastward into the Bangor Limestone across the south-

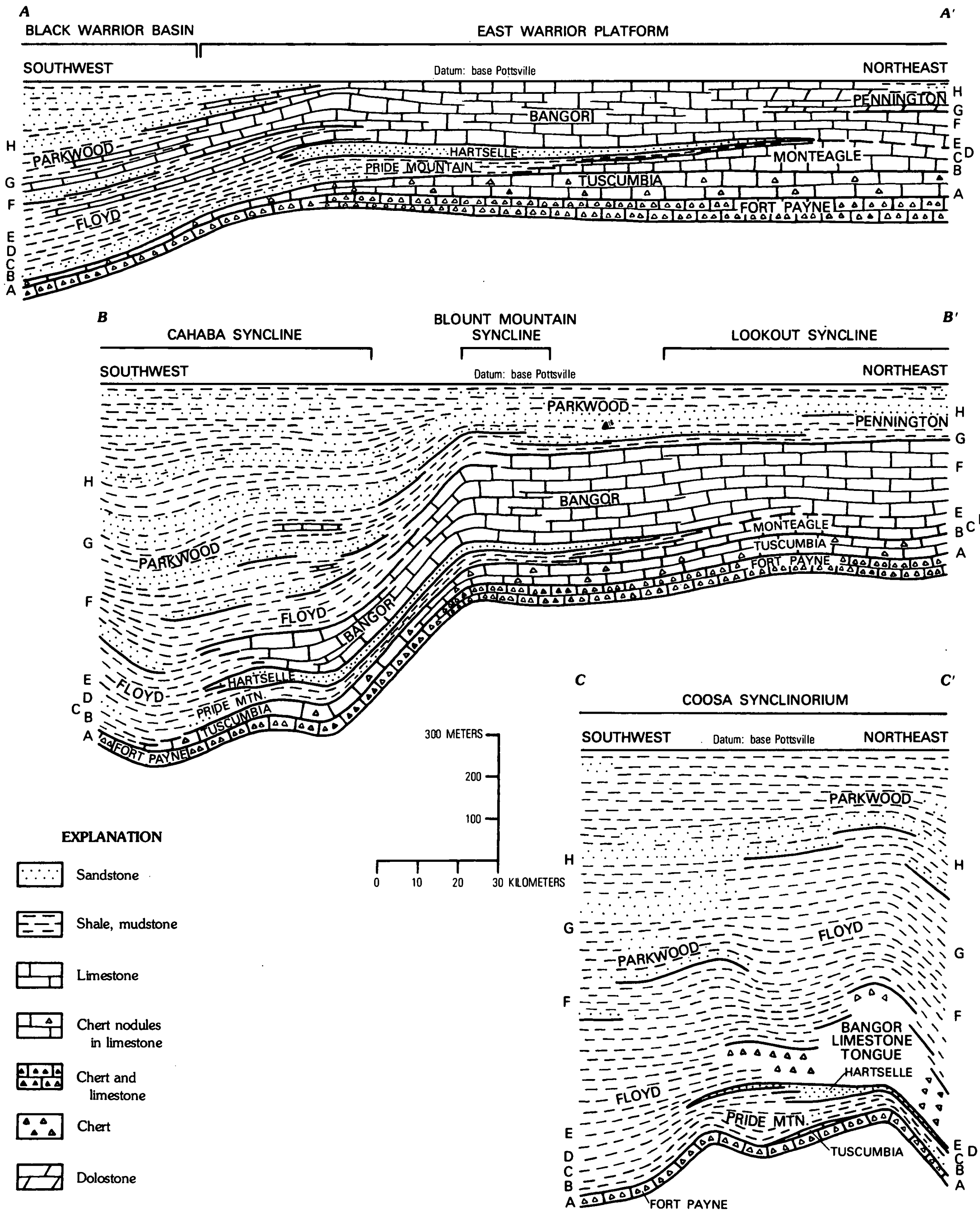


FIGURE 2.—Diagrammatic stratigraphic cross sections of Mississippian rocks in Alabama. End points of cross sections are shown on map in figure 1. Letters A through H on cross sections show approximate stratigraphic positions of maps in figure 5.

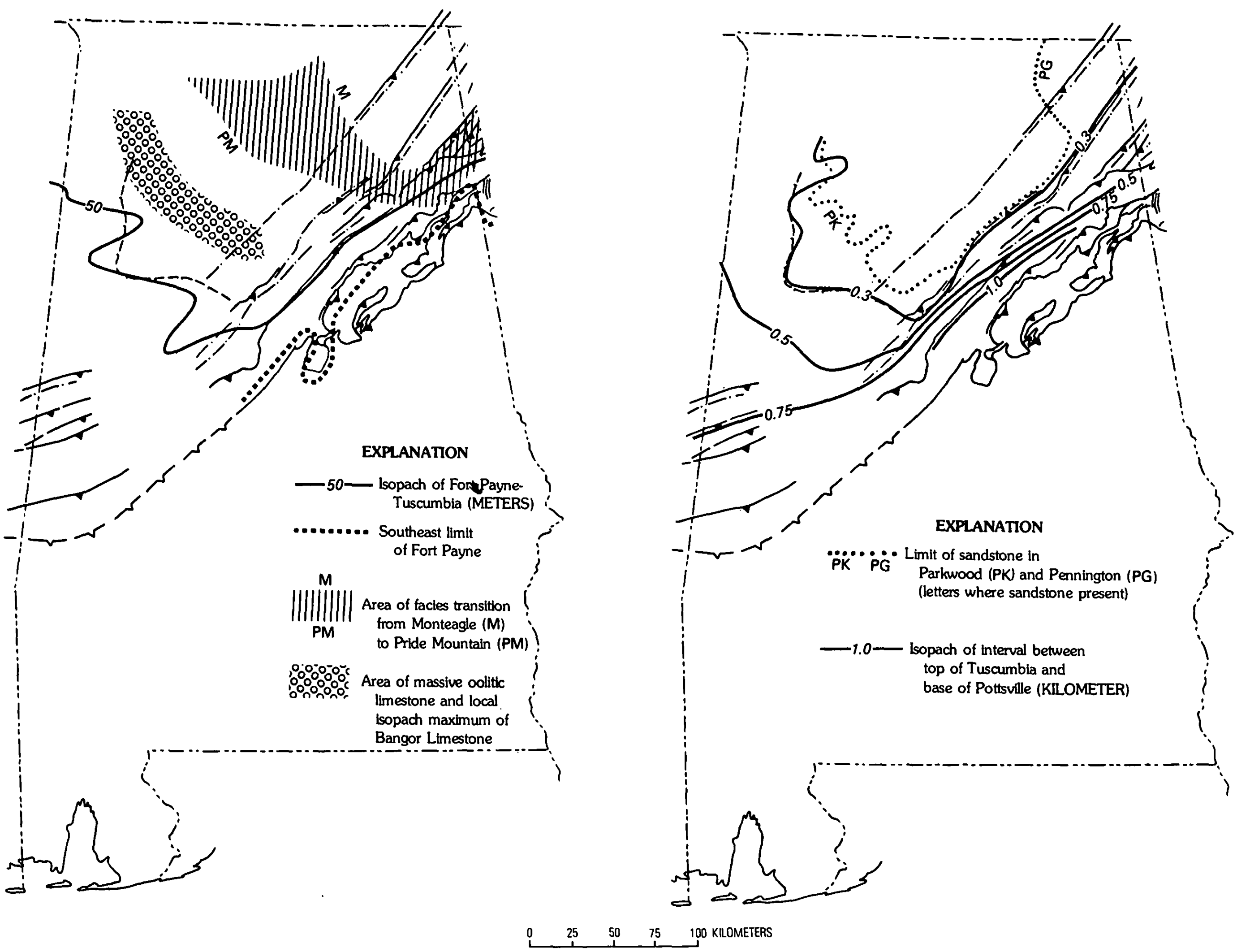


FIGURE 3.—Generalized isopach and facies maps of parts of Mississippian System in Alabama.

western part of the East Warrior platform. Similar patterns of distribution of the major facies prevail along Appalachian synclines; however, the clastic facies is thicker and extends much farther northeast along the more southeasterly structures. In the relatively thicker sections along Appalachian synclines, the upper part of the clastic facies extends far to the northeast above the Bangor Limestone (fig. 2). In the Coosa synclinorium, the clastic facies extends to the northeast end of the outcrop, and the carbonate facies is represented only by a southwest-thinning tongue of limestone and chert (fig. 2). Distribution of the Floyd-Parkwood clastic facies indicates that the rocks in Alabama are at the eastern fringe of a regionally extensive clastic wedge that includes the very thick Mississippian clastic rocks of the Ouachita Mountains (Thomas, 1974, p. 201; 1977, p. 1259).

The Pennington Formation is restricted to the northeastern corner of Alabama and grades westward into the upper part of the Bangor Limestone (fig. 2). The Pennington Formation of Alabama evidently is only the distal fringe of a regionally extensive clastic wedge centered farther northeast (Thomas, 1974, p. 205; 1977, p. 1258).

EVOLUTION OF STRATIGRAPHIC NOMENCLATURE

In 1879, Smith established a threefold division of Carboniferous rocks in Alabama and identified regional equivalents (fig. 4). The Lower Sub-Carboniferous was divided into Lower Siliceous (equivalent to Keokuk and Burlington) and Upper Siliceous (equivalent to St. Louis). The Upper Sub-Carboniferous or Mountain Limestone (equivalent to Chester) contained the entire carbonate sequence

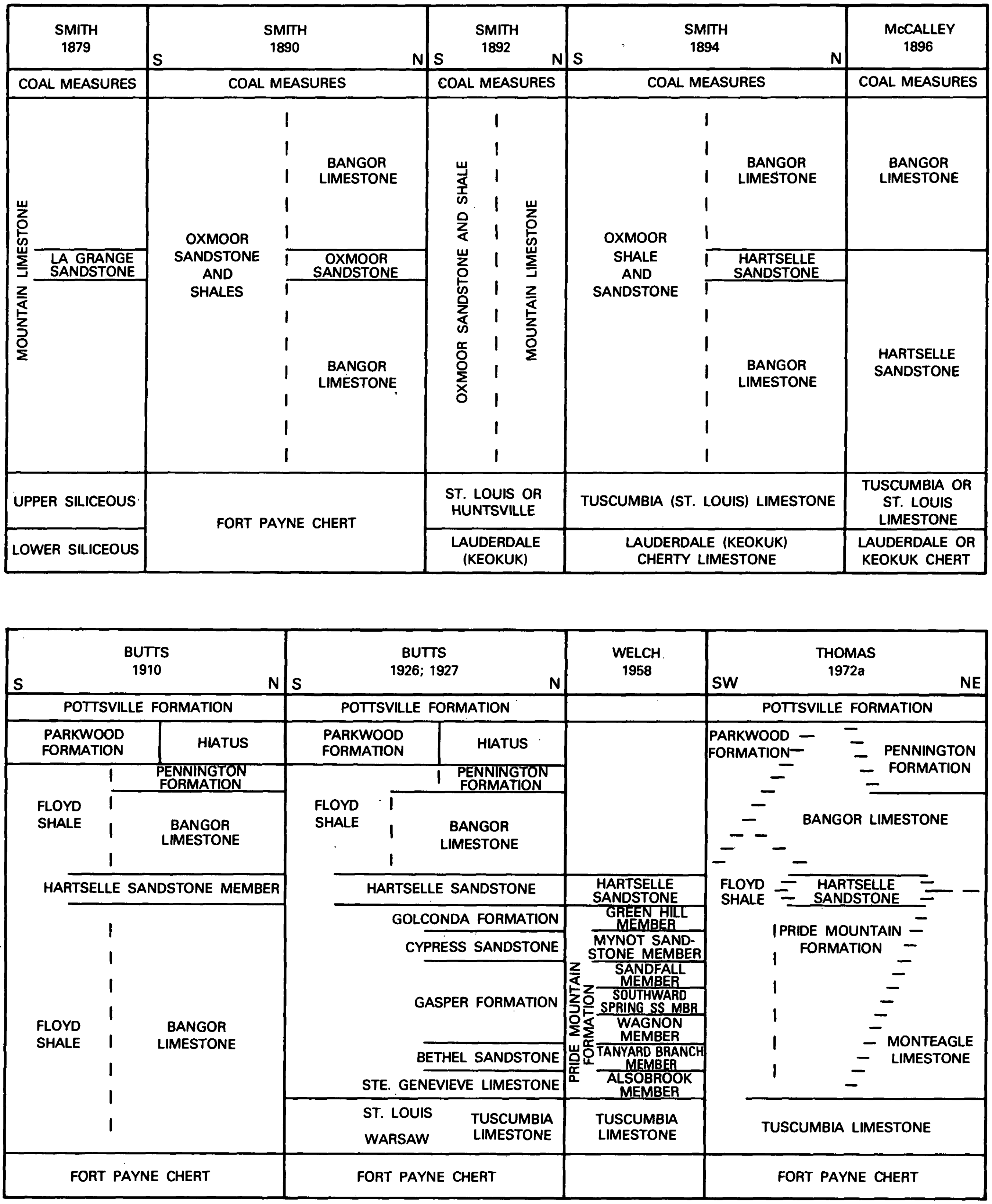


FIGURE 4.—Evolution of stratigraphic subdivision and namenclature of Mississippian rocks in Alabama.

above the lower cherty unit. Smith (1879, p. 17) designated the local name, LaGrange Sandstone, for a persistent sandstone within the Mountain Limestone. The Coal Measures included the coal-bearing sequence later assigned to the Pennsylvanian System.

Later, Smith (1890) applied local formation names to Mississippian stratigraphic units (fig. 4). The Fort Payne Chert encompassed all the cherty limestones in the siliceous Lower Sub-Carboniferous. The carbonate sequence above the Fort Payne Chert was called the Bangor Limestone. Toward the south in Alabama, the Bangor Limestone is replaced by a sandstone and shale succession called Oxmoor Sandstone and Shales (Smith, 1890, p. 155). The name Oxmoor was extended to replace Lagrange for the sandstone within the limestone sequence. The Oxmoor included the entire southwestern clastic sequence.

In summary reports, Smith (1892, 1894) defined two divisions of the beds originally called Fort Payne Chert (fig. 4). The upper cherty limestone unit was referred to as St. Louis or Huntsville in 1892 and as the Tuscumbia (St. Louis) Limestone in 1894. The lower subdivision was called Lauderdale (Keokuk) in 1892 and Lauderdale (Keokuk) cherty limestone in 1894. Smith (1894) used the name Hartselle Sandstone to replace Lagrange and Oxmoor for the sandstone unit within the Bangor Limestone.

McCalley (1896, p. 40) restricted Bangor to the limestone above the Hartselle Sandstone and extended the Hartselle Sandstone downward to include a succession of sandstone and shale beds below the Bangor Limestone and above the Tuscumbia (fig. 4). McCalley (1896, p. 40) recognized a prominent sandstone (Hartselle of earlier and later use) at the top of his Hartselle and described the westward or southwestward thickening of the sandstone-shale unit.

Butts (1910, p. 7) recognized equivalence of the carbonate sequence of northern Alabama to part of the clastic sequence to the south and modified the stratigraphic nomenclature to reflect that interpretation (fig. 4). Fort Payne Chert was restricted to the bedded chert previously called Lauderdale cherty limestone. Butts (1910, p. 7) extended Bangor Limestone downward to the top of the redefined Fort Payne and recognized a gradational contact between the Fort Payne and cherty limestone of the lower Bangor. Following Smith (1894), Hartselle Sandstone was defined as a member of the Bangor. Butts (1910, p. 8) extended use of Floyd Shale from northwest Georgia as the shaly lower part of the clastic sequence and defined a new name, Parkwood Formation, for the sandstone-shale succession of the upper part. Floyd and Parkwood replaced Oxmoor (fig. 4). The name Pennington Formation was extended from Virginia for shale above the Bangor Limestone (fig. 4). Butts (1910, p. 7) described the Pennington as being overlain by the Pottsville Formation on the north and by the Parkwood Formation on the south. Butts (1910, p. 7) concluded that the Bangor and Pennington are contemporaneous with the Floyd and are older than the Parkwood. He (1910, p. 8) suggested that where Parkwood is present, sedimentation was continuous from Mississippian into Pennsylvanian. Absence of Parkwood below the Pottsville north of Birmingham was regarded as an indication of regional unconformity between Mississippian and Pennsylvanian rocks (Butts, 1910, p. 8).

In the classic report on the geology of Alabama, Butts (1926) retained the use of local stratigraphic names for several units and extended names from the Mississippi Valley for other stratigraphic subdivisions in Alabama (fig. 4). Tuscumbia Limestone was used interchangeably with Warsaw and St. Louis for the cherty limestone above the Fort Payne Chert. Formation names extended from the Mississippi Valley were applied to the succession of shale, limestone, and sandstone between the Tuscumbia and the Hartselle (fig. 4). Bangor Limestone was restricted to beds above the Hartselle Sandstone (Butts, 1926, p. 195), and Hartselle was raised to formation rank (Butts, 1926, p. 192). The Pennington Formation apparently was described only for beds between Bangor and Pottsville in northern Alabama (Butts, 1926, p. 199); later, Butts (1927, p. 12) considered the shale between Bangor and Parkwood south of Birmingham (Pennington of Butts, 1910, p. 7) as part of the Floyd Shale.

Recognizing the impracticality of identification of the Mississippi Valley units for the beds between Tuscumbia and Hartselle in northwestern Alabama, Welch (1958) defined the entire succession of shale, limestone, and sandstone as the Pride Mountain Formation. Welch (1958) provided member definition for each part of the formation, which is described as consisting "of relatively thick units of shale that alternate with thinner units of limestone, sandstone, and siltstone" (fig. 4). The Pride Mountain Formation constitutes a clastic tongue in the lower part of the Mississippian carbonate sequence;

it grades northeastward into the limestone sequence in northeastern Alabama.

Stratigraphic subdivisions currently used for Mississippian rocks by the Geological Survey of Alabama (fig. 4) were outlined in a comprehensive review of Mississippian stratigraphy of Alabama (Thomas, 1972a). The southwestern clastic facies is divided into the Floyd Shale and the Parkwood Formation. Generally, the Floyd Shale overlies the Tuscumbia Limestone. The Tuscumbia evidently grades southeastward into shale, and where the Tuscumbia is absent, Floyd Shale rests directly on the Fort Payne Chert. A tongue of the lower part of the clastic sequence extends northeastward into the carbonate facies and is divided into the Pride Mountain Formation (shale, sandstone, and limestone) and the Hartselle Sandstone at the top. The Hartselle Sandstone pinches out both to the southwest within the shale unit in the lower part of the clastic facies and to the northeast within the carbonate facies. Southwest of the pinchout of the Hartselle Sandstone, the Pride Mountain Formation below is not distinct from the Floyd Shale above, and the Floyd Shale extends down to the top of the Tuscumbia Limestone. Toward the northeast, in northeastern Alabama, the Pride Mountain Formation grades into a limestone unit between the Tuscumbia and Hartselle. The name Monteagle Limestone was extended from southern Tennessee for the limestone above the Tuscumbia and below the Hartselle Sandstone or Bangor Limestone (Thomas, 1972a, p. 19), and Monteagle replaced the names Butts (1926) had extended from the Mississippi Valley. The upper part of the Mississippian carbonate sequence in Alabama is the Bangor Limestone. The Bangor overlies the Hartselle Sandstone, and toward the northeast where the Hartselle pinches out, the Bangor rests directly on Monteagle Limestone. East of the pinchout of the Hartselle Sandstone, the Monteagle and Bangor Limestones are not differentiated. In northeastern Alabama, the upper part of the Bangor grades northeastward into a clastic facies of shale, mudstone, sandstone, dolostone, and limestone. The name Pennington Formation has been restricted to the clastic facies on the northeast (Thomas, 1972a, p. 83).

LITHOSTRATIGRAPHY

MAURY SHALE

The Maury Shale is a thin persistent unit of green clay shale characterized by phosphatic nodules. In northern Alabama, the Maury is generally less than 2 m thick; however, the formation provides a distinctive lithologic marker at the base of the Mississippian System.

FORT PAYNE CHERT

The Fort Payne Chert in Alabama is typified by buff-weathered chert in irregular nodular beds. Commonly, the weathered chert contains abundant molds of echinoderm columnals and brachiopods, and the texture of some of the weathered chert suggests decalcified siliceous limestone. In unweathered exposures and in the subsurface, the Fort Payne is dark-gray to light-gray siliceous micrite and blue-gray to smoky chert in irregular beds and nodules. The formation locally includes light-gray coarse bioclastic limestone in lenses less than 3 m thick. The Fort Payne Chert includes some dark shale in northwestern Alabama (Butts, 1926, p. 164) and shaly beds in eastern Alabama. In northern Alabama, the formation contains geodes.

The Fort Payne ranges in thickness from more than 50 m on the East Warrior platform to less than 20 m on the southwest in the Black Warrior basin. The formation also thins southeastward across the Appalachian fold and thrust belt. Apparently the Fort Payne Chert pinches out southeastward along an irregular line along the Coosa deformed belt and the upplunge southwest end of the Coosa synclinorium (fig. 3).

The contact between the Fort Payne Chert and Tuscumbia Limestone is gradational from the siliceous micrite and bedded chert typical of the Fort Payne upward to a succession of light-colored bioclastic limestone and micrite containing abundant nodules of light-colored chert (Thomas, 1972a, p. 12). Differentiation of the two units is progressively less distinct westward in the Black Warrior basin. Where the Tuscumbia Limestone is absent along the southeastern Appalachian structures, the Fort Payne is overlain by dark clay shale and argillaceous limestone of the Pride Mountain Formation-Floyd Shale.

TUSCUMBIA LIMESTONE

The Tuscumbia Limestone consists mainly of light-gray micrite and bioclastic limestone in thick beds. Crossbedded, coarse crinoidal limestone beds are locally as much as 3 m thick. Oolitic limestone is rare. In northeastern Alabama, thin lenses and beds of finely crystalline dolostone and dolomitic limestone are scattered randomly throughout the Tuscumbia; dolostone is more common in equivalent beds in southern Tennessee (Ferguson and Stearns, 1967, p. 56). Light-gray and white chert nodules are common throughout the formation; dark-gray chert is less common. Part of the chert contains fossil molds. Fenestrate bryozoans are locally abundant. Concentrically banded, concretionary chert is abundant locally.

The Tuscumbia Limestone is more than 50 m thick on the East Warrior platform in north-central Alabama; it thins gradually southwestward in the Black Warrior basin to less than 15 m (fig. 2). Along Appalachian synclines, the formation thins and pinches out to the southeast and southwest, and it is absent at the southwest end of the Cahaba syncline and along the Coosa synclinorium, except locally on the northwest limb (fig. 2).

Where the Tuscumbia is overlain by the clastic facies, the basal beds of the Pride Mountain Formation-Floyd Shale commonly are shaly, oolitic, and (or) sandy limestone that suggests an upward gradation into the shale succession. The pinchout of the Tuscumbia along Appalachian synclines may be a result of lateral gradation into the lower part of the clastic facies (Thomas, 1972a, p. 17). Alternatively, thinning of the Tuscumbia in the Black Warrior basin has been attributed to an unconformity at the top of the formation (Welch, 1958; 1959). In northeastern Alabama, the contact between the Tuscumbia and overlying Monteagle Limestone is gradational; the Monteagle is characterized by light-colored massive oolitic limestone and contains significantly less chert, dolostone, and micrite than does the Tuscumbia.

MONTEAGLE LIMESTONE

The Monteagle Limestone is characterized by light-gray oolitic limestone in crossbedded, massive beds more than 3 m thick. Thick-bedded bioclastic limestones are common. Interbeds of micrite are less common. Interbeds of finely crystalline dolostone and dolomitic limestone are rare and are randomly distributed. Nodules of gray and black chert are rare. The Lost River Chert, a marker in the lower Monteagle of Tennessee (Ferguson and Stearns, 1967, p. 57), does not appear to be laterally persistent in Alabama. In the northeastern corner of Alabama, the middle part of the Monteagle contains a distinctive unit of interbedded limestone and shale about 8 m thick (Thomas, 1972a, p. 21).

In northeastern Alabama, the Monteagle is approximately 65 m thick and is almost entirely limestone. Toward the southwest on the East Warrior platform, the Monteagle grades southwestward to clay shale of the Pride Mountain Formation (figs. 2, 3). The facies boundary between the Monteagle and Pride Mountain rises stratigraphically northeastward, and a thin tongue of clay shale of the upper Pride Mountain extends northeastward above the Monteagle and below the eastward-pinching Hartselle Sandstone. East of the pinchout of both Pride Mountain and Hartselle, the Monteagle is overlain by the Bangor Limestone in a continuous succession of limestone beds. Although a Monteagle-Bangor contact may be projected eastward, the two formations are clearly separable only where the Hartselle and (or) Pride Mountain intervene, and the undifferentiated Monteagle-Bangor cannot be reliably subdivided farther east (Thomas, 1972a, p. 22).

The Monteagle Limestone extends southeastward into Lookout syncline and grades southwestward to the Pride Mountain Formation near the southwest end of the syncline, just as it does on the East Warrior platform (figs. 2, 3). Southeast of the Lookout syncline, the Monteagle grades into the clastic facies (Pride Mountain-Floyd).

BANGOR LIMESTONE

The Bangor Limestone is mainly bioclastic limestone and oolitic limestone. The formation also includes micrite and thin beds of shaly argillaceous limestone and calcareous shale. Thin laterally discontinuous beds of maroon and green blocky mudstone are scattered through the upper half of the formation. Chert is generally restricted to the upper part of the Bangor. A few small masses of coral are scattered widely. In northeastern Alabama, a dolostone unit extends from the basal Pennington Formation into the Bangor LImestone.

The Bangor Limestone ranges approximately from 130 to 180 m in thickness on the East Warrior platform. A linear isopach and limestone isolith maximum is alined approximately with the southwestern edge of the East Warrior platform in northwestern Alabama and trends southeastward diagonally across the platform northeast of the edge (Thomas, 1972a, pl. 11; 1974, fig. 6). Southwest of the linear isopach-isolith maximum, thickness of limestone decreases where the Bangor grades southwestward into the clastic facies (Thomas, 1972a, p. 50). Similarly, the Bangor thins northeastward where the upper part grades laterally into the Pennington Formation (fig. 2).

The Bangor thickens southeastward to more than 180 m along the Sequatchie anticline and Blount Mountain and Lookout synclines. Farther southeast in the Appalachian fold and thrust belt, the Bangor generally is less than 150 m thick, but there, much of the Bangor-equivalent interval is in the Floyd-Parkwood clastic facies (fig. 2). However, the Bangor Limestone also thins southwestward and grades to clastic rocks along strike of the Cahaba syncline. A similar pattern prevails along the Coosa synclinorium (fig. 2), where the southwest-thinning Bangor Limestone Tongue of the Floyd Shale is mostly weathered chert on the northwest limb and mostly limestone along the Coosa deformed belt.

Oolitic limestone is most abundant along the linear isopach maximum across the southwestern part of the East Warrior platform (fig. 3); along the same area, the formation contains three separate massive oolitic limestone units, each as much as 12 m thick (Jones, 1928, p. 13; Thomas, 1972a, p. 49). Farther northeast on the East Warrior platform, oolitic limestone units appear thinner and less extensive, and both oolitic and bioclastic limestones are generally in thick beds or large lenses, which are crossbedded.

On the East Warrior platform, the Bangor is overlain by the Pottsville Formation. The contact is within a succession that includes (in ascending order) limestone, maroon and green mudstone, carbonaceous shale and thin-bedded sandstone, and the characteristic thick massive sandstone of the lower Pottsville. Thickness of fine clastic rocks between the top of the limestone succession and the massive sandstone is generally less than 20 m but varies locally. Various components of the gradational succession are not everywhere present, and locally the massive sandstone appears to rest directly on the limestone. The succession indicates that the Bangor-Pottsville contact is gradational, but channels are suggested where the massive sandstone rests on limestone. However, the possible channels appear to be local, and the contact apparently is not a regional unconformity (Thomas 1972a, p. 94).

FLOYD SHALE

The Floyd Shale is a dark-gray clay shale that constitutes the lower part of the southwestern Mississippian clastic sequence. In the Black Warrior basin, the Floyd grades upward into the Parkwood Formation, and the upper part of the Floyd grades northeastward into the Bangor Limestone (fig. 2). The Floyd and Parkwood grade northeastward into the Bangor along an irregular southeast-trending line near the southwestern edge of the East Warrior platform; however, an extensive tongue of the lower part of the Floyd Shale extends far northeast beneath the Hartselle Sandstone as the Pride Mountain Formation. Sandstone units characteristic of the Pride Mountain extend southwest into the lower Floyd. Along Appalachian synclines, where the Mississippian System is thicker than it is in the Black Warrior basin, the Floyd-Parkwood contact rises northeastward above the most extensive Bangor Limestone, and the Floyd Shale intervenes between the Parkwood and the Bangor (fig. 2). The clastic facies extends much farther northeast along Appalachian synclines than it does on the East Warrior platform. In the Coosa synclinorium, the Floyd includes a southwest-thinning tongue of Bangor Limestone, as well as the northeast, southeast, and southwest limits of the Hartselle Sandstone (fig. 2). The Floyd Shale extends northeast to the end of exposures in the Coosa synclinorium.

The Floyd Shale is predominantly dark-gray clay shale. Siderite nodules are scattered through the sequence. Parts of the shale sequence are calcareous and include shaly, argillaceous limestone beds. Within the Floyd in the Black Warrior basin, a limestone tongue of the lower Bangor contains dark-gray chert.

Around the southwest end of the Coosa synclinorium, the lower Floyd Shale includes beds less than 3 m thick of dark-gray argillaceous limestone that contains abundant fenestrate bryozoans, echinoderm columnals, and brachiopods. Farther southwest, south of the Black Warrior basin on the Pickens-Sumter anticline, the lower part of the Floyd contains limestone units that attain an aggregate thickness of about 60 m. At the northeast end of the Coosa deformed belt and southeast of Lookout syncline, the Floyd contains relatively thick limestone units; however, complex structure obscures the stratigraphic position of the limestones. To the east in Georgia, the lower part of the Floyd Shale contains a limestone tongue equivalent to the Tuscumbia and (or) Monteagle, and the Floyd is overlain by a tongue of the Bangor Limestone. The limestones in the Floyd of eastern Alabama may be equivalent to either or both limestone tongues within the clastic sequence in Georgia.

PRIDE MOUNTAIN FORMATION AND HARTSELLE SANDSTONE

The Pride Mountain Formation and Hartselle Sandstone constitute a laterally extensive tongue of shale and sandstone that extends from the lower part the Floyd Shale and pinches out northeastward into the carbonate facies between the Monteagle and Bangor Limestones (figs. 2, 3). Thickness of the tongue is generally less than 110 m. The clastic tongue contains four separate sandstone units, of which the lower three are in the Pride Mountain Formation and the upper is the Hartselle Sandstone. Each of the four sandstone units is broadly linear in distribution and trends southeast, parallel with the major facies boundaries across the southwestern part of the East Warrior platform. Each of the linear sandstones pinches out southeastward along trend. The Pride Mountain sandstone units are thin or absent in the Appalachian fold and thrust belt southeast of the Birmingham anticlinorium. The Hartselle Sandstone extends as far southeast as the northwest limb of the Coosa synclinorium.

The southwest and southeast limits of the four sandstones are within the gray shale of the lower part of the clastic facies. By definition, the Pride Mountain includes the shale and sandstone succession below the Hartselle Sandstone; beyond the limit of Hartselle Sandstone, beds equivalent to the Pride Mountain are included in the lower part of the Floyd Shale (fig. 2). Sandstone units of the Pride Mountain extend farther southwest than the Hartselle and are, therefore, included in the Floyd Shale. The area of the lower sandstone unit is relatively wide and extends from the East Warrior platform southwestward into the Black Warrior basin. The middle and upper units are confined to narrow areas on the platform; however, northwest along trend, both extend across the platform edge into the Black Warrior basin. Farther west in the Black Warrior basin in Mississippi, the sandstones have a more blanketlike distribution (Thomas, 1972b, p. 98; 1974, p. 196). The three sandstone units in the Pride Mountain pinch out northeastward into a shale succession that, farther northeast, grades into the Monteagle Limestone beneath the Hartselle Sandstone.

The Pride Mountain (lower Floyd) sandstones are characteristically quartzose; however, the sandstone units commonly contain beds of partly sandy bioclastic limestone. Locally the sandstone grades laterally to limestone. The lower beds of the Pride Mountain (lower Floyd) are generally shaly and (or) oolitic limestone, and locally the lower sandstone unit is interbedded with the basal limestone. The sandstone units grade laterally to thin-bedded or shaly argillaceous sandstone and shale. The units locally consist of very fine grained sandstone in ripple-laminated beds and lenses less than 5 cm thick. Clay laminae and beds of shale alternate with the thin sandstone beds. In some places, the laminae are disrupted by abundant burrows, and the bed surfaces are marked by numerous trails. Locally, channel-filling conglomerate at the base of a sandstone unit contains clasts of limestone, claystone, and sandstone as much as 10 cm in diameter and fragments of corals, bryozoans, and brachiopods (Thomas, 1972a, fig. 13). Near the northeast limit of each sandstone, lithology and thickness vary locally.

Apart from the sandstone units, the Pride Mountain Formation consists of gray clay shale and includes calcareous shale and shaly argillaceous limestone. The calcareous rocks generally contain abundant fossils of bryozoans and brachiopods. Parts of the shale succession contain abundant siderite nodules. Plant fragments are scattered in some of the shale beds (Butts, 1927, p. 12).

The Hartselle Sandstone is the thickest and most extensive of the sandstone units on the East Warrior platform. Maximum thickness of the formation is more than 45 m along a narrow southeast-trending area across the southwestern part of the East Warrior platform. The linear area of maximum thickness is parallel with and only 18 km northeast of the southwest limit of the sandstone. Northeast of the well-defined linear thick sandstone, the formation thins irregularly eastward. Limited data suggest other discontinuous southeast-trending isolith maxima separated by broad areas of thinner sandstone (Beavers and Boone, 1976, p. 11). Farther east, the sandstone thins gradually and pinches out eastward between the Monteagle and Bangor Limestones. Near the east limit of sandstone, the Hartselle includes lenses of alternating thin laminae of quartzose sandstone and oolitic bioclastic limestone. Where the Hartselle overlies the thin east-pinching tongue of Pride Mountain shale, sandstone fills channels nearly 1 m deep, and where the Hartselle overlies the Monteagle Limestone, the upper limestone beds are sandy. Thickness of sandstone varies abruptly near the east limit; possibly, some sandstone lenses are isolated farther east within the carbonate facies. Eastward beyond the limit of sandstone, the Hartselle horizon within the limestone succession may be marked by a thin bed of shale and (or) locally by crossbedded lenses and channeled limestone beds. In north-central Alabama, the Hartselle Sandstone grades upward to the Bangor Limestone through a few meters of calcareous clay shale and argillaceous limestone.

The Hartselle Sandstone is generally a light-colored fine-grained quartzose sandstone. In northwestern Alabama, the formation includes two major facies: thick-bedded crosslaminated matrix-free sandstone and thin-bedded ripple-laminated sandstone that has a terrigenous matrix and mudstone interbeds (Beavers and Boone, 1976, p. 11). The Hartselle is characterized generally by thick-bedded crossbedded sandstone. Some beds are ripple marked, and thin-bedded ripple-laminated sandstone locally is marked by trails. Flat clay pebbles less than 3 cm in diameter are scattered in the sandstone beds at some localities. Beds of shale and shaly sandstone make up a small proportion of the formation. Whole and fragmented fossils of brachiopods, bryozoans, and blastoids are common locally. Plant fossils, including tree segments as much as 60 cm long and 15 cm across, are imprinted on sandstone and shale beds. Large tree fragments, including a stump, were collected from the Hartselle of northwestern Alabama (McCalley, 1896, p. 171–176).

Near the southwest end of the Lookout syncline and in the area farther north, the Pride Mountain Formation grades northeastward to the Monteagle Limestone, and the Hartselle pinches out northeastward within the carbonate facies. Along the Coosa synclinorium, where the clastic facies extends farther northeast, the Hartselle Sandstone pinches out northeastward within the shale succession in the lower part of the clastic facies.

PARKWOOD FORMATION

The Parkwood Formation is a succession of alternating units of shale and sandstone and is divisible into four cyclic intervals. Part of each cycle is dominated by sandstone; however, shale interbeds are common. Generally, the sandstone grades up into a dominantly shale unit, which grades up into a higher sandstone. Where the formation is thick, each cycle commonly includes more than 100 m of beds. Some sandstone units are locally more than 30 m thick, and sandstone generally constitutes 15–40 percent of the formation. The base of the formation is defined as the base of the lowest sandstone unit, and because the lower sandstone units successively pinch out northeastward, the base of the formation ascends stratigraphically in that direction. Aggregate thickness of sandstone and total thickness of the formation generally increase southwestward.

The Parkwood Formation pinches out northeastward along an irregular, southeast-trending line that extends across the East Warrior platform and into the Appalachian fold and thrust belt (figs. 2, 3). Along the Appalachian synclines, where the clastic facies is thickest, the Parkwood extends much farther northeast than on the East Warrier platform (figs. 2, 3). On the southeast limb of the Sand Mountain syncline and in Lookout syncline, Parkwood strata blend northeastward with clastic rocks of the southwest-thinning Pennington Formation, and the northeastern limit of Parkwood clastic sediments is obscure. The Parkwood extends northeast to the up-plunge end of the Coosa synclinorium and the northeast end of the Coosa deformed belt.

The sandstones are characteristically very fine to fine grained, argillaceous, and micaceous, but some are more quartzose. Flattened clay pebbles less than 3 cm in diameter are locally abundant. Beds range from thin and shaly to thick bedded and from planar to lens shaped. Ripple marks are relatively common, and some of the sandstones are crossbedded. Some beds and lenses are characterized by flaser bedding. Burrows and trails mark some beds. Thin clay partings and clay shale beds are common.

Between the sandstone units are intervals of gray clay shale, silty clay shale, and mudstone. Nodules and thin nodular beds of siderite are common throughout but apparently are most abundant in the lower part of the formation. Silty laminae within the shales are locally interrupted by abundant burrows.

Contacts of sandstone units with underlying and overlying clay shales are commonly gradational. Locally, sandstone units rest on scoured basal contacts, and sandstone fills shallow channels in the underlying shale. Lenses of clay-pebble and limonite-concretion conglomerate mark the bases of some sandstones, but other channel-filling sandstones are not conglomeratic.

Extensive tongues of limestone extend from the Bangor Limestone southwest into the shale-dominated parts of the Parkwood. Argillaceous, bioclastic, and cherty limestones and rare oolitic limestone compose the tongues. Calcareous mudstone and maroon and green mudstone beds are associated with the limestone beds.

Marine fossils are abundant locally. The limestone beds contain abundant brachiopods, bryozoans, and echinoderms. Shale units locally contain abundant molds of brachiopods, pelecypods, and bryozoans. Poorly preserved molds of brachiopods and bryozoans are included in some of the sandstone beds, and molds of echinoderm columnals are widely scattered.

Carbonaceous shale and sandstone containing small plant fragments are common in the upper part of the formation. Large plant fossils are preserved locally in sandstone. Carbonaceous shale near the top of the formation contains thin beds of clayey coal. The coal beds and the greatest concentration of carbonaceous sandstone and shale are in the upper 75 m of the Parkwood in the Cahaba syncline.

Across the Black Warrior basin and southwest edge of the East Warrior platform, the Parkwood grades northeastward laterally into the Bangor Limestone. Along the Appalachian synclines, the lower Parkwood grades northeastward into the Floyd Shale, which constitutes a transitional facies between the Parkwood and the Bangor. The Parkwood is overlain by a thick massive unit of quartzose sandstone, quartz-pebble conglomerate, and carbonaceous sandstone, which marks the base of the Pottsville Formation. In some places, the basal Pottsville sandstone fills erosional channels cut several meters into the underlying Parkwood beds, but at other localities, the contact is planar and appears conformable.

PENNINGTON FORMATION

The Pennington Formation is a succession of shale, mudstone, sandstone, dolostone, and limestone that overlies part of the Bangor Limestone in northeastern Alabama (figs. 2, 3). In the area northwest of the Wills Valley anticline, the clastic succession grades westward to limestone of the upper Bangor, but farther south along Appalachian structures, the Pennington merges southwestward with the northeast-wedging Parkwood clastic sequence. Along and northwest of the Sequatchie anticline, the base of the Pennington is marked by dull-gray, micrograined dolostone interbedded with maroon, green, and gray mudstone. The distinctive dolostone interval is virtually coextensive with the succeeding clastic rocks, but the dolostone extends farther west into the limestone sequence. Southeast of the Sequatchie anticline, the dolostone is not commonly exposed and the lower part of the Pennington is gray shale and maroon and green mudstone.

The Pennington Formation is predominantly gray clay shale. Maroon and green mudstones generally make up less than 10 percent of the total thickness. The formation contains beds of bioclastic, oolitic, and micritic limestones, typical of the Bangor Limestone, and the proportion of limestone increases westward. Toward the east, beds of very fine to fine-grained generally argillaceous sandstone are common in the upper part of the Pennington. The sandstone beds generally are complexly overlapped lenses or crossbeds; and, in part, the sandstone grades laterally to mudstone. The sandstone is generally carbonaceous, and plant fragments are common. The sandstone-bearing succession commonly includes carbonaceous shale and thin shaly coal beds, which are generally less than 30 cm thick. In eastern Alabama, one coal bed apparently grades laterally within a few tens of meters to a nodular bed of siderite that contains brachiopods and gastropods. Thickness of coal beds is greater to the northeast in Georgia and Tennessee, and some beds in the same stratigraphic position have been mined. The interval of sandy carbonaceous beds thickens eastward in Alabama to more than 30 m, and farther northeast, the equivalent succession is separated from the Pennington as the Raccoon Mountain Formation in Tennessee.

The Pennington Formation overlies the lower part of the Bangor Limestone and grades laterally westward into the upper Bangor. The Pennington is overlain by massive sandstone of the lower Pottsville Formation. The coal-bearing upper Pennington (or Raccoon Mountain) appears to be gradational upward to the Pottsville. Probably no major unconformity separates the Pennington and the Pottsville, although channel filling marks the base of the Pottsville sandstone in a few places.

BIOSTRATIGRAPHY

The Maury Shale contains abundant conodonts. The formation evidently encompasses three assemblage zones (*Siphonodella isosticha-S. cooperi* zone, *Gnathodus semiglaber-Pseudopolygnathus multistriata* zone, and *Bactrognathus-Polygnathus communis* zone) of the late Kinderhookian and early Valmeyeran (Drahovzal, 1967, p. 12).

The Fort Payne Chert of northern Alabama contains the characteristic Keokuk forms, *Spirifer logani* and *Brachythyris suborbicularis,* and thus is correlative with at least the Keokuk of the Mississippi Valley (Drahovzal, 1967, p. 14). Fossils representative of Kinderhook, Fern Glen, Burlington, and Keokuk have been collected from the Fort Payne Chert at several places in Alabama (Butts, 1926, p. 166–167). Butts (1926) evidently included the Maury Shale with the Fort Payne, and, exclusive of the basal shale and associated limestone beds, the

Fort Payne is equivalent to Keokuk (Drahovzal, 1967, p. 14).

The Tuscumbia Limestone in Alabama is equivalent to the Warsaw, Salem, and St. Louis of the Mississippi Valley (Drahovzal, 1967, p. 14). The lower Tuscumbia in northern Alabama contains a Warsaw-Salem fauna, including *Marginirugus magnus, Reticularia setigera,* and *Spirifer bifurcatus*; the upper part of the Tuscumbia contains a St. Louis fauna, characterized by *Lithostrotionella castelnaui* and *Lithostrotion proliferum* (Drahovzal, 1967, p. 14). In northwestern Alabama, the St. Louis coral fauna is found only in small areas, and Butts (1926, p. 175) concluded that the St. Louis is absent except locally.

The Pride Mountain Formation includes the units for which Butts (1926), on the basis of fossil faunas, extended the identification of the Ste. Genevieve, Bethel, Gasper, Cypress, and Golconda formations from the Mississippi Valley to Alabama (Thomas, 1972a, p. 26). The lower limestone unit of the Pride Mountain is recognized as equivalent to Ste. Genevieve because it locally contains abundant *Inflatia inflata* (*Productus inflatus*) (Drahovzal, 1967, p. 16). Butts (1926, p. 187–189) identified the Gasper by the presence of *Campophyllum gasperense, Chonetes chesterensis, Talarocrinus,* and other forms. Butts (1926, p. 184) correlated the underlying sandstone (now the lower sandstone unit of the Pride Mountain) with the Bethel Sandstone because it is overlain by limestone containing fossils "of lower Gasper age." However, the characteristics of *Talarocrinus* above the sandstone in Alabama are more like those of the Renault than those of the Paint Creek in the Mississippi Valley, and the sandstone may be as old as Aux Vases (Drahovzal, 1967, p. 16). Butts (1926, p. 192) identified the Golconda on the basis of *Camarophoria explanata,* and he (p. 189) correlated the underlying sandstone (now the upper sandstone unit of the Pride Mountain) with the Cypress Sandstone on the basis of stratigraphic position. A goniatite fauna from the lower part of the Pride Mountain Formation in northwestern Alabama includes *Goniatites granosus, Neoglyphioceras subcirculare, Girtyoceras limatum,* and *Lyrogoniatites* sp. cf. *L. utahensis* (Drahovzal, 1972, p. 34–35); comparison with sparse goniatites from the Illinois section and with conodont ranges suggests a Hombergian age (J. A. Drohovzal, oral commun., 1978).

The lower part of the Monteagle Limestone of northeastern Alabama contains a Ste. Genevieve fauna, characterized by *Platycrinites penicillus* (*Platycrinus huntsvillae*) (Butts, 1926, p. 182; Drahovzal, 1967, p. 16). The upper part of the Monteagle contains a Gasperian fauna, including *Chonetes chesterensis* (Drahovzal, 1967, p. 18). Golconda equivalents have not been found in the Monteagle in Alabama (Drahovzal, 1967, p. 19); however, Butts (1926, p. 191) reported *Pterotocrinus capitalis* from the section farther northeast in Tennessee.

The Hartselle Sandstone has been correlated with the Hardinsburg Sandstone of Illinois on the basis of stratigraphic position between beds containing Golconda and Glen Dean faunas (Butts, 1926, p. 195).

The lower part of the Bangor Limestone contains a Glen Dean fauna, including *Prismopora serrulata, Pentremites pyramidatus,* and *Pentremites brevis* (Butts, 1926, p. 199). More recent work has confirmed the correlation of lower Bangor with Glen Dean on the basis of *Pterotocrinus depressus* and *Pentremites robustus-maccalliei* (Drahovzal, 1967, p. 20) as well as nonfenestrate bryozoans (McKinney, 1972). The age of the upper part of the Bangor is less well established. *Pterotocrinus tridecbrachiatus* from near the top of the Bangor in north-central Alabama indicates correlation with the Kinkaid Limestone of Illinois (Drahovzal, 1967, p. 21). Drahovzal (1967, p. 21) reported a blastoid fauna, tentatively identified as *Pentremites laminatus,* that by correlation with conodont zones in Arkansas suggests correlation of the highest Mississippian beds in Alabama with the Grove Church Formation of the Mississippi Valley.

The Floyd Shale contains fossils at few places. Butts (1926, p. 204) reported brachiopod-bryozoan faunas that indicate an age range of at least Gasper to Glen Dean. Rock-stratigraphic correlations show that the Floyd grades laterally into units of the carbonate facies between the Tuscumbia and the lower part of the Bangor.

Fossils have been collected from several outcrops of the Parkwood Formation in the Appalachian fold and thrust belt. Butts (1926, p. 206) reported a collection from the Parkwood Formation that was "a mixture of Pennsylvanian and Mississippian fossils" and listed *Derbya kaskaskiensis* and *Hustedia mormoni,* Pennsylvanian forms, and *Spirifer leidyi* and *Reticularia setigera,* Mississippian forms. The lower part of the Parkwood contains Mississippian fossils such as *Archimedes* and *Fenestella tenax* (Butts, 1926, p. 206). A collection from a sandstone in the upper part of the Parkwood is probably of Pennsylvanian age, but G. H. Girty (in a communication quoted by Butts, 1927, p. 13) expressed caution about the age assignment. The collection includes such forms as *Spirifer rockymontanus, Composita subtilita,* and *Deltopecten occidentalis* (Butts, 1926, p. 206; 1927, p. 13). Fossil plants of Pocahontas age have been reported from the upper part of the Parkwood (Moore and others, 1944, p. 686). On the basis of these data from outcrops along Appalachian structures, the lower part of the Parkwood has been considered Mississippian and the upper part, Pennsylvanian (Butts, 1927, p. 13; Culbertson, 1963a, p. E49; Wanless, 1975, p. 23).

The Parkwood clastic facies grades laterally into the Bangor Limestone, and the two facies intertongue across a wide area. The rock-stratigraphic relationship suggests that the Parkwood and Bangor are temporally equivalent. However, the Bangor contains a well-documented Mississippian fauna, and time equivalence of Bangor and Parkwood is incompatible with the reported Pennsylvanian fossils of the upper Parkwood along Appalachian synclines. Possibly, differences in faunas of the Parkwood and Bangor reflect paleoecologic controls rather than time-stratigraphic controls.

On the basis of rock-stratigraphic relationship, the Pennington Formation is considered to be equivalent to the upper part of the Bangor Limestone (Thomas, 1972a, p. 89).

In a detailed investigation of crinoids in Mississippian rocks in Alabama, Burdick (1971) recognized three successive crinoid zones, in ascending order, the *Platycrinites penicillus* zone, *Talarocrinus* zone, and *Agassizocrinus* cf. *A. conicus* zone. The *Platycrinites penicillus* zone is distinctive of Ste. Genevieve; *Talarocrinus,* of lower Chesterian; and *Agassizocrinus* cf. *A. conicus,* of middle and upper Chesterian. The crinoid zones have been defined for the Mississippi Valley region, and Burdick (1971) found that in the Alabama section, the three zones are mutually exclusive. In Alabama, the *Platycrinites penicillus* zone is in the lower part of the Monteagle Limestone in northeastern Alabama and in the Pride Mountain Formation of northwestern Alabama (Burdick, 1971, p. 19). The *Talarocrinus* zone is recognized in the upper part of the Monteagle and in the Pride Mountain (Burdick, 1971, p. 20). The *Agassizocrinus* cf. *A. conicus* zone in Alabama is found as low as the base of the Hartselle Sandstone and extends through the stratigraphically higher beds of the Hartselle, Bangor, and Pennington formations (Burdick, 1971, p. 21–22).

BASE OF POTTSVILLE AND PROBLEM OF MISSISSIPPIAN-PENNSYLVANIAN BOUNDARY

The lower part of the Pottsville Formation in northern Alabama is a massive quartzose sandstone and quartz-pebble conglomerate. Conglomeratic beds locally include carbonized plant fragments and siderite pebbles. The sandstone unit is as much as 200 m thick but that includes a persistent middle shale interval (Culbertson, 1963a, fig. 193.1).

Traditionally, the base of the Pottsville in Alabama has been regarded as part of a regional unconformity beneath the massive sandstone. The upward succession from prodelta shales of the Floyd, to distributary-front and marine-bay sandstones and shales of the Parkwood, and to delta-plain and barrier sandstones of the Pottsville suggests continuous sedimentation rather than a major unconformity. Channel fillings at the base of the massive sandstone may reflect local channels within the delta plain. The Pennington-Pottsville contact may be interpreted similarly. Where the Pottsville overlies the Bangor Limestone, the gradational interval is relatively thin, but the succession commonly includes components of an upward transition from shallow-marine limestone to deltaic and coastal clastic sediments. The geographic extent of the Bangor Limestone is limited by Mississippian clastic facies that prograded onto the carbonate shelf from the southwest (Parkwood) and northeast (Pennington). Continuation of those processes evidently resulted in more widespread progradation of the overlying Pottsville sediments to completely cover the area of Bangor Limestone deposition in north-central Alabama. Thus, the contact of the Pottsville with the underlying Mississippian System can be regarded as part of a depositional continuum rather than as part of a regional unconformity.

The base of the massive sandstone at the base of the Pottsville commonly has been considered to mark the approximate position of the Mississippian-Pennsylvanian boundary. In part, that age assignment is based on the assumption of a regional unconformity coincident with a systemic boundary. In Alabama, Mississippian rocks are clearly documented by biostratigraphic data. Beds above the base of the massive sandstone of the lower Pottsville contain plant fossils, palynomorphs, and some invertebrate fossils that are of Pennsylvanian age (Butts, 1926, p. 213; Upshaw, 1967). However, available biostratigraphic

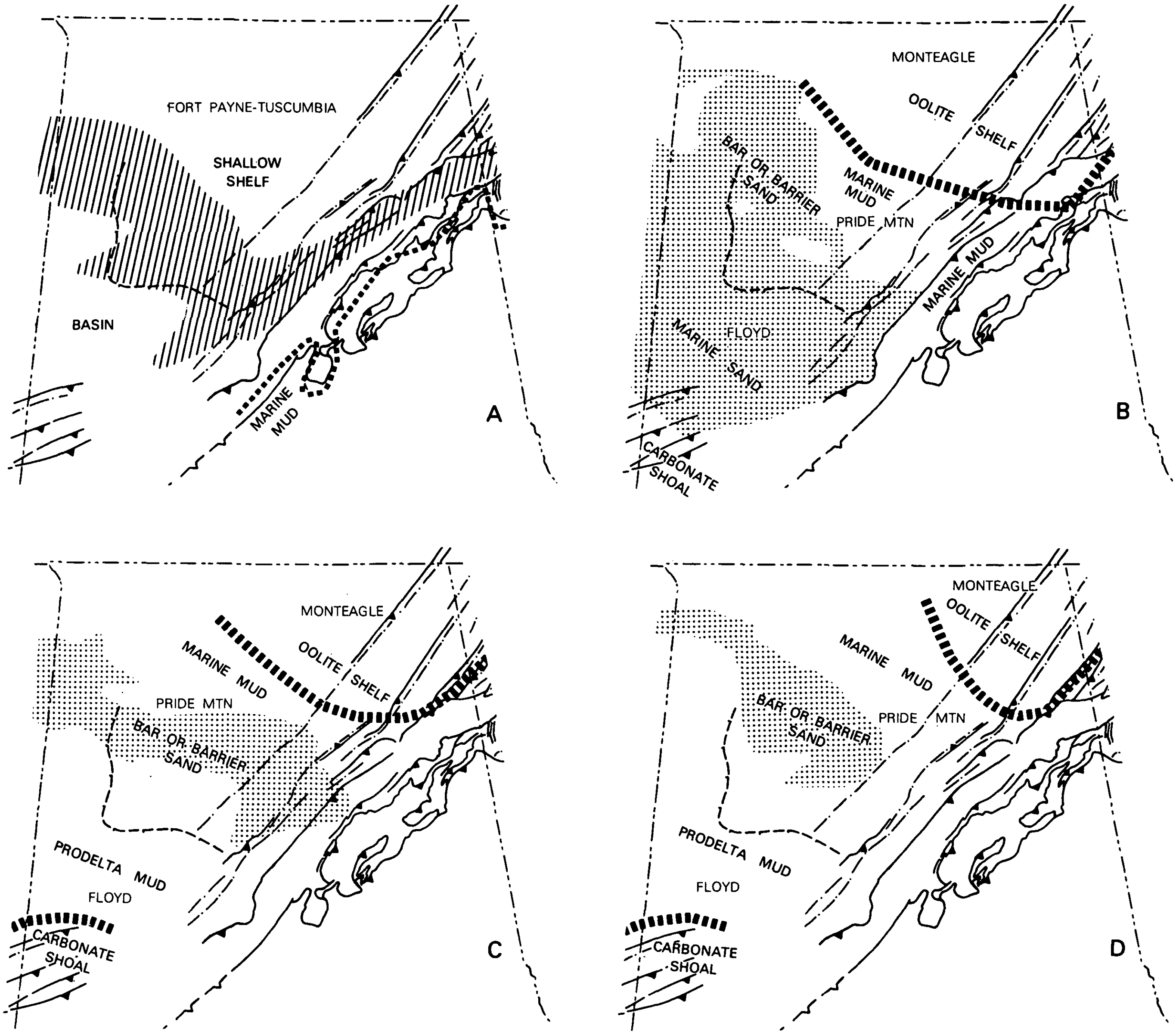
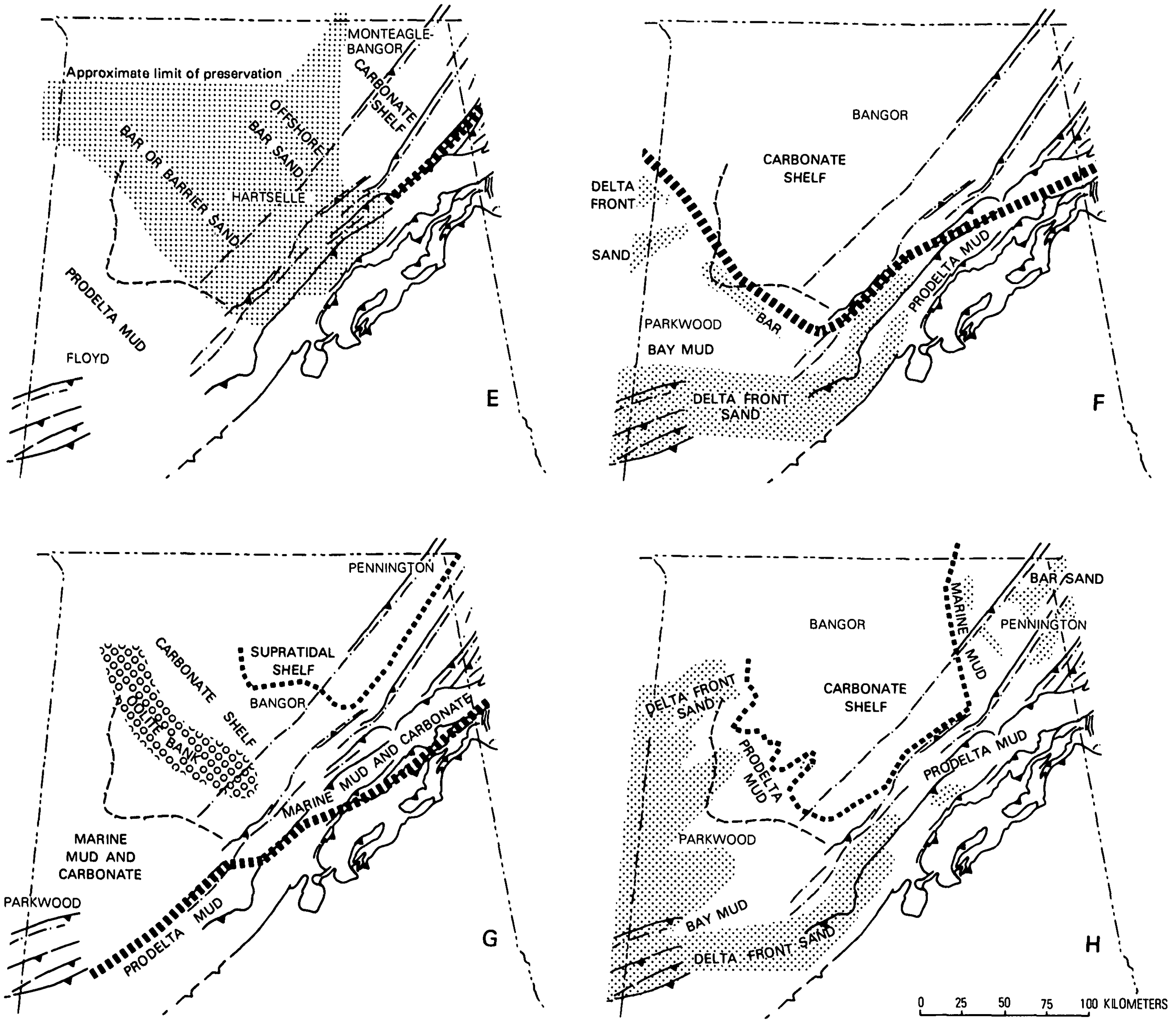


FIGURE 5.—Generalized lithofacies and paleogeographic maps of Mississippian rocks in Alabama. Approximate stratigraphic position of each map is shown by letter on cross sections in figure 2.

data do not precisely define the Mississippian-Pennsylvanian boundary.

Available data indicate that the stratigraphically highest part of the Bangor is of Mississippian age. In northeastern Alabama, the Pennington Formation grades into the upper part of the Bangor and thus appears to be equivalent to the Bangor. Farther northeast, the upper part of the Pennington apparently is continuous with the Raccoon Mountain Formation in Tennessee, and the Raccoon Mountain Formation commonly is considered to be Pennsylvanian (Culbertson, 1963b; Milici, 1974, p. 118). These correlations do not conform to a single time-stratigraphic surface at the systemic 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 equivalents of the Raccoon Mountain Formation in the northeast corner of Alabama are Mississippian (Milici, 1974, p. 118).

Faunas of the Bangor Limestone are characteristic Mississippian forms; however, Butts (1926, p. 206; 1927, p. 13) reported both Mississippian and Pennsylvanian fossils from the Parkwood. A Mississippian fauna in the Bangor and the reported Pennsylvanian fossils in the Parkwood seem incompatible with the observation that the Parkwood and Bangor formations intertongue both in the Black Warrior basin and in Appalachian synclines. Possibly the differences in the faunas reflect the dif-



A. Fort Payne-Tuscumbia, B. Floyd/lower Pride Mountain/Monteagle. C. Floyd/middle Pride Mountain/Monteagle. D. Floyd/upper Pride Mountain/Monteagle. E. Floyd/Hartselle/Monteagle-Bangor. F. Lower Parkwood (example of prograding sandstone)/Bangor. G. Parkwood (example of limestone tongue)/Bangor/lower Pennington. H. Upper Parkwood (example of prograding sandstone)/Bangor/upper Pennington.

ferent sedimentary environments. Outcrops along the Cahaba syncline offer the best opportunity for detailed study of the relative importance of paleoecology and biostratigraphic position in controlling variations in local fossil faunas of the Bangor and Parkwood. Fossilferous units include the limestone of the Bangor as well as both shale and sandstone of the Parkwood. Along the Cahaba syncline, stratigraphic positions of the different faunas may be mapped accurately with respect to both vertical succession and facies boundaries. Detailed studies could provide understanding of time-dependent variations in the faunas of both the carbonate and clastic facies as well as time correlation between the faunas of the two intertonguing facies. The problem of biostratigraphic identification of the Mississippian-Pennsylvanian boundary is a common one, and the outcrops along the Cahaba syncline provide an opportunity for a significant contribution to understanding of that problem.

DEPOSITIONAL AND TECTONIC FRAMEWORK

The Fort Payne-Tuscumbia chert and cherty limestone succession reflects deposition on a broad shallow-marine shelf on the East Warrior platform (fig. 5A). On the southwest in the Black Warrior basin, the Fort Payne-Tuscumbia is thinner, and vertical differentiation of two rock types is indistinct. Thinning off the platform may be a result of less rapid accumulation of bioclastic sediment in lower energy environments, and possibly the thinner section in the basin represents the same time span as the thicker section on the platform. Alternatively thinning may be a result of lateral gradation of the upper part of the Tuscumbia into the northeast-prograding clastic facies. Another suggested alternative is that thinning results from an unconformity at the top of the Tuscumbia (Welch, 1959). Toward the southeast, the Fort Payne-Tuscumbia thins off the East Warrior platform into Appalachian synclines, and the entire cherty unit pinches out locally. Interbeds of limestone in the Floyd Shale suggest that the Fort Payne-Tuscumbia grades vertically and laterally southeastward into the clastic facies. Higher on the East Warrior platform toward the northeast, dolostone interbeds are more common. In northwest Georgia, the dolostone is associated with quartz geodes containing relict anhydrite (Chowns, 1972, p. 90). The suggested sabkha environment (Chowns, 1972, p. 90) is on the presumably highest supratidal part of the platform.

The oolitic and bioclastic limestones of the Monteagle and Bangor indicate high-energy environments on a shallow-marine shelf (fig. 5). The massive crossbedded units are laterally discontinuous, and interbeds of lime mudstone and shaly limestone suggest deposition in protected areas between carbonate bars. The prolific marine invertebrate fauna includes corals, echinoderms, brachiopods, and bryozoans. Thick units of oolitic limestone in the Monteagle are limited to northeastern Alabama, but in the Bangor, massive linear units of oolitic limestone across the southwestern part of the East Warrior platform suggest a high-energy shelf-edge system (fig. 5G). Southwest of the oolite shelf, the Bangor Limestone tongues reflect lower energy environments in the Black Warrior basin, and components of a shelf, ramp, and basin sequence can be identified (Scott, 1976, p. 720). The southwestward gradation from carbonate to clastic facies extends into the Appalachian synclines, but the limestones suggest lower energy environments, presumably in deeper water in contemporaneous synclines off the southeastern edge of the shelf.

The clastic facies on the southwest is composed of a prograding succession of prodelta shales (Floyd) and delta-front sandstones (Parkwood). The clastic facies makes up most of the Mississippian System in the Black Warrior basin and along the deeper Appalachian synclines. A tongue of shale and sandstone (Pride Mountain and Hartselle) extends from the lower part of the clastic facies northeastward onto the East Warrior platform, where the Mississippian is otherwise dominated by the carbonate facies.

The Pride Mountain and Hartselle include four sandstone units that are broadly linear in distribution and that trend southeast across the southwestern part of the East Warrior platform (figs. 5B, 5C, 5D, and 5E). The sandstone units in the Pride Mountain contain limestone beds and locally grade laterally to limestone. Toward the northeast, the Pride Mountain sandstones grade into marine shales that, farther northeast, are replaced by oolite bars of the Monteagle (figs. 5B, 5C, and 5D). In contrast, the Hartselle Sandstone extends eastward and pinches out within the carbonate facies. Toward the southwest, the linear sandstones pinch out into gray shale of the Floyd. Northwestward along trend, the linear sandstones extend across the platform edge and into the Black Warrior basin in Mississippi, where the sandstones are more blanketlike (Thomas, 1972b, p. 98; 1974, p. 196). The linear sandstones end southeastward along trend in the Appalachian fold and thrust belt (figs. 5B, 5C, 5D, and 5E). Although that aspect of sand distribution may be a function of the sediment-dispersal system, evidently the linear sandstones were limited mainly to the shallow platform and did not extend far southeast into the contemporaneously subsiding Appalachian synclines. Contemporaneous slump faults in the basal beds of the Hartselle Sandstone indicate paleoslopes in the direction of structural dip on both limbs of the Birmingham anticlinorium (Thomas, 1968).

Sedimentary structures in the Pride Mountain-Hartselle sandstones indicate a variety of depositional processes characterized by high-energy environments. Tidal channels are indicated by local rock-clast conglomerate. Lateral and vertical associations of rock types and sedimentary structures in the Hartselle of northwestern Alabama indicate the effects of both longshore and tidal currents (Beavers and Boone, 1976, p. 12). Tree fossils, especially the stump reported from the Hartselle (McCalley, 1896, p. 171–176), suggest partly forested areas. Shells of marine organisms are concentrated locally in the high-energy sands. Near the eastern limit of Hartselle Sandstone, sandstone and oolitic bioclastic limestone are interlaminated in crossbedded high-energy bar deposits.

The linear shapes of the Pride Mountain-Hartselle sandstone units and distribution of the sandstone relative to that of the major carbonate and clastic facies suggest deposition as a succession of bar or barrier sand complexes (Thomas, 1972a, p. 105; 1974, p. 200). The linear sandstones are within a clastic tongue that extends northeastward from the lower part of the Floyd Shale, and the Floyd is overlain by the Parkwood Formation, which contains northeastwardly prograding deltaic sandstones. However, the Parkwood sandstones are evidently younger than the Pride Mountain and Hartselle sandstones, and the source of the Pride Mountain and Hartselle sands is not conclusively established. Swann (1964, p. 653) suggested that sand supplied through the Illinois basin by the Michigan River system prograded as far south as the Black Warrior basin. Regardless of the source of sand, the Pride Mountain-Hartselle sandstones are distributed along the boundary between the regional carbonate and clastic facies, and the orientation of the linear sandstones suggests a high-energy environment near the southwestern edge of the East Warrior platform. The more blanketlike sandstones in the Black Warrior basin in Mississippi are interpreted to be marine sands. More precise definition of environments represented by the linear sandstones will result from better understanding of their relation to facies in the Floyd Shale on the southwest, of the system of sand supply, and of sedimentary features within the sandstones.

Along the Coosa synclinorium, the Bangor Limestone Tongue in the Floyd Shale demonstrates intertonguing of the clastic and carbonate facies. Farther east in Georgia, the clastic sequence contains two limestone tongues—a tongue of Bangor Limestone and a lower limestone tongue in the Floyd Shale in the stratigraphic position of the Tuscumbia and (or) Monteagle. The lower limestone may extend southwest as far as the northeast end of the Coosa deformed belt, but there it evidently grades southwestward to the shale facies in a pattern similar to the southwestward gradation from Monteagle Limestone to shale on the East Warrior platform.

Along the Pickens-Sumter anticline south of the Black Warrior basin in the subsurface in west-central Alabama, the lower part of the Floyd Shale includes limestone beds (figs. 5B, 5C, and 5D) that are in the same stratigraphic position as the sandstone units in the Floyd and Pride Mountain on the East Warrior platform, but no genetic relationship is apparent. Possibly the limestones denote a local carbonate shoal associated with a contemporaneous Pickens-Sumter anticline; alternatively, they may mark the northern edge of a more extensive carbonate shelf that extends farther south into the fold and thrust belt.

The Floyd Shale constitutes a prodelta mud deposit that grades upward into deltaic sediments of the Parkwood Formation. Parkwood sandstones are interpreted to be delta-front and distributary sediments that are interbedded with marine-bay shale and mudstone (figs. 5F, 5G, and 5H). Distribution of the sandstones suggests northeastward prograding from a sediment source southwest of the Black Warrior basin of western Alabama and eastern Mississippi. The more sandy part of each of the Parkwood cycles reflects a major episode of delta prograding. The shaly parts of the Parkwood include interdistributary-bay sediments and contain extensive tongues of the Bangor Limestone which denote transgression and delta destruction. Bay-fill fine clastic sediments generally grade upward to distributary-front sandstones. A few of the sandstones were deposited on scoured surfaces evidently in small distributary channels. Most Parkwood sediments are in the marine-delta front and interdistributary-bay facies; little of the succession suggests delta-plain deposits. Sedimentary features and fossil faunas of the Parkwood suggest a near-shore marine environment (Whisonant, 1970, p. 141). Interdistributary marsh deposits in the locally carbonaceous uppermost beds of the Parkwood represent the highest preserved part of the delta complex. Later Parkwood sandstones are more extensive than older ones, and the upper part of the Parkwood progrades northeastward onto the southwestern edge of the East Warrior platform. The Parkwood grades upward into conglomerate, sandstone, shale, and coal of the Pottsville Formation, which progrades northeastward farther than the Parkwood and overlies the Bangor Limestone on the East Warrior platform.

The Floyd-Parkwood clastic facies is much thicker and extends farther northeast along the Appalachian synclines than in the Black Warrior basin and East Warrior platform. The same general pattern of cyclical delta progradation and transgression is recognizable within the Parkwood Formation in the synclines. The greater thickness and extent of the clastic facies suggest that the synclines subsided contemporaneously with Mississippian deposition and that the structural troughs provided channels along which sediment was selectively transported northeastward. Distribution of sandstone in the Parkwood in the Cahaba syncline does not parallel that in the Coosa synclinorium. Sections in the Cahaba syncline generally contain about 50 percent more sandstone than sections across strike in the Coosa synclinorium; however, the total thickness of the section in the Coosa synclinorium averages 25 percent greater than that in the Cahaba syncline. These distribution patterns suggest contemporaneous downwarp of two separate synclines. Northeastward prograding of the Parkwood, northeastward decrease in sandstone, and southwestward thinning of the Bangor Limestone are compatible with the interpretation that the clastic sediment was transported longitudinally northeastward along the synclines from a source on the southwest. Thus, a regionally consistent pattern of northeastward progradation and a provenance on the southwest are indicated for the Floyd-Parkwood clastic sediments in both the Black Warrior basin and the Appalachian synclines (Thomas, 1972a; 1974, p. 203).

Other interpretations have been proposed for location of the provenance and dispersal system of Parkwood clastic sediments. Crossbedding in Parkwood sandstones in the Cahaba and Coosa synclines shows significant modes toward both the north-northwest and the south-southwest (Whisonant, 1967, p. 1871). Citing the interpretation of crossbedding and heavy-mineral data indicative of a metasedimentary provenance, Whisonant (1967, p. 1872) postulated possible northwestward transport from a sediment source on the southeast in the Appalachian Piedmont. However, that provenance location and transport direction are not supported by the regional distribution of the Parkwood clastic facies and the equivalent carbonate facies. Furthermore, Carrington (1967, 1972) concluded that some metasedimentary rocks in the Piedmont represent Parkwood-equivalent sediments.

Another alternative for the Parkwood dispersal system is derived from regional studies of the Michigan River system deltaic sediments in the Illinois basin (Swann, 1964). Swann (1964, p. 653) suggested that at some times the Michigan River system prograded southward from the Illinois basin and transported sediment to the northeastern edge of the Ouachita trough and the western part of the Black Warrior basin. Welch (1971) concluded that Mississippian sandstones in the Black Warrior basin were supplied from the north, probably through the Illinois basin. That interpretation requires that Parkwood deltaic sediments prograded southward or southeastward into the Black Warrior basin.

In northeastern Alabama, the Pennington Formation constitutes a clastic facies that prograded southwestward onto the carbonate-shelf sediments of the Bangor Limestone (figs. 5G, 5H). Evidently the location of the facies boundary was not influenced by a shelf edge. The dolostone unit in the lower Pennington suggests a supratidal shelf that was subsequently covered by shallow-marine fine clastic sediments (fig. 5G). The shallow-marine mudstone and limestone are supplanted farther east by sandstone, shale, and carbonaceous beds that represent marine bays, small bars, and coastal lagoons and marshes (fig. 5H). Lateral gradation of a coal bed to brachiopod-bearing siderite, and interfingering of bar sandstone with marine shale, suggest small-scale environmental features on a plain nearly at sea level. The Pennington is overlain by massive sandstones of the Pottsville Formation which constitute a coarser fraction of the southwest-prograding clastic complex. The Pottsville extends beyond the Pennington clastic succession and overlies the Bangor Limestone farther west.

Provenance and dispersal studies of Pottsville sandstones in Alabama have implications for interpretations of underlying Mississippian clastic sediments. Crossbedding in the basal Pottsville sandstones of northeastern Alabama indicates transport toward the west or southwest (Tanner, 1959, p. 224; Schlee, 1963, p. 1446; Chen and Goodell, 1964, p. 70; Metzger, 1965, p. 27). This direction is most persistent in northeastern Alabama, where the Pottsville overlies the Pennington clastic facies, and beyond the western limit of the Pennington, where the Pottsville progrades over the Bangor Limestone. In Northwestern Alabama, crossbedding orientation is more diverse (Schlee, 1963, pl. 1; Metzger, 1965, p. 27). On the basis of geometry of beach and barrier-island sandstones of the basal Pottsville, Hobday (1974, p. 223) concluded that two sediment supply systems (from the northeast and from the south) merged in north-central Alabama. Compositional variation in Pottsville sandstones of central Alabama indicates a source on the south (Davis and Ehrlich, 1974, p. 177). These interpretations may be assembled to suggest that the Pottsville of Alabama includes two components that converged on the East Warrior platform from the northeast and from the south. Thus, the northeast-prograding Parkwood continues upward into one component of the Pottsville and the southwest-prograding Pennington continues upward into the other component.

Mississippian clastic rocks in Alabama are parts of two regional clastic wedges in the Appalachian-Ouachita structural system (Thomas, 1974, p. 206; 1977). The Floyd-Parkwood-Pottsville clastic sequence is part of a large-scale clastic wedge centered on the Ouachita structural salient. The Mississippian-Pennsylvanian clastic sequence extends from Alabama westward in the subsurface across the Black Warrior basin in Mississippi toward the Ouachita Mountains, where the thickness is much greater than that in the Black Warrior basin. The wedge includes a lower unit of shale (Stanley of Ouachita Mountains; Floyd of Black Warrior basin) and an overlying succession of sandstone and shale (Jackfork-Atoka of Ouachita Mountains; Parkwood-Pottsville of Black Warrior basin). Depositional features of the Ouachita sediments indicate a deep-water flysch environment (Cline, 1960, p. 100; 1970, p. 100), whereas the thinner sequence on the east in the Black Warrior basin comprises a prograding delta system (Thomas, 1974, p. 200). The indicated dispersal pattern suggests a common source area southeast of the Ouachitas and southwest of the Black Warrior basin (Thomas, 1974, p. 202; 1976, p. 337).

Similarly, the southwest prograding Pennington clastic facies in northeastern Alabama is evidently at the southwestern fringe of a large-scale clastic wedge centered farther northeast (Thomas, 1977, p. 1258). The center of that wedge appears to be within the Tennessee structural salient, probably in southwestern Virginia, where the Pennington is much thicker and coarser than it is in Alabama. Regional facies relations indicate that Upper Mississippian clastic sediments prograded southwestward along the Appalachians in Tennessee (Ferm and others, 1972, fig. 3). In Alabama, the Pennington at the fringe of the wedge grades southwestward into the carbonate facies. The overlying southwest-prograding Pottsville clastic sequence extends farther west and southwest above the Bangor Limestone.

Mississippian-Pennsylvanian clastic wedges prograde from southwest and northeast onto the shallow-marine carbonate facies in the Bangor Limestone in north-central Alabama. Each of the two converging clastic wedges is centered on a regional structural salient (Ouachita and Tennessee salients), and the intervening carbonate facies is within a regional structural recess in Alabama (Thomas, 1977).

The Black Warrior basin and East Warrior platform are reflected in distributions of thickness and facies throughout the Mississippian System. However, the Fort Payne-Tuscumbia rocks show gradual southwestward change, whereas the younger Bangor and Parkwood facies reflect a relatively abrupt change at the platform edge. Possibly the East Warrior platform and the western edge of the platform became more pronounced in the later Mississippian. Facies and thickness of the Mississippian System indicate contemporaneous subsidence of the Appalachian synclines southeast of the East Warrior platform.

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PENNSYLVANIAN STRATIGRAPHY OF ALABAMA

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THE MISSISSIPPIAN AND PENNSYLVANIAN (CARBONIFEROUS) SYSTEMS IN THE UNITED STATES–ALABAMA AND MISSISSIPPI

PENNSYLVANIAN STRATIGRAPHY OF ALABAMA[1]

By W. EVERETT SMITH [2]

ABSTRACT

Pennsylvanian strata crop out in the northern half of Alabama and underlie much of the State at depth. Folding and faulting and subsequent erosion of the southern Appalachians have resulted in isolation of several outcrop areas termed the Warrior, Coosa, Cahaba, and Plateau coal fields.

General subdivisions of the rock sequence have been made on the basis of coal groups, floral zones, and lithology. The most recent classification system was proposed by H. R. Wanless, who used the terminology subinterval A_1, and subinterval A_2 and interval B (youngest). Major rock types include sandstone, siltstone, shale, mudstone, underclay, and bituminous coal. The coal is generally ranked as high volatile A to low volatile and ranges from 3 to 15 percent of ash and less than 2 percent of sulfur. Estimates of State coal reserves range from 13.9 billion short tons to 35.5 billion short tons. The several coal fields are generally considered to have been part of a major depositional basin during Pennsylvanian time; however, the fields vary greatly in sediment thickness and lithologic patterns, and most coal beds have not been correlated with certainty between the fields. Most of the Pennsylvanian rocks in Alabama probably are early (Pocahontas) and middle (New River) Pottsville in age. Time transgression of lithologic units in a northeastern direction appears likely, sediment sources being primarily to the south and east.

INTRODUCTION

This paper summarizes basic geologic information and concepts thus far acquired on Pennsylvanian rocks in Alabama. Because of its summary nature, the paper makes all too brief reference to the geologic data and only passing comment or inference on many fundamental concepts and issues. The published information on the Alabama Pennsylvanian System is relatively sparse, and important published reports are now practically inaccessable to many investigators. The writer wishes to call attention early in this discussion to the recently published comprehensive work on the Pennsylvanian System in the United States by McKee, Crosby, and others (1975) which includes discussions of Pennsylvanian rocks in the southern Appalachians by Wanless (1975).

Few geologists have given sufficient attention to Pennsylvanian rocks in Alabama to acquire insight to the whole system. It was only in the 1870's that interest in the coal beds in the Pennsylvanian focused attention on these rocks, and from this early period until the early 1900's, geologic investigations of the Pennsylvanian rocks were essentially descriptions of the coal-bearing horizons. In this respect, Henry McCalley (1891, 1898, 1900) did much of the first field investigations and prepared descriptive reports. Prouty (1912) and Butts (1907, 1910, 1911, 1926, 1927, 1940) were also early contributors. In recent years, Rothrock (1949), Culbertson (1964), Ferm (Ferm and Ehrlich, 1967; Horne, Ferm, and others, 1976), Metzger (1961, 1965), and Thomas (1972) have contributed information on stratigraphy, paleoecology, and tectonism. Recently, many geologists again have given attention to local stratigraphy of Pennsylvanian rocks in connection with exploration for and development of coal.

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 Geological Survey of Alabama.

DISTRIBUTION

Rocks of Pennsylvanian age crop out in northern Alabama and underlie much of the State at depth. Folding and faulting and subsequent erosion of the southern Appalachians have resulted in isolation of several different outcrop areas which are herein referred to as coal fields.[3] Four major fields are the

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[3] Some geologists now refer to these areas as coal basins or use the term "basin" synonymously with the term "field," although it should be recognized that the two terms in the strictest sense carry different connotations.

Warrior, Plateau, Coosa, and Cahaba.

The Warrior field (Mellen, 1947; McCalley, 1898, 1900; Metzger, 1965; Wanless, 1975) is the largest outcrop area of Pennsylvanian rocks in Alabama, comprising approximately 12,680 km^2 in the northwestern quarter of the State. Mellen (1947) proposed that the Warrior basin be defined as a triangular area of approximately 35,000 sq mi of normal Paleozoic sediments bounded on the north by Tennessee, on the southeast by the southwest-plunging Appalachian Mountains of Alabama, and on the southwest by the buried Ouachita Mountains of eastern Arkansas and northern Mississippi. Mellen (1947) noted that this area, whether or not correctly described as a basin, has been one of great negative epeirogenic tendency.

Physiographically, the area of the Warrior field not covered by Coastal Plain sediments is part of the Cumberland Plateau. The field is bounded on the north by the southern flank of the Nashville dome and on the southeast by folds and thrust faults of the Sequatchie Valley anticline and faulted anticlines of the Bessemer-Birmingham valley. On the southwest, in the subsurface the field may be limited by concealed thrust faults (Wanless, 1975; Kidd, 1976). Strata of the Warrior field dip south and thicken in the same direction. The field is structurally less complex than other areas in the State, but gentle folds, large-scale joint features, and normal and reverse faults of significant magnitude are found in the field. Sediments in the Warrior field include eight[4] coal groups having more than 20 minable beds in some part of the field. Gas is being produced from Mississippian horizons underlying the field in northwestern Alabama.

The Plateau field is the name given to several coal-bearing plateau areas in northeast Alabama similarly divided by eroded anticlines. The field includes more than 11,660 km^2 including Lookout Mountain, Blount Mountain, Altoona Mountain, Sand Mountain (Raccoon Mountain), West Sand Mountain, and many small remnant mountains in extreme northeastern Alabama. Some geologists also include in the Plateau field certain areas that other geologists consider the northern part of the Warrior field, particularly those outcrop areas of coal beds below the Black Creek coal bed. The Pennsylvanian rocks in the Plateau region contain more than 25 coal beds.

The Coosa field is a folded and faulted synclinorium, which includes approximately 725 km^2. It is about 96 km long, about 8 km wide and contains more than 15 coal beds of mineable thickness. The Cahaba field southeast of Birmingham includes an area of approximately 906 km^2 and contains about 60 coal beds. The several coal fields are considered to have been more or less continuous during Pennsylvanian time; however, the fields vary greatly in rock thickness and lithologic patterns, and most coal beds have not been correlated with certainty between the fields.

In the subsurface, Pennsylvanian rocks in Alabama have been identified as far south as Marengo County (Kidd, 1976). South of central Marengo County, these rocks have not been identified; they are apparently covered by thrust-faulted older rocks (Kidd, 1976). This thrust faulting is hypothesized to have been generally toward the northwest and generally along a line extended from southern Bibb County through southern Sumter County and into Mississippi. Kidd (1976) also indicated thrust faulting of older sedimentary rocks over Pennsylvanian rocks in southern Greene and northern Sumter Counties. Kidd's map of the configuration of the top of the Pennsylvanian rocks in west-central Alabama (Kidd, 1976) shows a dip to the southwest into Missisipi.

South of the Appalachian Valley and Ridge province in Alabama, Pennsylvanian-age rocks appear to be terminated, possibly by thrust-faulted older sedimentary rocks or by metamorphic rocks.

STRATIGRAPHY

White, as reported by Butts (1927), showed that the lower-middle Pottsville boundary in West Virginia is approximately at the horizon of the Black Creek coal in the Alabama Warrior coal field. Read, as reported by Metzger (1965), identified and determined the ages of plant remains in the uppermost exposed beds of the Warrior field (above the guide coal seams) to be latest early New River. Thus, most of the Pennsylvanian rocks in Alabama probably are early (Pocahontas) and middle (New River) Pottsville in age. Palynology studies by Upshaw (1967) are in accord with these age assignments, although Upshaw (1967) pointed out that precise age equivalents cannot be established because detailed palynological studies of Pocahontas and New River type sections have not been made. Upshaw

[4] Six coal groups were recognized by McCalley (1900), including the Brookwood, Gwin, Cobb, Pratt, Horse Creek (including the Mary Lee coal), and Black Creek. In recent years, the Utley coal group has been recognized. In addition, the term "J group" has been used by some geologists and miners, in reference to the J, K, L, and M beds which are below the Black Creek coal group in the Blue Creek basin.

further suggested that beds older than the lowest Pottsville of the type area (and older than the lowest Morowan of Arkansas) may be included in the Pottsville Formation of Alabama. West of Alabama, in the subsurface of Mississippi, beds of Kanawha age are included with the Pottsville unit and contain abundant *Laevigatosporites ovalis* in association with *Endosporites globifermis* (Upshaw, 1967, p. 18). The studies by Upshaw show time transgression of lithologic units to be all in a northeastern direction. Ferm and Ehrlich (1967) supported this concept of time transgression of lithologic units.

Butts (1926, p. 206) assigned all Pennsylvanian rocks in Alabama (except those of the Erin Shale) to the Pottsville Formation. He considered the Parkwood to be part of the Mississippian sequence and placed the base of the Pennsylvanian in Alabama at the base of the Brock coal bed, which he judged to be at a horizon in the lower Pottsville Formation as low as the lowest Pennsylvanian throughout the Appalachian coal fields. He noted however that the upper Parkwood may include a mixture of Pennsylvanian and Mississippian fossils, and that no sharp line of division appears within the Parkwood that would serve as a division line between the Mississippian and Pennsylvanian (See discussion by Thomas, this chapter for detailed discussions of Mississippian-Pennsylvanian boundary.) Culbertson (1963, p. 49; 1964) defined the top of the Parkwood as being at the base of sandstone members at the base of the Pottsville Formation, including the Shades Sandstone Member in the Cahaba and Coosa fields, the Boyles Sandstone Member in the Warrior field, and the Lower Conglomerate (McCalley, 1891) in the Plateau field (fig. 6).

Wanless (1975) considered the upper part of the Parkwood Formation to be within the Lower Pennsylvanian. According to Butts (1926) and Wanless, the Erin Shale (phyllite in the metamorphic Talladega Series) is apparently of Pennsylvanian age, although its relationship to other Pennsylvanian rocks is undetermined.

The Pennsylvanian Subcommittee, R. C. Moore, Chairman (Moore and others, 1944), has assigned most of the Pennsylvanian rocks in Alabama to the Morrow Series (Lower Pennsylvanian) which includes Read's (according to Moore, and others, 1944) floral zone of *Neuropteris pocahontas* and *Mariopteris eremopteroides*, floral zone of *Mariopteris Pottsvillea* and *Aneimites*, and floral zone of *Mariopteris pygmaea*. The subcommittee assigned uppermost Pennsylvanian rocks in the Cahaba and Warrior fields to the Kanawha Series (which include Read's (according to Moore and others, 1944) floral zone of *Cannophyllites* and floral zone of *Neuropteris tenuifolia*).

McCalley (1900) proposed a classification of the Pennsylvanian rocks of Alabama based on six coal groups, using the lowest coal within each group as the base. Metzger (1965) proposed a similar system of subdivision but suggested that the most persistent coal bed in each group rather than the lowermost bed be used as the group market. Neither McCalley or Metzger assigned specific names to the various subdivisions, although Metzger, to facilitate discussion of the sediments, designated the units from oldest to youngest as stratigraphic intervals A, B, C, D, E, F, and G.

Wanless' (1975) discussion of the Alabama Pennsylvanian, which is a part of a comprehensive discussion of the Pennsylvanian System of the United States (McKee, Crosby, and others, 1975) uses the classification system set up in that report and classifies Alabama's Pennsylvanian rocks as interval A (containing subintervals A_1 and A_2) and interval B (youngest). This classification system has been used in the present discussion.

Fossils in the Pennsylvanian sequence of Alabama are relatively abundant. Fossil flora are the most abundant, but zones of marine invertebrates also are found. Butts (1926) reported at least four fossiliferous horizons (presumably excluding fossil flora associated with many of the coal beds) in the Warrior field and listed the more common forms (as identified by G. H. Girty) as follows:

Lingula carbonaria
Schizophoria n. sp. (very common)
Derbya crassa
Productus cora semireticulatus
Marginifera muricata
Spirifer rockymontanus
Hustedia mormoni
Composita subtilita
Solenopsis solenoides?
Aviculopecten hertzeri rectilateralis
Deltopecten occidentalis
Myalina swallowi
Pleurophorus tropidophorus
Schizodus aff. *symmetricus*
Edmondia aff. *E. gibbosa*
Leda bellistriata

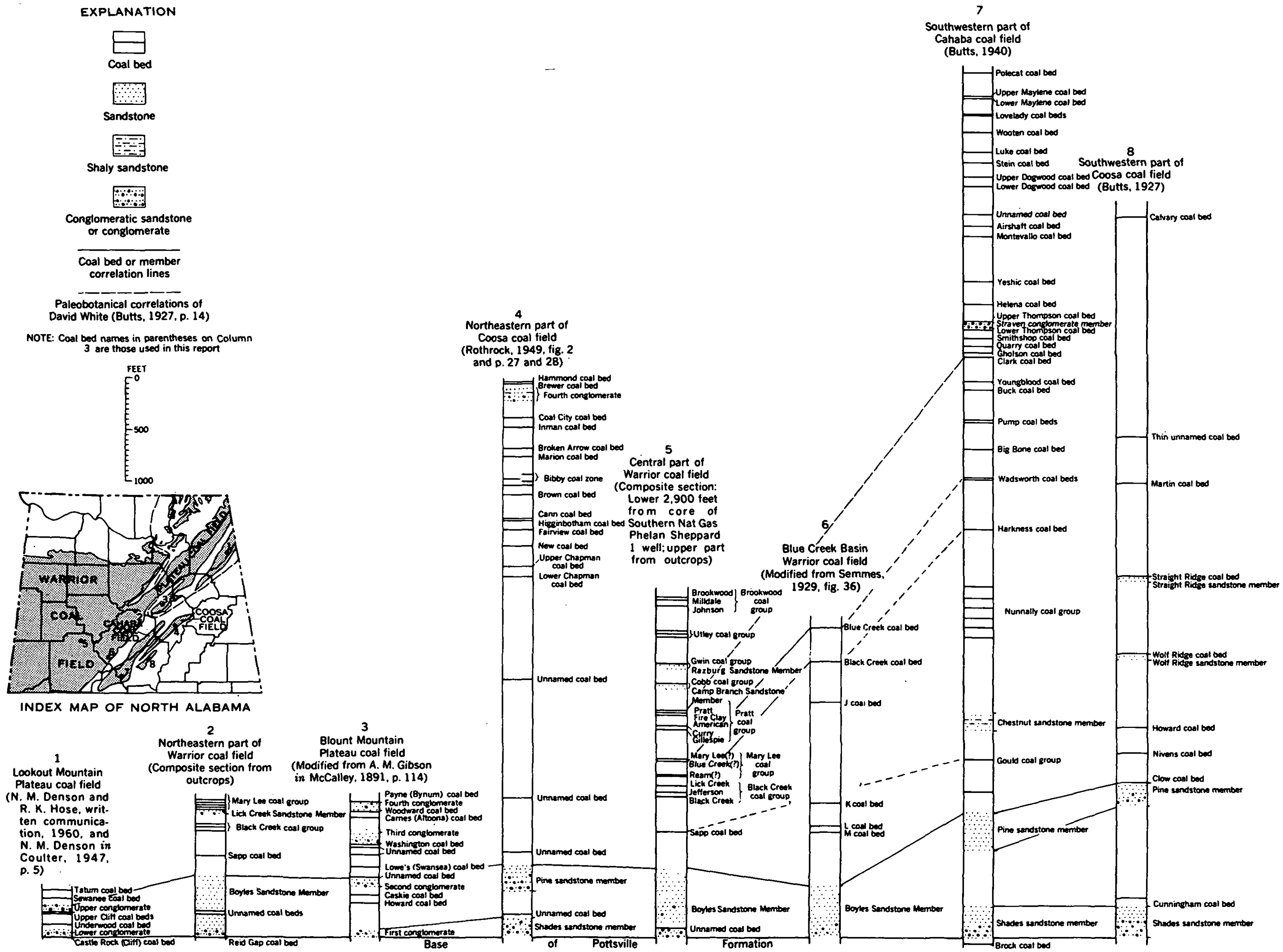

FIGURE 6.—Columnar sections showing position of coal beds and sandstone members of the Pottsville formation in Alabama (from Culbertson, 1964).

Yoldia oweni
Anthracomya (Naiadites) elongata
Estheria dawsoni

Butts (1926) noted that except for the last two fossils, most of the species seem to range through the full thickness of the Pennsylvanian sequence, although they are not restricted to the Pennsylvanian elsewhere in the United States.

Metzger (1965, p. 13) listed the following forms from an exposure in the Warrior field:

Stereostylus sp.
Fenestrellina
Lingula carbonaria Swallow
Orbiculoidea capuliformis (McChesney)
Chonetes choteauensis Mather
Desmoinesia nana (Meek and Worthen)
Dictyoclostus sp.
Juresania ovalis Dunbar and Condra
Linoproductus insinuatus? (Girty)
Schizophoria oklahomae Dunbar and Condra
resupinoides (Cox)
sp.
Spirifer occidentalis Girty
Wellerella osagensis (Swallow)
Dentalium sp.
Plagioglypta sp.
Bellerophon crassus Meek and Worthen
Euphemites carbonarius (Cox)
Phymatopleura nodosus (Girty)
Pseudozygopleura rothi Knight
Straparolus (Amphis capha) reedsi Knight
Trepospira depressa Cox
Worthenia sp.
Gastrioceras sp.
Liroceras liratum (Girty)
Pseudorthoceras sp.
Astartella newberryi Meek
Aviculopinna sp.
Cypricardinia carbonaria Meek
Dunbarella knighti Newell
Edmondia gibbosa (McCoy) ?
Nucula anadontoides Meek
subrotunda Girty
Nuculana meekana (Mark)
sp.
Parallelodon tenuistriatus (Meek and Worthen)
Pteria sp.
Schizodus affinis Herrick
cuneatus? Meek
Paladin sp.
Crinoid stems
Thuroholia sp.
Fish teeth, undetermined

Butts (1926) listed fossil flora as *Lepidodendron* sp., *Lepidodendron obovotum, sigillaria mamilloris calamites suckowii, Neuropteris smithii, Pecopteris buttsii*, and *Alethopteris lonchitica*.

McKee (1975) studied Pennsylvanian sedimentary rock-fossil relationships in part of the Warrior field. Several unpublished studies by major oil companies reportedly have been made of Pennsylvanian palynology in the Warrior field. Upshaw (1967) recognized more than 90 species of palynomorphs in the Pennsylvanian sedimentary rocks of the Warrior field and found species of *Lycospora* and *Densosporites* to be numerically dominant in most samples. In addition, he provided a partial list of forms from several stratigraphic positions within the Pottsville sequence (table 1).

TABLE 1.—*A list of selected taxa from Pennsylvanian strata of the Warrior basin, Alabama*
[From Upshaw, 1967]

Taxa	Sample locality[1] (1)	(2)	(3)
Knoxisporites dissidius Neves	×		
Proprisporites laevigatus Neves	×		
Trinidulus diamphidios Felix and Paden	×		
Tricidarisporites fasciculatus (Love) Sullivan and Marshall	×		
Convolutispora florida Hoffmeister, Staplin and Malloy	×	×	
Reinschospora speciosa (Loose) Schopf, Wilson and Bentall	×	×	
Bellispores nitidus (Horst) Sullivan	×	×	
Densosporites irregularis Hacquebard and Barss	×	×	
Crassispora kosankei (Potonio and Kremp) Bhardwaj	×	×	
Knoxisporites triradiatus Hoffmeister, Staplin and Malloy	×	×	
Knoxisporites stephanephorus Love	×	×	
Lycospora uber (Hoffmeister, Staplin and Malloy) Staplin	×	×	×
Lycospora noctuina Butterworth and Williams	×	×	×
Savitrisporites nux (Butterworth and Williams) Sullivan	×	×	×
Florinites visendus (Ibrahim) Schopf, Wilson and Bentall	×	×	×
Wilsonites sp. (100–160 microns)	×	×	×
Cirratriradites saturni (Ibrahim) Schopf, Wilson, and Bentall	×	×	×
Tantillus triquetrus Felix and Burbridge	×	×	×
Ahrensisporites querickei (Horst) Potonie and Kremp	×	×	×
Cristatisporites indignabundus (Loose) Potonie and Kremp	×	×	×
Schulzospora rara Kosanke	×	×	×
Camptotriletes superbus Neves	×	×	×
Discernisporites irregularis Neves	--	×	
Reinschospora triangularis Kosanke	--	×	×
Apiculatisporis variocorneus Sullivan	--	×	×
Laevigatosporites ovalis Kosanke	--	--	×
Dictyotriletes bireticulatus Ibrahim	--	--	×

[1] (1) Below the Black Creek coal including some units assigned to the Parkwood Formation by Culbertson (1963); (2) Black Creek coal to Brookwood coal; and (3) above the Brookwood coal.

SUBINTERVAL A_1

Rocks included in subinterval A_1 are those of the upper part of the Parkwood Formation and those of the lower part of the Pottsville Formation. The upper boundary of subinterval A_1 is considered by Wanless (1975) to be at the base of the Black Creek coal group or the equivalent Harkness coal bed. Culbertson (in Wanless, 1975, p. 29) gives reasons why subinterval A_1 is equivalent to floral zones 4 and 5. According to Culbertson (in Wanless, 1975, p. 29), some workers have mistakenly assumed that the lower part of the Pottsville Formation, as defined by White (according to Butts, 1927), below the Black Creek coal group or the equivalent Harkness coal bed, includes only floral zone 4. No well-established floral-zone fossils mark the top or the base of subinterval A_1 (Wanless, 1975). Wanless has discussed distribution and thickness of strata in subinterval A_1, the northern extent of which may have been in the general vicinity of the present Tennessee River.

Sedimentary rocks of subinterval A_1 are considered to occur in all the coal fields in Alabama and may be represented by the Erin Shale (Wanless, 1975) within the metamorphic Talladega Series. Subinterval A_1 strata are absent on the Plateau remnants in northeastern Alabama but are present south of the Tennessee River. Thomas (1972) has measured approximately 44 m of Parkwood sediment at Isbell quarry in Franklin County, northwest Alabama, but the thickness of Parkwood strata here that can be assigned to subinterval A_1 is unknown. From northern Alabama, subinterval A_1 sedimentary rocks thicken southeastward to a maximum of more than 510 m near Birmingham. Subinterval A_1 sedimentary rocks range in thickness from 900 m to more than 1,500 m in the Cahaba coal field; in the Coosa coal field, they are about 1,500 m thick. In Sumter County in the southern part of the Warrior field, a thickness of 489 m has been reported (Wanless, 1975). Metzger (1965, p. 10) called attention to thinning of the rocks in subinterval A_1 and suggested that inasmuch as the area of thinning is directly in line with the later formed Blountsville or Sequatchie anticline, the sedimentation might have been controlled by local tectonic activity even in early Pottsville time.

Subinterval A_1 strata consist of mudstone, claystone, siltstone, sandstone, conglomerate, and thin coal beds. Sandstone generally is more abundant than the other types of sedimentary rocks in north-central Alabama and is generally less abundant in basins that include thousands of feet of strata (Wanless, 1975). The Parkwood Formation includes both orthoquartzitic sandstone and graywacke sandstone as well as a considerable volume of gray slightly silty shale. Rocks herein referred to as belonging to subinterval A_1 have often been referred to informally as "the lower unproductive zone" in reference to the relatively few thin coal beds within the sequence.

Ferm (Ferm and Ehrlich, 1967), in discussing the general petrology of Pennsylvanian sedimentary rock in Alabama, classified most of the coarser sediments as lower rank graywacke and reported varying proportions of strained and sheared (metamorphic) quartz, sodic feldspar, a great variety of low-grade micaceous metamorphic rock fragments, and some detrital volcanic fragments. Heavy minerals include staurolite, kyanite, epidote, garnet, muscovite, chlorite, tourmaline, and zircon. Studies by Ferm (Ferm and Ehrlich, 1967) also show that components of finer grained sedimentary rocks are similar to those of the coarser grained rocks but include a considerable amount of illite and lesser kaolinite. Ferm (Ferm and Ehrlich, 1967) also stated that quartz content of the low-rank graywackes diminishes from north to south.

The number of coal beds in subinterval A_1 is greatest in the southern Plateau field (Blount Mountain) and in the Coosa and Cahaba fields. These fields contain as many as 15 coal beds, but maximum cumulative thickness is only 4.5 to 5.8 m (Wanless, 1975). The number of beds decreases to the west and northwest. Wanless (1975) pointed out that the average thickness of coal beds in Alabama is remarkedly less than the average thickness of similar-age sediments in the Pocahontas field of Virginia, although the environments of coal deposition were similar. Culbertson (1964) showed stratigraphic position of the coal beds and sandstone members in the lower Pottsville (fig. 1).

Wanless (1975) suggested an easterly or southeasterly sources for subinterval A_1 sediments, citing pattern of grain-size distribution and crossbedding (Schlee, 1963, p. 1448). Metzger (1965) interpreted crossbedding data to indicate that the predominant flow of sedimentary detritus in the Warrior field was from northeast to southwest, that flow direction in the northeastern part of the Warrior field was to the southwest, and that flow direction in the western part of the field was to the west. Wanless (1975) gave the opinion that the moderately coarse grained rock in north-central Alabama suggests there was a nearby land area, probably east or southeast of present outcrops, and that the pattern of grain size distribution is consistent with an easterly source for sediments, as inferred by cross-bedding measurements (Schlee, 1963, p. 1448). Ehrlich (1965; Davis and Ehrlich, 1974, p. 177) postulated a southern source on the basis of distribution of unstable minerals, an apparent increase from south to north in relative percentage of quartz in the low-rank graywackes, and a southward thickening and increasing proportion of sandstone in the sedimentary sequence. Ferm (Ferm and Ehrlich, 1967) observed that this source area may have extended into the Ouachita orogenic belt. Hobday (1974, p. 223) on the basis of geometry of basal Pottsville beach and barrier-island facies, concluded that two distinct sources may have existed in the lower Pennsylvanian clastic rocks in northern Alabama, one in the northeast and the other to the south.

Individual beds or lithologic units in the Pottsville sequence are laterally discontinuous, and, at present, data are insufficient to delineate accurately the lateral distribution of even major lithologic units. Many workers now accept, as a working hypothesis, the concept of prograding delta systems to explain the variations in lithology and distribution patterns. Ferm and Ehrlich (1967) suggested that lower Pottsville and Parkwood orthoquartzites can be attributed to a beach-barrier system, which separated deltaic from offshore facies and became much broader as progradation proceeded from the "geosynclne" on to the "shelf"; they further suggested that some of the Parkwood graywacke sandstone apparently represents local overriding of the barrier system by rapidly prograding deltaic deposits, whereas other Parkwood graywackes probably represent sediment that was transported through barrier passes to accumulate in offshore bars below the zone of intensive wave action.

PLATEAU FIELD

Insufficient work has been done to define boundaries of subintervals A_1, A_2 and interval B in the Plateau field; Wanless (1975) noted, however, that subinterval A_1 strata are absent in the Plateau field north of the Tennessee River but appear in the field south of the river. Because of this lack of stratigraphic detail, the description of the Plateau field in this paper is given here under discussion of subinterval A_1 strata.

Strata on Blount Mountain in the Plateau field consists of four principal conglomerate members: the First, Second, Third, and Fourth Conglomerates (Gibson, 1891, 1893). Although Gibson has provided considerable detail on strata of the Plateau field, his two reports, as Culbertson (1964) observed, are often in conflict or are inconsistent with regard to thickness of strata. In brief, the stratigraphic sequence in the Plateau field may be described as follows: the First conglomerate, correlated by Butts (1910) as the equivalent of the Boyles Sandstone Member in the Warrior field, lies at the base of the Pottsville sequence and is estimated to be as much as 30 m thick. The First Conglomerate is overlain by a shale, sandstone, and coal sequence estimated to be about 70 m thick. This variable sequence is overlain by the Second Conglomerate, estimated to be as much as 45 m thick. stone, and coal beds, reported by Gibson to be either The Second Conglomerate is overlain by shale, sand-240 m thick and containing 11 coal beds (Gibson, 1891, p. 114) or 728 m thick and containing 25 coal beds (1893, p. 29). This coal-bearing sequence is overlain by the Third Conglomerate, which may be as much as 45 m thick. The Third Conglomerate is overlain by shale, sandstone, and coal beds reported by Gibson to be either 67 m thick and containing 4 coal beds (Gibson, 1891, p. 114), or 342 m thick and containing 15 coal beds (Gibson, 1891, p. 29). This sequence is overlain by the Fourth Conglomerate, which was reported by Gibson (1893, p. 22) to consist of an upper section 3 to 4.5 m thick, a second section about 12 m thick, and a lower section about 30 m thick. The Fourth Conglomerate is reported to be about 15 m beneath the highest strata exposed on Blount Mountain. Gibson (1893, p. 29) reported this strata in T. 12 S., R. 3 E., to consist of shale, thin- and thick-bedded sandstone, clay, ironstone, underclay, and coal beds.

Many of the coal beds are thin and discontinuous on Blount Mountain. The Howard and Caskie coal beds are between the First and Second Conglomerates. The Swansea, Washington, and several unnamed coal beds lie between the Second and Third Conglomerates. According to Culbertson (1964), the Swansea is also know as the "Inland" and "Jagger" coal beds. The Swansea is reported to be as much as 1 m thick and has been mined along the northwest edge of Blount Mountain (Culbertson, 1964). The Altoona or "Underwood" and Woodward coal beds are between the Tihrd and Fourth Conglomerates, the Woodward being immediately underneath the Fourth Conglomerate. The Altoona is about 76 cm thick and has been mined on the surface as well as underground. The Bynum coal bed directly overlies the Fourth Conglomerate in a small area on Blount Mountain in T. 12 S., R. 3 W., but is generally too thin to be mined independently (Culbertson, 1964, p. 315).

The section on Lookout Mountain in the Plateau field, as described by Culbertson (1964), includes the Lower Conglomerate, overlain by a thin sequence (about 30 m thick) of shale, sandstone, and coal beds, including the Underwood coal bed and Upper Cliff coal beds. These units are overlain by the Upper Conglomerate, which is overlain by a series of shale, sandstone, and coal beds, including the Sewanee coal bed and the Tatum coal bed. Culbertson (1964) noted that a coal bed termed the Castle Rock (Cliff) coal bed underlies the Lower Conglomerate.

WARRIOR FIELD

The Boyles Sandstone Member is a basal conglomeratic orthoquartzite sandstone in the Warrior field; it ranges from 60 to 213 m in thickness, as indicated from oil and gas test-hole logs. This unit is interbedded with varying amounts of gray shale, thin-bedded micaceous sandstone, and locally, one or more thin coal beds (Culbertson, 1964). The lower part of the Boyles Sandstone Member is generally conglomeratic and the upper part, nonconglomeratic, although conglomeratic lenses are reported in the upper part in a few localities. The Boyles forms steep bluffs along the northern edge of the Warrior field, prominent ridges along the southeastern edge of the field, and the ridges bordering the Sequatchee Valley. The unit is thinnest along the southeast margin of the Warrior field and reportedly thickens westward and southwestward in the subsurface. The Boyles Sandstone Member usually includes a predominantly shaly unit, which has been used by some workers to divide the Boyles into two unnamed sandstone units. According to Culbertson (1964), the Boyles can be divided into a third sandstone unit at a few places in the Warrior field, such as along the southeast edge of the Blue Creek basin. In several other places in the Warrior field, Culbertson (1964) observed that the intervening shaly unit either has graded to sandstone, has been cut out by the overlying sandstone bed, or is insignificantly thin. The upper boundary of the Boyles Sandstone Member in the Warrior field is indistinct at some localities where the orthoquartzite beds grade upward to dark micaceous sandstone beds.

In the Blue Creek basin of the Warrior field, approximately 600 m of strata beneath the Black Creek coal group includes several coal beds. A coal bed locally called the Polecat in Marion and Winston Counties may be equivalent to the Sapp (Culbertson, 1964). The J, K, L, and M beds are reported to be persistent throughout the basin. The J bed is reported to be about 90 m below the Black Creek coal bed and to have an average thickness across the basin of 76 cm (Culbertson, 1964, p. B21).

CAHABA FIELD

Subinterval A_1 in the Cahaba field includes the Shades Sandstone Member at the bottom and extends upward to the bottom of the Harkness coal bed. The Shades Sandstone Member is considered the equivalent of the Boyles Sandstone Member of the Warrior field and is generally overlain by a shale sequence, which separates it from the Pine Sandstone Member. Culberton (1964) correlated the Pine Sandstone Member with sandstone sequences in the upper part of the Boyles Sandstone Member of the Warrior field. Two sandstone units, the Chestnut Sandstone Member and the Rocky Ridge Sandstone Member and several coal beds occur in the interval between the Pine Sandstone Member and the upper boundary (base of Harkness coal bed) of subinterval A_1 in the Cahaba field, (Culbertson, 1964, p. B36). The Chestnut ranges from 30 to 60 m in thickness and is a quartzose sandstone that makes a prominent ridge along the entire Cahaba field (Culbertson, 1964). The Chestnut is separated from the underlying Pine Sandstone Member by 150 to 240 m of strata, which is mostly shale and which contains the Gould coal bed (Butts, 1927, p. 14; 1940, p. 11). The Rocky Ridge Sandstone Member is a thick-bedded conglomeratic quartzose sandstone about 15 to 30 m thick that lies about 730 m above the Chestnut Sandstone Member in the interval between the Buck and Pump coal beds (Culbertson, 1964, p. B36).

COOSA FIELD

The Shades and Pine Sandstone Members constitute the lower part of the Pennsylvanian sequence in the Coosa field. The Shades is a sparsely conglomeratic quartzose sandstone about 60 m thick separated from the Pine Sandstone Member by about 60 to 90 m of shale and fine-grained sandstone (Rothrock, 1949). About 1,450 m of strata overlies the Pine, and no specific upper boundary of subinterval A_1 sediments has been identified.

SUBINTERVAL A_2

In Alabama, the middle part of the Pottsville Formation is considered to be subinterval A_2. In the Plateau field, only the lower part of subinterval A_2 is recognized, although the lower boundary in this field is ill defined. Subinterval A_2 in Alabama may include floral zone 5 fossils in its lower part near the Black Creek coal group (Wanless, 1975), as inferred by occurrence of floral zone 5 near the Battle Creek coal bed in the Gizzard Formation in Tennessee, a unit apparently correlative with Alabama subinterval A_2 sedimentary rocks. Wanless (1975) stated that floral zone 6, characterized by *Marecopteris pygmaea* and *Neuropteris tennesseana* was reported above the Mary Lee coal in the Warrior field by White (according to Butts, 1927, p. 15). In addition, the Wadsworth coal in the Cahaba field (Butts, 1927) has yielded this flora. The Erin Shale (phyllite), in the Talladega metamorphic series in Clay County may include strata of subinterval A_2, according to Wanless (1975). Wanless (1975) observed that in the Alabama coal basins, the sandstones of subinterval A_2 are less easily distinguished from those overlying them than they are in Tennessee and northward.

The upper part of the Pottsville Formation in Alabama is mostly strata of subinterval A_2 and is characterized by sandstone, siltstone, mudstone, underclay, coal beds, shale, and zones of marine and brackish-water fossils. Culbertson (1964) described the rocks as a somewhat rythmical sequence; however, Wanless suggested that although a semblance of cyclic sedimentation may appear in a given stratigraphic section, such cycles are only apparent when the patterns of lateral and vertical distribution of the sedimentary rocks are studied. Shale is the predominant rock type, ranging from medium gray and silty to grayish black and carbonaceous. Shale may grade vertically and laterally to argillaceous gray siltstone and gray to tan very fine grained sandstone. Ripple marks are commonly preserved in the siltstone and fine-grained sandstone. Interbeds of shale, siltstone, and sandstone are common. Siderite or ankerite concretions, usually less than 7 cm in maximum diameter are common in the shale. Siderite may occur as a lens as much as 30 cm thick and more than a meter in diameter, and at some localities, layers of siderite less than 2.5 cm thick are interbedded with the shale (Culbertson, 1964). Sandstones frequently have sedimentary structures (crossbedding, ripple and current marks) and are massive to thick bedded, fine to coarse grained, and well indurated. Thickness of the sandstones varies laterally and is as much as 30 m. Culbertson (1964) pointed out that the sandstones differ from the orthoquartzite sandstone beds of the Boyles Sandstone Member (within subinterval A_1) in that they are darker gray and contain mica, clay, and carbonaceous material, including coalified plant fragments.

WARRIOR FIELD

Subinterval A_2 strata in the Warrior field includes the Black Creek coal bed at the bottom and the Brookwood coal group at the top. As noted earlier, the thin succession of rocks capping Plateau regions north of the Tennessee River (northern part of the Plateau field in northeastern Alabama) consists largely or entirely of the lower part of subinterval A_2 (Wanless, 1975). From this outcrop area, these strata thicken southward. From west-central Walker County to northern Tuscaloosa County, the sequence thickens in a distance of 30 km from 153 m to 646 m (Wanless, 1975). Wanless noted that the sparse well data in Pickens and Sumter Counties indicate that south of the belt of rapid thickness change, subinterval A_2 strata appear to be uniform in thickness.

The more prominent sandstone beds in subinterval A_2 rocks in the Warrior field have been named as sandstone members and include, from oldest to youngest, the Bremen, Lick Creek, Camp Branch, and Razburg. Many linear channel-fill sandstones occur in the Pottsville, and Culbertson (1964) has provided some general information on distribution of one of the channels within the Pratt group. New stratigraphic and lithologic data are being rapidly accumulated from the Warrior field through ongoing coal exploration and coal mining and through exploration for gas and petroleum. In the near future it may be possible to begin studies of the distribution of some of the lithologic units within the Pottsville.

Subinterval A_2 rocks in the Warrior field include the major coal beds of that field. These beds are grouped into seven coal groups, which are, from oldest to youngest: Black Creek, Mary Lee, Pratt, Cobb, Gwin, Utley and Brookwood. Of the more than 25 coal beds within these groups, not all are persistent or of sufficient average thickness to be mined. Bituminous coal beds and underclays are regionally more persistent in the Warrior field than are most of the other lithologic units. Clay, siltstone, and siderite partings in the coal range from a few centimeters to as much as 3 m in thickness (Culbertson, 1964). The individual coal beds may pinch out, coalesce, or split. The coal underclay generally lacks bedding features, is light gray, and frequently shows root marks (stigmaria) (Culbertson, 1964).

CAHABA FIELD

Wanless (1975) places subinterval A_2 strata in the Cahaba field from the base of the Harkness coal bed to the base of the Yeshic coal bed. Pennsylvanian strata reach a maximum thickness of 2,740 m and are described by Culbertson (1964) as consisting of a lower part (Shades Sandstone Member and Pine Sandstone Member previously mentioned as belonging to subinterval A_1 strata), a middle part consisting of shale, sandstone, and commercial coal beds, and an upper part consisting of thick conglomerate beds and commercial coal beds. Culbertson (1964) defined the middle part as lying between the Pine Sandstone Member and the Straven conglomerate (fig. 6, locality 7).

A unique conglomerate member, the Straven, occurs in the upper part of subinterval A_2 sedimentary rocks in the Cahaba field. The Straven Conglomerate Member is characterized by large pebbles and cobbles as much as 20.3 cm in diameter and a higher portion of pebbles to matrix. Culbertson (1964) gave thickness of this conglomerate as 9 to 32 m in the Montevallo and Maylene basins of the Cahaba field. Butts (1910, p. 10) indicated that the Straven thins to the north, and suggested (Butts, 1940, p. 13) that the pebbles were derived from erosion of the Waxahatchee Slate, Brewer Phyllite, Wash Creek Slate, Weisner Quartzite, and Copper Ridge Dolomite, exposures of which are a few kilometers southeast of the Cahaba field. Culbertson (1964) reported that more than 35 coal beds occur in the 1,950 m-thick "productive" part of the sequence, which he defines as lying above the Gould coal bed. Of these, more than 22 beds are between the Harkness and Yeshic coal beds. Coal beds included in this interval are, in order of decreasing age: Wadsworth, Big Bone, Pump, Buck, Youngblood, Clark, Gholson, Quarry, Smithshop, Lower Thompson, Upper Thompson (Upper and Lower Thompson separated by Straven Conglomerate), and Helena.

NORTHEASTERN COOSA FIELD

Wanless (1975) did not specify the lower boundary of subinterval A_2 strata in the Coosa field; he designated the top of subinterval A_2 as the bottom of the Brewer coal bed. A specific upper boundary of the "middle barren part" was not suggested by Culbertson (1964).

In northeastern Coosa field, Culbertson (1964), p. B45) described the strata as being divisible into three parts—a lower part consisting of the Shades and Pine Sandstone Members, a middle barren part, and an upper coal-bearing part. Culbertson's "middle barren part" is not the exact equivalent of subinterval A_2 strata as defined by Wanless (1975). In the Wattsville basin of northeastern Coosa County, Rothrock (1949) estimated a total thickness of Pennsylvanian strata of about 1,650 m. Here, Rothrock (1949) reported Pennsylvanian strata above the Pine Sandstone Member as being 1,440 m thick, including in the lower 840 m, lenticular beds of sandstone, siltstone, and claystone that locally contain three nonpersistent coal beds generally less than 30 cm thick. Overlying this sequence (Rothrock, 1949, p. 23) is 600 m of coal-bearing strata which consists chiefly of fine- to medium-grain sandstone, carbonaceous claystone, and siltstone interbedded with coal beds.

Culbertson (1964) recognized 14 named beds of bituminous coal in northeastern Coosa County (fig. 6, locality 4), which vary in areal extent. Within this sequence of coal-bearing strata, about 60 m above the Coal City coal bed, is a 45-m-thick sandstone bed containing scattered quartz pebbles. This is the Fourth or upper conglomerate of Gibson (1895, p. 79). The Brewer coal bed, the bottom of which marks the top of subinterval A_2 strata, lies above the Fourth Conglomerate.

SOUTHWESTERN COOSA FIELD

Butts (1927) reported Pennsylvanian strata in the Yellow Leaf Basin of southwestern Coosa field as 2,220 m thick, of which 1,740 m consists of strata overlying the Pine Sandstone Member. Of this 1,740 m, the lower 1,140 m is composed of shale and sandstone and contains two main sandstone members—the Wolf Ridge and Straight Ridge—and seven coal beds. The remaining 600 m (an undetermined thickness of which probably includes interval B strata) consists of shale and thin sandstone. The Wolf Ridge Sandstone Member is about 360 m above the Pine Sandstone Member and is 15 to 30 m thick. The Straight Ridge Sandstone Member is about 244 m above the Wolf Ridge Sandstone Member. Of the seven coal beds, most are thin. Prouty (1912) measured a section in Yellow Leaf Basin of southwestern Coosa basin and gave the following data on the coal beds observed above the second conglomerate (Pine Sandstone): Clow, 15 to 76 cm; Double Ridge, 7 to 40 cm; Straight Ridge, 20 to 60 cm; Martin, 15 to 365 cm; Marker, 0 to 15 cm; and unnamed coal bed, 7 to 30 cm. In addition, Butts (1927, p. 19) reported a coal bed named the Cunningham as 2 m thick. Culbertson (1964) is of the opinion that this thickness is confined to a very small area.

INTERVAL B

Wanless (1975) noted that rocks of Interval B are characterized by extraordinary lithologic complexity in the Appalachian region and that the sandstones within the interval are generally less conglomeratic, finer grained, and less quartzose than those of Interval A. Interval B strata have not been adequately defined in the Warrior, Coosa, and Chahaba basins, although Wanless (1975), p. 35) suggested some lower boundaries of rocks in these regions. Interval B is considered to include floral zones 7 and 8 of Read and Mamay (1964). Zone 7 is characterized by *Megalopteris spp.*, which are found in the basal part of Interval B. Zone 8 is charaterized by *Neuropteris tenuifolia* (Wanless, 1975).

During Interval B time, according to Wanless (1975, p. 39), the Appalachian and Black Warrior basins were bordered on the southeast by tectonically deformed highlands that probably extended from Philadelphia, Pa., to Georgia and were the probable principal source of the detrital sediments. Wanless (1975, p. 40) suggested that, in general, Interval B in the Appalachian area consists largely of fluviatile and deltaic deposits that accumulated on a surface of very low relief. In Alabama, however, coarser detrital sediment appears to have been derived from nearby elevated land areas south of the Cahaba and Coosa fields. The southern Cahaba field is among the few areas in the Appalachians that show much conglomerate in upper Pennsylvanian strata (Wanless, 1975, p. 40). This conglomerate was described by Butts (1940).

WARRIOR FIELD

In the Warrior field, Wanless (1975) considers all Pennsylvanian rocks above the Brookwood coal group to be within Interval B and has tentatively traced these rocks in western Alabama and Mississippi on the basis of electric logs. These strata occur only in the subsurface, as the Brookwood coal group is the highest outcropping unit in the Warrior field. Interval B strata in the Warrior field have not been studied sufficiently to permit their classification. Upshaw (1967, p. 18) noted that to the west in the subsurface of Mississippi, beneath the Cretaceous overlap, beds of Kanawha age are included with the Pottsville Formation. The upper boundary of Interval B in the Warrior field is considered to be the unconformable Cretaceous contact.

CAHABA FIELD

White (quoted by Butts, 1927, p. 14) suggested a boundary between middle and upper Pottsville strata in the Cahaba field, and Wanless (1975) referred to the rocks containing White's upper Pottsville as Interval B. In this field, Wanless (1975) considers all Pennsylvanian strata, including and younger than the Yeshic coal, to be within Interval B (Wanless, 1975, p. 35). The upper boundary of Interval B in the Cahaba field is the contact with unconformably overlying Cretaceous rocks (Wanless, 1975).

Butts (1940) showed approximately 725 m of sandstone and shale interbedded with coal beds overlying the Yeshic coal in the Cahaba field. Culbertson (1964, p. B–37) called attention to the many test holes drilled during 1957 in the Montevallo and Maylene basins of the Cahaba field and estimated that 10 to 20 percent of the upper Pottsville sequence consists of fine-grained, thin-bedded micaceous sandstone, shale, underclay, and about 20 coal beds. In addition, Culbertson (1964, p. B37) estimated that more than 50 percent of the upper Pottsville sequence consists of fine- to coarse-grained sandstone in beds as much as 30 m thick, a remaining 25 percent consisting of conglomerate and conglomeratic sandstone. Several coal beds, including the Yeshic, Montevallo, and Maylene, and some thin coal beds occur in the interval of the Cahaba field strata considered by Wanless to be Interval B. Culbertson (1964) has provided a general description of the stratigraphy of this interval. The Montevallo coal bed is 115 to 131 m above the Yeshic bed (the bottom of which is considered to be the lower boundary of Interval B) in the Maylene, Dry Creek, and Montevallo basins. Between the Montevallo and Maylene coal beds in the Maylene basin is a sequence of sandstone, conglomerate, and shale that averages about 390 m in thickness and in places contains as many as 15 coal beds. Wanless (1975, p. 39) stated that nearly twice this number of coal beds could be shown in southern Cahaba field if all the seperate benches are considered. Many of these coal beds are reported to be 35 cm thick and locally as much as 1.2 m thick. Butts (1927, fig. 5) named seven beds in the interval between the Montevallo and Maylene coal beds, including, in ascending order, the Airshaft, Dogwood (upper and lower), Stein, Luke, Wooten, and Lovelady. The Maylene coal consists of an upper and lower bed, the lower bed being 2 to 12 m below the upper. A coal bed called the Polecat is about 60 to 75 m above the Maylene and is the highest coal bed in the Pennsylvanian sequence in the Cahaba field (Culbertson, 1964).

COOSA FIELD

In the Coosa field, Pennsylvanian strata including the Brewer coal bed and rocks above it, is considered by Wanless (1975, p. 35) as Interval B. The upper boundary of the interval is considered to be the unconformable contact between the overlying Cretaceous sedimentary rocks. Culbertson (1964) termed the upper 600 m of the Pennsylvanian sequence in northeastern Coosa field as the "upper coal bearing part," near the top of which is the Brewer coal. The thickness of Interval B strata in the northeastern Coosa field, as inferred from the work of Rothrock (1949, p. 3) may be slightly more than 30 m, although Wanless (1975, p. 38) has interpreted the thick sequence of strata in the Wattsville basin in northeastern Coosa field as being entirely in Interval A. Within the Interval B sequence in northeastern Coosa County is the Hammond coal, which reaches a maximum thickness of 231 cm (Culbertson, 1964, p. B49).

Studies sufficient to delineate the lower boundary of Interval B have not been made in southwestern Coosa County. Wanless (1975, p. 38) referred to a thickness of 115 m of strata in the southern part of the Coosa field as Interval B strata.

COAL RESOURCES

The Pennsylvanian-age coal in Alabama is generally high-grade banded "bright" bituminous that is ranked as high volatile A to low volatile. Most of the coal is high volatile A bituminous. Ash content generally ranges from 3 to 15 percent, and sulfur content is usually less than 2 percent (Culbertson, 1964, p. B51). Culbertson (1964, p. B53) stated that the rank of Alabama coals increases generally from northwest to southeast and suggested that the probable cause for this is such interacting factors as the variation of amount of horizontal compression, composition of the coal, and weight of overlying beds during maximum depth of burial of the coal.

Many studies, based on field exploration programs have been made of Alabama coal resources. Most of these studies have been restricted to relatively small properties or to a small part of a coal field and are, for the most part, unpublished. Segments of the coal fields have been dealt with on a larger scale by the Geological Survey of Alabama (Daniel, 1969a, 1969b; Daniel and Fies 1971; Neathery and others, 1969a, 1969b). Various studies have been made of coal reserves, notably those by McCalley (1886), Warrior coal field; Campbell (1913, 1929), Warrior, Cahaba, and Coosa fields; Squire (1890, p. 13), Cahaba field; Butts (1907, p. 113; 1911, p. 143), Cahaba field; Prouty (1909, p. 923), Coosa field; Jones (1929, p. 25), Coosa field; Rothrock (1949, p. 88), Coosa field; Culbertson (1964) and Ward and Evans (1977), Warrior field. The various investigators have used a wide range of criteria in making their estimates of reserves, and the comparison of estimates is, therefore, difficult. Campbell (1929) estimated that the original reserves of coal in Alabama total 67,570 million short tons in beds that are 35 cm or more thick and that are under less than 3,000 feet of overburden. Culbertson (1964) estimated that coal reserves remaining in Alabama total 13,753.8 million short tons in beds that are 35 cm or more thick and that are under less than 914 m of overburden. Culbertson gave figures for the separate fields as follows: Warrior field, 11,904.6 million short tons or 86 percent of the State coal; Cahaba field, 1,766.3 million short tons or 13 percent of the State total; Coosa field, 41.4 million short tons or about 0.3 percent of the State total; Plateau field, 41.5 million short tons or about 0.3 percent of the State total. Culbertson (1964) noted that his estimates are considerably lower than those made by Campbell because: (1) reserves were not calculated for large areas where data were not available; (2) test-hole data from the Warrior field indicate a westward thinning of minable coal; and (3) assumptions (made by Culbertson) concerning thicknesses of coal away from areas of proved thickness are conservative. Ward and Evans (1977) have estimated total remaining reserves at 35 billion short tons with a recoverable reserve estimate of 18.4 billion short tons. At the time of this writing, the Geological Survey of Alabama is preparing estimates of the total State reserves based on latest available coal data.

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CARBONIFEROUS OUTCROPS OF MISSISSIPPI

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IN THE UNITED STATES—ALABAMA AND MISSISSIPPI

CARBONIFEROUS OUTCROPS OF MISSISSIPPI

By Alvin R. Bicker, Jr.[1]

ABSTRACT

Carboniferous outcrops in Mississippi are restricted both in areal extent and stratigraphic content. Outcrops of Paleozoic rocks are present only in Tishomingo County in the northeastern corner of the State. The Carboniferous outcrops include rocks of the Kinderhook, Osage, Meramec, and Chester Series of Mississippian age. Although Pennsylvanian rocks are present in the subsurface approximately 25 miles to the south, none are exposed.

INTRODUCTION

The Carboniferous outcrops of Mississippi are restricted to strata of Mississippian age. Late Carboniferous- or Pennsylvanian-age sedimentary rocks are present only in the subsurface. Mississippian outcrops are limited to Tishomingo County in the northeastern corner of the State, adjacent to Alabama and Tennessee (fig. 7). Tishomingo County is rectangular, its long axis trending north. It is approximately 37 miles long and approximately 15 miles wide. The county is bounded on the north by the State of Tennessee and the Tennessee River. The eastern boundary is the Mississippi-Alabama State line.

Most of the Carboniferous outcrops are in the northern and eastern parts of the county, along the Tennessee River and its tributaries, where overlying Cretaceous-age sediments or more recent terraces have been eroded. Major tributaries where Carboniferous strata are exposed are Yellow Creek, Indian Creek, Bear Creek, and tributaries of Bear Creek, mainly Little Bear, Pennywinkle, and Cripple Deer Creeks. A few isolated exposures are present in the southwestern part of Tishomingo County in the drainage system of Mackeys Creek and its tributaries. Mackeys Creek is a tributary of the Tombigbee River, which drains south. Mackeys Creek valley will be the route of the Tennessee-Tombigbee Waterway in this part of Tishomingo County.

The stratigraphic nomenclature used in this paper has not been reviewed by the Geologic Names Committee of the U.S. Geological Survey. The nomen-

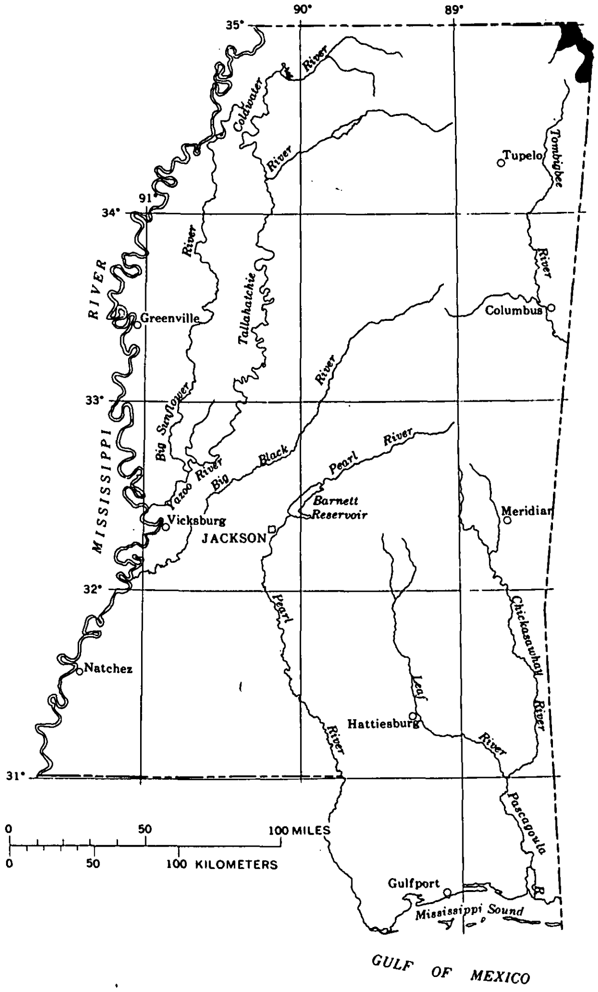

Figure 7.—Distribution of Mississippian outcrops in Mississippi.

[1] Mississippi Geological, Economic, and Topographical Survey, Jackson, Miss. 39216.

clature used here conforms with the current usage of the Mississippi Geological, Economic, and Topographical Survey.

HISTORY

Although previous writers had briefly referenced Paleozoic strata as being present in Mississippi, Harper (1857) was the first to specifically discuss the Paleozoic beds in the State. He reported Carboniferous strata in Tishomingo and Itawamba Counties as extending into the State from neighboring Alabama. The only part of the Carboniferous that Harper recognized, he designated Mountain Limestone; he considered that this unit consisted of limestone, sandstone, chert (hornstone), and clay. Harper recognized and labeled some faunal species contained in the limestone and clay.

Hilgard (1860) (fig. 8) more correctly delineated the stratigraphic horizon of the Carboniferous strata. He stated that, on the basis of faunal identification, the greater part of the Mississippian outcrops were within the limits of the Warsaw and Keokuk Limestones. He further stated that observations were insufficient to separate those beds belonging to each group. Hilgard, as Harper had earlier, did not indicate specific locations of Mississippian outcrops as far south as Itawamba County; however, both authors indicated Mississippian strata within the county on their respective charts or geologic maps. Hilgard believed that the Orange Sand overlay the Carboniferous in most places; the Tuscaloosa Group had not been designated at that time. However, he pointed out that data from water wells suggested that the Eutaw Group overlay the Carboniferous at certain localities in Tishomingo County. In his introductory paragraph, Hilgard noted diverse dips of the Mississippian strata and contemplated the probability of folds extending into Mississippi from Alabama and Tennessee.

Between 1860 and 1905, the area of Paleozoic outcrops must have been observed by other geologists, but records of their visits are difficult to find. During a visit to northeast Mississippi in the year 1884, Johnson (Smith and Johnson, 1887) noted the presence of gravel, lignite, and clay, which he assigned to a formation below the Eutaw. These beds of gravel, clay, and lignite were identified by Smith and Johnson (1887) as belonging to the Tuscaloosa Formation of Cretaceous age.

Crider (1906), in a paper on the geology and mineral resources of the State, described some of the Paleozoic outcrops. Crider may not have observed outcrops in the entire area he designated as containing Paleozoic. As Harper and Hilgard had shown earlier, Crider indicated that Paleozoic outcrops extended far south in Itawamba County. The idea of Paleozoic rocks being present at the surface in Itawamba County persisted until 1930, when Morse restricted the Paleozoic outcrops to Tishomingo County. Crider differentiated more of the Paleozoic strata than had previous writers. On the basis of faunal evidence collected along Yellow Creek in secs. 15 and 22, T. 1 S., R. 10 E., in northern Tishomingo County and identified by Charles Schuchert and E. M. Kindle, Crider was able to identify the oldest Paleozoic strata as lower Devonian, correlative with the New Scotland of New York. Crider's description of an outcrop on Whetstone Creek indicates that he recognized other beds that he considered to be Devonian in age, but he did not identify the formation. Although Crider was influenced by McCalley (1896) in his assignment of Mississippian strata, he neglected or chose not to recognize the upper beds as the Devonian black shale. Crider identified the lowest Carboniferous strata as the Tullahoma Formation and correlated it with the Tullahoma or Lauderdale chert, as had McCalley of the Alabama Survey. He identified the principal materials of the formation as highly siliceous fragmental chert, pulverized silica, and residual clay. Overlying the Tullahoma Formation, Crider recognized a highly fossiliferous limestone as the St. Louis Limestone. He suggested that a member of the upper part of this interval is equivalent to the Ste. Genevieve of Missouri. Crider identified the Chester Formation as the uppermost Carboniferous in Mississippi. The formation is represented by limestone, sandstone and shale. The one section described is near Mingo in southern Tishomingo County.

Lowe (1919), in a report on the general geology of the State, briefly discussed the Paleozoic strata. Lowe assigned the name Yellow Creek beds to the Devonian strata underlying the Mississippian. He stated that the beds at certain levels consisted of dark limestone containing fauna of Devonian age that are correlative with those of the New Scotland. Immediately overlying the Devonian, Lowe identified the Carboniferous strata as the Lauderdale Chert. General locations of outcrops were given. Lowe was the first to report the use of the name Tuscumbia for those beds overlying the Lauderdale chert that are correlative with the St. Louis. For the strata in the Chester series, Lowe used the name Hartselle Sandstone, as had the Alabama Survey. In this report is the only indication of the Carbonifer-

SYSTEM	SERIES	HILGARD 1860	CRIDER 1906	LOWE 1915	MORSE 1930	WELCH 1959	ALABAMA BUTTS 1926	ALABAMA THOMAS 1972	MC NAIRY COUNTY TENNESSEE RUSSELL 1972	THIS PAPER
MISSISSIPPIAN	CHESTERIAN		CHESTER FORMATION	HARTSELLE SANDSTONE	FOREST GROVE FORMATION HIGHLAND CHURCH MEMBER SOUTHWARD BRIDGE FORMATION SOUTHWARD SPRINGS SANDSTONE SOUTHWARD POND FORMATION ALLSBORO SANDSTONE ALSOBROOK FORMATION	FLOYD SHALE	PARKWOOD FORMATION PENNINGTON FORMATION HARTSELLE SANDSTONE GOLCONDA FORMATION CYPRESS SANDSTONE GASPER FORMATION BETHEL SANDSTONE STE. GENEVIEVE LIMESTONE FLOYD SHALE	PARKWOOD FORMATION PENNINGTON FORMATION BANGOR LIMESTONE HARTSELLE SANDSTONE FLOYD SHALE PRIDE MOUNTAIN FORMATION MONTEAGLE LIMESTONE		FOREST GROVE FORMATION HIGHLAND CHURCH MEMBER SOUTHWARD BRIDGE FORMATION SOUTHWARD SPRINGS SANDSTONE SOUTHWARD POND FORMATION ALLSBORO SANDSTONE ALSOBROOK FORMATION
	MERAMECIAN	WARSAW LIMESTONE	ST. LOUIS LIMESTONE	TUSCUMBIA LIMESTONE	IUKA FORMATION	TUSCUMBIA LIMESTONE	TUSCUMBIA LIMESTONE	TUSCUMBIA LIMESTONE		TUSCUMBIA LIMESTONE
	OSAGEAN	KEOKUK LIMESTONE	TULLAHOMA FORMATION	LAUDERDALE CHERT			FORT PAYNE CHERT	FORT PAYNE CHERT	FORT PAYNE FORMATION UPPER	IUKA FORMATION
	KINDERHOOKIAN				CARMACK LIMESTONE	FORT PAYNE CHERT MAURY SHALE			FORT PAYNE FORMATION LOWER	CARMACK LIMESTONE
					WHETSTONE BRANCH SHALE	CHATTANOOGA SHALE	CHATTANOOGA SHALE	MAURY SHALE	CHATTANOOGA SHALE	CHATTANOOGA SHALE

FIGURE 8.—Correlation chart of the Mississippian rocks of Mississippi.

ous strata that supposedly crop out in southern Itawamba County; Lowe stated that a sandstone member crops out on Bull Mountain Creek in northern Monroe County and adjacent regions.

The most complete record of Paleozoic rocks that crop out within Mississippi was given by Morse (1930). Many of the outcrops that Morse reported have since been partly or entirely inundated by the water of Pickwick Lake. Most of those that are partly inundated are so isolated that they are best reached by water. Most of the Devonian outcrops have been completely inundated; only a few feet of Devonian strata is visible above water level at isolated locations. Morse named the upper part of the Devonian the Whetstone Branch. The type locality is a small stream by the same name in sec. 31, T. 1 S., R. 11 E. Although Morse considered the Whetstone Branch to be in part correlative with the Chattanooga and to be Devonian in age, he reported the presence of fauna indicative of early Mississippian age in the upper section of the formation. He was skeptical of assigning the upper section to the Mississipian because he could not recognize a stratigraphic break between the upper and lower sections; therefore, he assigned the section to the Devonian.

Morse gave the lower part of the Mississippian the name Carmack, stating that the formation is largely Kinderhookian in age. He recognized pronounced unconformities at the base and top of the Carmack. He included all strata overlying the Carmack, between the Carmack and the base of the Chester, in the Iuka Terrane (now Iuka Formation), a unit consisting mostly of residual material in the form of clay and chert fragments. Outcrops included by Morse in the Iuka that contain unleached material are present only in western Alabama near the Mississippi State line. In Mississippi, strata of both the Fort Payne and Tuscumbia Formations were included in the Iuka Terrane by Morse. That part of the Iuka which Morse described in the south wall of Cripple Deer Creek, contained faunal evidence that indicated a St. Louis age. Other writers used the name Tuscumbia for correlative strata in Alabama and the subsurface of Mississippi.

Overlying his Iuka Terrane, Morse (1930) identified strata of the Chester Group, which he divided into six formations and to which he assigned names. In ascending order, these formations were the Alsobrook, Allsboro, Southward Pond, Southward Springs, Southward Bridge, and Forest Grove. Some of the formations are restricted, both at the outcrop and in the subsurface, and the names proposed by Morse are used only locally by few geologists. The uppermost Mississippian outcrops described by Morse were of the Highland Church Sandstone Member of the Forest Grove Formation. The most southerly outcrops of Highland Church that Morse described are in T. 7 S., R. 9 E., in the southwest part of Tishomingo County. The Highland Church is correlative with the Hartselle of Alabama; many geologists working in both areas prefer the name Hartselle when describing the strata in Mississippi.

Russell, during geological investigations for a proposed nuclear generating plant site for the Tennessee Valley Authority (1977), mapped an area in cooperation with TVA geologists in northern Tishomingo County. The area was designated as the Yellow Creek Plant Site. The site encompasses an area within a 5-mile radius centered in sec. 35, T. 1 S., R. 10 E. Russell and others (1972) previously had mapped quadrangles immediately to the north in Tennessee and had retained formational names in use in that State for strata present at the Yellow Creek Site. Russell showed the Chattanooga to be Devonian and Mississippian in age. The Mississippian section overlying the Chattanooga had been designated the Fort Payne Formation. Russell divided this section into the Lower Fort Payne and the Upper Fort Payne. The Lower Fort Payne is correlative with the strata that Morse designated as the Carmack; the Upper Fort Payne is equivalent to the lower part of Morse's Iuka Terrane.

This paper is presented as a guide to those who may have some interest in the Carboniferous outcrops within the State of Mississippi. It does not attempt to alter the nomenclature of the Mississippian strata or to resolve differences in nomenclature as used by different investigators. Formational names used herein are those deemed most satisfactory for the facies that appear at the surface in Mississippi.

GEOLOGICAL SETTING

Most geologists assign a Devonian and Mississippian age to the Chattanooga Shale. Morse (1930) gave the name Whetstone Branch to these sedimentary rocks and stated that faunal evidence indicated the lower part of the section to be undoubtedly Devonian. Although at some localities, the upper part of the formation appears to be closely associated with the Mississippian, Morse could not identify an unconformity within the section; therefore, he included the whole section in the Devonian.

The Carmack Limestone, as named by Morse is the lowermost Mississippian strata. It unconformably overlies the Chattanooga in some areas of outcrop. At several localities along the west bank of Pickwick Lake between Yellow Creek and Indian Creek in sec. 30, T. 1 S., R. 11 E., gently dipping thin-bedded Carmack Limestone can be seen above highly contorted more steeply dipping Chattanooga strata. The unconformable relationship between the Carmack and the Chattanooga is not as apparent at the few outcrops that are visible at other localities This is due in part to the small thickness of Chattanooga that is exposed above the water level of Pickwick Lake. In the most extreme northern outcrops, the Carmack Limestone overlies strata of Early Devonian age. In his cliff section, in sec. 22, T. 1 S., R. 10 E., Morse (1930, p. 21) showed the Carmack Limestone to overlie Devonian strata to which he assigned the name Island Hill. TVA geologists (1977) assigned the same Devonian strata to the Ross Formation and showed that the Lower Fort Payne of Mississippian age overlies the Devonian unconformably.

The Mississippian is overlain by rocks of Cretaceous age or by Quaternary terrace materials. Cretaceous strata overlap the Mississippian and are present at the outcrop except in those localities where erosion has removed the Cretaceous strata and fluvial Quaternary sediments have been deposited. In the northernmost outcrops, sediments of the Eutaw Group of Cretaceous age overlie the Carmack Limestone. Southward, succeedingly older Cretaceous sediments are in contact with progressively younger Mississippian beds. At the southernmost outcrops, strata of the Tuscaloosa Group overlie the Hartselle or Highland Church Sandstone Member of the Chester Series.

The Mississippian outcrops are near the eastern edge of the Mississippi Embayment, a southward-plunging structural trough that formed in Late Cretaceous-early Tertiary time. The axis of the trough coincides roughly with the present course of the Mississippi River. Post-Paleozoic tectonics and the overlying younger sediments obscured much of the evidence of late Paleozoic structural movement.

Lower Mississippian rock types suggest deposition on a broad relatively stable shelf. Regional dip of the outcrops is to the south and southeast, showing a homoclinal feature having minor undulations. This feature may have been a broad shelf south of the Pascola arch, a positive feature between the Ozark and Nashville domes. Northward updip thinning of pre-Mississippian strata suggests a positive feature to the north, on which the Mississippian strata onlapped, and indicates the presence of the Pascola arch at the time of Mississippian deposition.

Although faults have not been mapped in the outcrop area, the location and attitude of some of the Mississippian strata is highly suggestive of faulting. In addition, meager subsurface control indicates faulting involving Mississippian strata in the south-central part of Tishomingo County. This interpreted faulting is probably post-Mississippian; however, additional information is needed before a more accurate date can be assigned.

CARMACK LIMESTONE

The name Carmack Limestone was introduced by Morse (1930) for that strata overlying the Devonian-age Chattanooga (Whetstone Branch). The strata are correlative with the basal Fort Payne of Alabama (Butts, 1926; Thomas, 1972a) and the Lower Fort Payne of Tennessee (Russell and others, 1972). Also correlative, in part, is the St. Joe Formation, the basal member of the Iowa Series, which is downdip in the subsurface (Welch, 1959). The name Fort Payne has been used in the oil industry. Carmack Limestone is preferred herein because of the lithologic difference between these strata and those of the basal Fort Payne of Alabama. Thomas reported the Fort Payne of Alabama to consist of finely crystalline to microcrystalline siliceous limestone and smoky chert (the chert content of fresh rock being 50 percent), whereas the Carmack is predominantly a thin-bedded fine-grained, shaly limestone. When fresh, the limestone is usually gray to dark gray, weathering to brownish gray.

At the surface, the formation has a maximum thickness of 100 feet. Morse (1930) described 81.5 feet of Carmack at the cliff section before its inundation by Pickwick Lake. Other outcrops contain intervals that are covered by colluvial material, and the entire thickness of the Carmack section cannot be observed. Data from test wells within the outcrop area substantiate the maximum thickness assigned to the outcrop sections. Apparently the formation thins southward in the subsurface. Data from a test well in sec. 23, T. 3 S., R. 10 E., shows the formation to be 50 feet thick.

Outcrops of Carmack are numerous along the shoreline of the main body of Pickwick Lake, the Yellow Creek Embayment, and in the valleys of streams that drain into the lake. Outcrops of the

Carmack are not visible south of the latitude of sec. 16, T. 2 S., R. 11 E.

IUKA FORMATION

The name Iuka Terrane was introduced by Morse (1930) to include that section of Mississippian strata between the underlying Carmack Limestone and the base of the overlying rocks of the Chester series. The unit is now called the Iuka Formation. The section is correlative with the Fort Payne Chert and the Tuscumbia Limestone of Alabama (Thomas, 1972a) and, in part, with the Upper Fort Payne of Tennessee (Russell and others, 1972). In Mississippi, the formation consists of small to large blocks of residual chert interbedded with residual clay; in some localities, it contains beds of amorphous silica. The residual chert is the result of leaching of the calcium carbonate fraction of the original formation. In the northern outcrops, the formation is the residual material resulting from leaching of the truncated Fort Payne. To the south, the material present in the outcrops is progressively younger. In the latitude of sec. 15, T. 4 S., R. 11 E., the formation contains residual material whose faunal content identifies this part of the Iuka as being correlative with the Tuscumbia Limestone. Because of the lithologic similarities and insufficient faunal content, the two formations cannot be differentiated at the surface where they are present in their residual state.

Morse (1930) stated that at a few outcrops, evidence of pre-Chester erosion at the top of the Iuka indicates an unconformity. Subsurface data from oil test wells in secs. 15 and 21, T. 4 S., R. 11 E., suggest the presence of the unconformity. The southernmost well, in sec. 21, has competent bedded material that can be differentiated into the respective Fort Payne and Tuscumbia Formations. Other well data in the vicinity include a stratigraphic section that contains residual Iuka material (probably Tuscumbia equivalent) underlying Chester beds, suggesting possible pre-Chester leaching.

Thickness of the Iuka in the northern area of outcrop is approximately 100 feet. Near the southern edge of the outcrop, the formation has a thickness of 200 feet.

TUSCUMBIA LIMESTONE

Morse (1930) chose not to differentiate the Tuscumbia Limestone from the Iuka Terrane, although he recognized a few thin limestone beds present at the surface in the southern part of the Iuka outcrop. Even though Morse identified the materials as correlative with the Tuscumbia or St. Louis Limestone, he included it with the Iuka.

In 1970, a limestone quarry was opened in sec. 22, T. 4 S., R. 11 E., in the area of outcrop of chystalline limestone that Morse (1930) included in the Iuka. The quarry shows a competent section of crystalline limestone that should be correlative with the Tuscumbia Limestone.

The limestone is light gray, medium to coarse crystalline, and contains many fossil imprints and light-gray chert. Scattered joints and small void spaces are filled with asphaltic material.

The full thickness of the limestone has not been exposed, nor has the underlying contact been reached. However, test-hole data indicate that the Tuscumbia in this area is more than 100 feet thick. The formation dips to the south, and in the latitude of the Tishomingo-Itawamba County boundary, subsurface data show the Tuscumbia section to be 70 feet thick.

Surface exposures that can be identified as Tuscumbia Limestone are restricted to the valley of Cripple Deer Creek.

ALSOBROOK FORMATION

Morse (1930) assigned the basal 85 feet of the Chester Series to the Alsobrook Formation. The formation is correlative with the St. Genevieve of Alabama (Butts, 1926) or the basal section of the Pride Mountain of Alabama (Thomas, 1972a). The type locality and most exposures are east of the Mississippi-Alabama State line near the small village of Allsboro.

The formation, as described by Morse (1930), consists of 8 feet of highly fossiliferous limestone overlain by 44 feet of green clay shale. Overlying the shale is a sandstone bed 36 feet thick, which in turn is overlain by a 5-foot bed of clay shale. Faunal content of the limestone clearly indicates a Chester age for the basal limestone.

In Mississippi, outcrops of the Alsobrook Formation are restricted to the valley of Cripple Deer Creek, where widely scattered small outcrops of thin beds of limestone are overlain by green shale. The limestone does not contain faunal evidence that would definitely indicate the age of the strata; however, the stratigraphic position of the limestone relative to the nearby Tuscumbia Limestone strongly suggests a basal Chester section. The sandstone designated the Cripple Deer Sandstone Member is not present at the surface in Mississippi. Subsurface data from a test well on the divide immediately south of Cripple Deer Creek, includes a sandstone section at the stratigraphic position of the Cripple Deer. This sandstone member appears to be correlative with the Lewis Sandstone, which produces hydrocarbons to the south in Monroe County, Miss.

ALLSBORO SANDSTONE

The 3-foot section of sandstone above the Alsobrook Formation at the type locality was designated the Allsboro Sandstone by Morse (1930). The Allsboro, together with the Cripple Deer Sandstone Member, is correlative with the Bethel of Alabama (Butts, 1926) and with the lower sandstone member of the Pride Mountain of Alabama (Thomas, 1972a). The type locality in Alabama is the same as that given for the Alsobrook Formation; other outcrops of Allsboro Sandstone described are also in Alabama. Isolated outcrops of sandstone within the valley of Cripple Deer Creek may be Allsboro, but exact stratigraphic position of these outcrops is undetermined. Most of the Paleozoic beds are covered by Cretaceous sand and gravel, which prevents an accurate assessment of their position.

Morse described the Allsboro Sandstone at the type locality as being dark gray, coarse grained, and containing a petroleum residue. Other descriptions indicate that the sandstone varies in thickness and character at different localities. Although this variation was noted by Morse (1930, p. 131), he still chose to separate the Allsboro Sandstone from the Cripple Deer Sandstone Member. The variation suggests a facies change, which may indicate that perhaps the Allsboro and the Cripple Deer should have been included in the same unit.

SOUTHWARD POND FORMATION

Overlying the Allsboro Sandstone is a shale sequence separated by thin beds of limestone. The entire sequence is approximately 75 feet thick; the intervening limestone beds are 9, 1, and 3 feet thick. Morse (1930) designated this section as the Southward Pond Formation and assigned the limestone beds the designations A, B, and C. The section is correlative with the Gasper Formation of Alabama (Butts, 1926) and with that part of the Pride Mountain between the lower sandstone unit and the middle sandstone unit (Thomas, 1972a).

Both the limestone and shale are extremely fossiliferous and at different localities afford the best collecting of Paleozoic fauna of all the Mississippian strata. The basal limestone is a dark-gray, very oolitic, highly fossiliferous, slightly asphaltic unit that is distinctive and easily recognized. The middle and upper limestone beds are dark-gray crystalline fossiliferous units but are not as easily recognizable as the lower limestone unit. The shale units are usually green, fossiliferous, and at some localities very limy.

The type locality is near the northwest part of Cypress Pond, a low swampy area that was an old meander of Bear Creek, in sec. 17, T. 5 S., R. 11 E. At the time of Morse's investigation, the low area was named Southward Pond. Other outcrops of the Southward Pond Formation are in the valley of Pennywinkle Creek and at several scattered outcrops in McDougle Creek in the western part of Tishomingo County. The outcrops in Pennywinkle Creek afford the best fossil-collecting area in the Paleozoic outcrop belt.

SOUTHWARD SPRINGS FORMATION

Overlying the Southward Pond Formation is a sandstone section that Morse (1930) designated the Southward Springs Sandstone and that is now called the Southward Springs Formation. The Southward Springs is correlative with the Cypress of Alabama (Butts, 1926) and with the middle sandstone unit of the Pride Mountain Formation (Thomas, 1972a). Outcrops of the Southward Springs are restricted to the area north and south of Cypress Pond. Outcrops north of the pond are in the southwest quarter of sec. 8, T. 5 S., R. 11 E.; outcrops south of the pond are in sec. 18.

The northern exposure consists of 26 feet of shaly sandstone and sandy shale, yellowish buff, weathering to yellowish red. The upper part of the section is calcareous and fossiliferous. At the southern exposure, only about 15 feet of the section can be observed. Both exposures are covered partly by colluvium, and the entire section cannot be seen. Fossils from both exposures are mainly brachiopods.

The stratigraphic position of the Southward Springs Formation suggests that the sandstone is correlative with the Evans sand, which produces hydrocarbons in Itawamba and Monroe Counties, south of the outcrop area.

SOUTHWARD BRIDGE FORMATION

South of Cypress Pond, near the abandoned bridge crossing Bear Creek, in the valley wall of the creek, is an exposure of alternating shale, sandy shale, and limestone, which Morse (1930) designated the Southward Bridge Formation. The Southward Bridge Formation is correlative with the Golconda of Alabama (Butts, 1926) and with the upper part of the Pride Mountain Formation (Thomas, 1972a).

The whole interval is not exposed at Southward Bridge. The upper limestone member is missing here but is present a short distance upstream in the Bear Creek valley. The basal shale section is black, carbonaceous, and contains thin limestone beds. Upper shale intervals are blue-gray, calcareous, sandy, and fossiliferous. The limestone members are bluish gray, massive, fine crystalline, and fossiliferous. Thickness of the entire interval is approximately 90 feet. The limestone members are 4 to 6 feet thick, and the intervening shale beds are as much as 40 feet thick.

The larger outcrops of the Southward Bridge Formation are in the valley of Bear Creek in T. 5 S., R. 10 and 11 E. However, in western Tishomingo County, small outcrops are present in the bed of McDougle Creek in sec. 5, T. 5 S., R. 10 E. At this location, greenish-gray shale and brown crystalline fossiliferous limestone can be observed in the bed of the creek. Colluvial material covers much of the area, and only thin beds of Paleozoic rocks are visible.

FOREST GROVE FORMATION

HIGHLAND CHURCH SANDSTONE MEMBER

The section of shale, shaly sandstone, and sandstone overlying the uppermost limestone member of the Southward Bridge Formation was named the Forest Grove Formation by Morse (1930). A persistent massive sandstone at the top of the interval has been designated as the Highland Church Sandstone Member. The basal part of the Forest Grove Formation has been correlated with the Golconda of Alabama (Butts, 1926) or with the upper part of the Pride Mountain (Thomas, 1972a). The massive Highland Church is correlative with the Hartselle Sandstone of Alabama (Butts, 1926, Thomas, 1972a).

The basal section below the massive Highland Church contains alternating beds of gray to dark-gray, sandy, slightly calcareous shale and thin beds of fine-grained sandstone. Both the shale and sandstone may contain fossils at some localities. Lithology of the massive Highland Church is generally consistent throughout its outcrop area. The sandstone is generally light colored, well sorted, fine to medium-grained, locally calcareous, and fossiliferous.

Outcrops of the Highland Church and the underlying shale of the Forest Grove are numerous in the valley of Bear Creek in T. 5 and 6 S., R. 10 and 11 E. Outcrops of the Highland Church are present also in the valley of Mackeys Creek in southwestern Tishomingo County in S. 26, T. 6 S., R. 9 E. The outcrops of Highland Church in Mackeys Creek are the most southerly and the youngest Mississippian strata present at the surface.

Thickness of the combined interval of the basal Forest Grove and the overlying Highland Church is approximately 125 feet. At the outcrop, only 25 to 30 feet of Highland Church and as much as about 50 feet of the basal Forest Grove can be observed. Data from core holes in the area of Mackeys Creek show the Highland Church to be 47 feet thick and the basal Forest Grove to be 77 feet thick.

Toward the south in the subsurface, the Highland Church and Forest Grove, like much of the Chester-age strata, pinch out or are not identifiable because of facies changes. In the latitude of central Itawamba County, the Highland Church-Forest Grove section probably grades into the marine carbonate, the Bangor limestone, and is not present as a separate identifiable unit.

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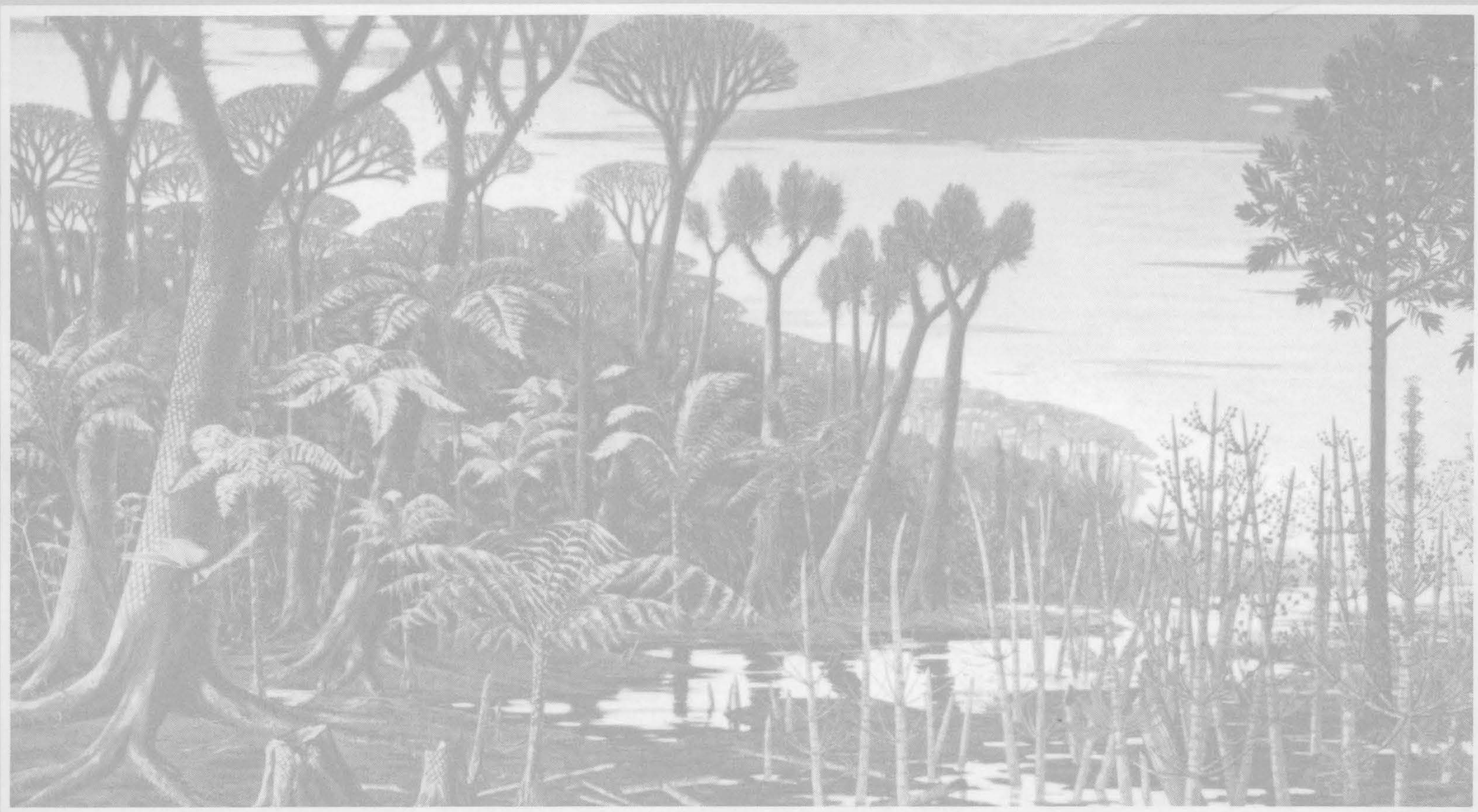
The Mississippian and Pennsylvanian (Carboniferous) Systems in the United States



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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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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.

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