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# SUBSURFACE CHARACTERIZATION AND SEUQENCE STRATIGRAPHY OF LATE MISSISSIPPIAN STRATA IN THE BLACK WARRIOR BASIN, ALABAMA AND MISSISSIPPI

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# ABSTRACT OF THESIS

# SUBSURFACE CHARACTERIZATION AND SEUQENCE STRATIGRAPHY OF LATE MISSISSIPPIAN STRATA IN THE BLACK WARRIOR BASIN, ALABAMA AND MISSISSIPPI

A depositional framework for the Mississippian (Chesterian) Pride Mountain Formation/Hartselle Sandstone clastic tongue and the lower Bangor Limestone carbonate ramp in the Black Warrior basin, Mississippi and Alabama, is constructed from approximately 250 geophysical well logs, 15 well cuttings descriptions, and outcrop data. The framework is based upon cross sections, isopach maps, and transgressive-regressive sequence stratigraphy.

The Lowndes-Pickens synsedimentary fault block controlled sediment dispersal in during Pride Mountain/Hartselle deposition. The basin filled from the southwest, which pushed the depocenter northeastward during Hartselle deposition. The Hartselle sub-basin is composed of the Hartselle barrier-island and back-barrier deposits to the southwest, including the Pearce siltstone. The Pearce siltstone, a previously unidentified subsurface unit, was deposited in a restricted environment controlled by the Lowndes-Pickens block.

The Pride Mountain, Hartselle, and lower Bangor succession contains one complete and one partial transgressive-regressive stratigraphic sequence. An exposure surface at the top of the Hartselle Sandstone and Monteagle Limestone is a maximum regressive surface. The upper part of the Bangor ramp is highly cyclic and grades from oolitic shoal deposits southwestward into a condensed section, the Neal black shale, at the toe of the ramp. The entire thickness of the lower Bangor is equivalent to the Neal shale.

Keywords: Floyd/Neal shale, Pearce siltstone, Hartselle sub-basin, Lowndes-Pickens block, Black Warrior basin

Carrie A. Kidd
November 14, 2008

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THESIS

Carrie Ann Kidd

The Graduate School

University of Kentucky

2008

# Subsurface Characterization and Sequence Stratigraphy of Late Mississippian Strata in the Black Warrior Basin, Alabama and Mississippi

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THESIS

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A thesis submitted in partial fulfillment of the
requirements for the degree of Master of Science in the
College of Arts and Sciences
at the University of Kentucky

By

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Lexington, Kentucky

Director: Dr. William A. Thomas, Professor of Geology

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2008

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# CHAPTER ONE
# INTRODUCTION

Increasing oil and gas prices accompanied by a diminishing hydrocarbon supply has led to a boom in exploration and development of unconventional resources. With the recent discovery of gas in the Barnett Shale in the Fort Worth basin, unconventional shale gas plays in nearby Ouachita foreland basins have also seen increased interest and activity. Recent shale gas exploration has targeted the Fayetteville Shale (Arkansas) in the Arkoma basin, and the Floyd/Neal Shale in the Black Warrior basin, as well as the Marcellus Shale in the Appalachian basin and the Haynesville Shale (Louisiana) in the Gulf Coastal Plain. The Mississippian and Pennsylvanian rocks of the Black Warrior basin contain abundant hydrocarbon deposits in the form of coal, natural gas, coalbed methane, oil, and tar sands. The U.S. Geological Survey estimates the Black Warrior basin still contains approximately 8.5 trillion cubic feet of undiscovered natural gas, 5.9 million barrels of undiscovered oil, and 7.6 million barrels of undiscovered natural gas liquids (White and Read, 2007).

The Black Warrior foreland basin is located within the structural recess of the Appalachian-Ouachita thrust belts in northern Alabama and Mississippi (Thomas, 1988). The basin formed during late Paleozoic time as a result of Ouachita thrusting to the southwest. The basin fill is an Upper Mississippian to Lower Pennsylvanian synorogenic clastic wedge. The Mississippian part of the clastic wedge can be divided into three tongues that pinch out into carbonate facies to the northeast (Thomas, 1988). The Pride Mountain Formation and Hartselle Sandstone (lower clastic tongue) represent the earliest clastic sediments deposited in the basin. Overlying the Pride Mountain and Hartselle is the regionally extensive lower Bangor Limestone carbonate ramp and the Floyd/Neal black shale, which was deposited at the toe of the ramp in the southwestern part of the basin.

### ***Purpose***

The excitement surrounding the Floyd/Neal shale has prompted the need for additional research on the relationship between the Bangor Limestone and Floyd/Neal shale in the Black Warrior basin. To better understand this relationship, this study has looked at the stratigraphic architecture of the underlying Pride Mountain/Hartselle clastic tongue to relate the evolution of the basin to the carbonate ramp and black-shale facies. The goal of this research is to 1) provide subsurface characterization of the Pride Mountain Formation, Hartselle Sandstone, lower Bangor Limestone, and Floyd/Neal shale on the basis of lithology, facies relationships, well-log expression, thickness, and distribution; 2) compare the subsurface characterizations to published studies and discuss results in terms of sediment dispersal patterns, depositional environments, and controls on sediment deposition; 3) define a depositional framework for the lower clastic tongue (Pride Mountain and Hartselle) in relation to the overall filling of the Black Warrior basin; 4) further constrain the relationship between the Bangor Limestone ramp and the Floyd/Neal shale; and 5) develop a sequence stratigraphic framework in terms of transgressive-regressive cycles, following methodology of Embry and Johannessen (1992).

# CHAPTER TWO
# REGIONAL FRAMEWORK

## *Tectonics and Structure*

The late Paleozoic Black Warrior basin is located within the structural recess of the Appalachian-Ouachita thrust belts in northern Alabama and Mississippi (Fig. 2.1). The cratonward-concave curve of the thrust belts mimics the shape of the margin of the Laurentian crust. A northeast-striking latest Precambrian rift segment and a northwest-striking Early Cambrian transform fault bound the Alabama promontory (Thomas, 1991).

The triangular-shaped Black Warrior basin subsided as a result of loading by the Ouachita accretionary prism on the southwest (beginning ~338 Ma). The southeastern part of the basin was later truncated and folded by the northeast-trending Appalachian thrust belt beginning in Early Pennsylvanian time (~313 Ma) (Whiting and Thomas, 1994). Subsidence rates are interpreted to have increased from 1.10-1.22 in/1000 years during Mississippian time to 11.38-12.0 in/1000 years during Pennsylvanian time (Hines, 1988). The deepest part of the basin is in a recess, concave to the north, in eastern Mississippi, adjacent to the Ouachita thrust belt (Thomas, 1988). The basin is 230 miles wide (northwest to southeast) and 188 miles long (northeast to southwest), resulting in an area of approximately 23,000 square miles (Ryder, 1994).

Several prominent structural features affected sediment dispersal during Mississippian time. The Black Warrior basin fill was deposited in a southwest-dipping, homoclinal passive-margin succession (paleoslope dip < 2 degrees) that extends from the distal (craton) margin of the basin to the proximal Appalachian-Ouachita thrust belts (Thomas, 1988). Sedimentation in northeastern Alabama occurred on the East Warrior platform, a broad, stable shelf in the northeastern part (craton side) of the basin. The southwestern edge of the platform extends from Franklin to Jefferson Counties, Alabama, and dips off into the Black Warrior basin to the southwest (Thomas, 1972a; Beavers and Boone, 1976).

The most important internal structure that briefly affected sediment dispersal in the basin during Late Mississippian (Chesterian) time was the Lowndes-Pickens fault block. The Lowndes-Pickens block, defined by Higginbotham (1986), is described as where the stratigraphic section (Pride Mountain Formation and Hartselle Sandstone) persistently thins to the south. The study concluded that thickness variations in the basin were a result of the differential upward movement of this synsedimentary fault block and possibly, to a lesser extent, sedimentation rates. The movement was interpreted to have been caused by reactivation of Precambrian basement faults during the Ouachita-Appalachian collisions. The northeast-striking boundary of the rectangular block closely parallels late Precambrian rift segments, and the northwest-striking boundary parallels northwest-striking transform faults (Higginbotham, 1986).

Normal faults, downthrown to the southwest, parallel the northwest-trending Ouachita orogenic belt and are common throughout the basin (Thomas, 1988). Faults cutting through the Upper Mississippian and Lower Pennsylvanian strata are interpreted as post-depositional (Thomas, 1988; Pashin, 1993). Mesozoic and Cenozoic strata unconformably overlie the faults, indicating no post-Paleozoic movement. The entire basin was later tilted to the southwest as a result of structural evolution of the Gulf Coastal Plain (Thomas, 1988).

### *Facies Relationships*

The Black Warrior basin is filled by a Late Mississippian (Late Meramecian to Chesterian) to Early Pennsylvanian southwest-thickening, synorogenic clastic wedge, overlying an Early Cambrian to Mississippian passive-margin succession capped by the Mississippian Fort Payne Chert and Tuscumbia Limestone (Osagean to Meramecian). The Mississippian part of the clastic succession has a maximum thickness of 1,600 feet (Thomas, 1988). These rocks are exposed in northern Alabama (Colbert County) and are buried at depths greater than 6,000 feet in west-central Alabama (Pickens County). The Mississippian part of the clastic wedge can be divided into three tongues. From oldest to youngest they are: the Pride Mountain Formation, Hartselle Sandstone, and equivalent lower Floyd Shale (lower tongue); the upper Floyd Shale and lower Parkwood Formation (middle tongue); and the upper Parkwood (upper tongue) (Fig. 2.2). The Mississippian clastic facies pinch out northeastward between southwest-thinning carbonate tongues (Fig. 2.2) (Thomas, 1972a).

The Tuscumbia Limestone and Fort Payne Chert were the last sediments deposited on the passive margin before active-margin clastic sedimentation began (Fig. 2.2) (Thomas, 1972a). The lower tongue of the clastic wedge contains a succession of four quartzose sandstones, mudstone, and limestone. The Pride Mountain Formation contains three sandstones (Lewis=Mynot, “Middle”=Southward Spring, and Evans=Tanyard Branch sandstones, in ascending order, informal drilling nomenclature) (Welch, 1957; Thomas, 1972a). The Hartselle Sandstone, the fourth sandstone upward from the Tuscumbia Limestone, conformably overlies the Pride Mountain Formation in the northeastern part of the basin. In the eastern part of the basin, the Pride Mountain Formation thins southward from more than 350 feet in Mississippi and Alabama to less than 100 feet on the Lowndes-Pickens block (Fig. 2.3) (Higginbotham, 1986). In the western part of the basin, beyond the northwestern edge of the block, the Pride Mountain thins slightly from north to south. The Lewis sandstone interval extends across the block and is the only persistent Pride Mountain sandstone unit on top of the block (Higginbotham, 1986). The Middle and Evans Pride Mountain sandstones and Hartselle Sandstone pinch out against the northeastern and northwestern boundaries of the block (Fig. 2.4) (Higginbotham, 1986). The Pride Mountain Formation and Hartselle Sandstone also pinch out farther to the northeast between southwest-thinning tongues of the Monteagle Limestone and lower Bangor Limestone. In the northeast, the Monteagle Limestone carbonate ramp lies directly on top of the Tuscumbia Limestone in northeastern Alabama (Handford, 1978; Meisfeldt, 1985).

The Bangor Limestone can be divided into three parts: the lower Bangor ramp, the Millerella limestone tongue, and the upper Bangor (Fig. 2.2). The lower Bangor Limestone (base of Bangor to Millerella limestone) is a regionally extensive carbonate ramp, the base of which overlies the Hartselle Sandstone and the Pride Mountain Formation. The Bangor ramp carbonates thin southwestward from more than 500 feet in Marion County, Alabama, to less than 100 feet in east-central Mississippi where it passes into the Floyd (Neal) Shale at the toe of the ramp (Black Shale in Fig. 2.5) (Higginbotham, 1986; Mars and Thomas, 1999). Lying above the lower Bangor Limestone ramp is the middle tongue of the Mississippian part of the clastic wedge (Parkwood Formation and upper Floyd Shale). The Parkwood Formation is divided into the “upper” and “lower” Parkwood, which are separated by the Millerella limestone tongue of the Bangor Limestone (Meisfeldt, 1985; Thomas, 1988). The Millerella limestone is a very persistent, but thin, limestone. The Millerella is used as a correlation marker in the western part of the basin but cannot be traced within the main body of the Bangor to the northeast. The Millerella limestone is underlain by the lower Parkwood and equivalent lower Bangor ramp, and the Millerella is overlain by the upper Parkwood and equivalent upper Bangor. The Parkwood Formation and Bangor Limestone are overlain by the Pennsylvanian Pottsville Formation (Thomas, 1988).

The Paleozoic rocks of the basin are overlain by Mesozoic and Cenozoic coastal plain sediments of the Mississippi embayment (Thomas, 1972a; Bearden and Mancini, 1985). As much as 11,500 feet of sediment has been eroded from the overlying Pennsylvanian, Mesozoic, and Cenozoic cover has been removed by erosion in Alabama, which suggests that Mississippian strata reached a maximum burial depth of 18,000 feet (Hines, 1988; Thomas, 1988).

### *Revision of Nomenclature*

Stratigraphic nomenclature of the Black Warrior basin has been evolving since the 1880's in an effort to provide additional detail and clarification of the stratigraphic succession. Figure 2.6 shows the major stratigraphic revisions published in the past 80 years. The stratigraphic nomenclature was developed primarily on the basis of stratigraphic relationships interpreted from outcrops in northern Alabama. This study finds that the current subdivisions are not suitable for the subsurface stratigraphy. The nomenclature revisions proposed by this study, were derived from the cross sections (Plate 1) and are presented at this point in the paper in order to reduce confusion in the following chapters.

Currently, the Pride Mountain Formation and lower Floyd Shale are divided by an arbitrary cutoff drawn stratigraphically downward from the southwest limit of the Hartselle Sandstone (Fig. 2.6, columns 3 and 4). There is no facies change across the arbitrary cutoff between the Pride Mountain and Floyd Shale. Sandstones, which are continuous with the Pride Mountain Formation sandstones, extend across the arbitrary boundary. In the southwestern part of the basin, the clastic succession between the top of the Tuscumbia Limestone and the base of the Parkwood Formation is assigned to the Floyd Shale (Butts, 1926; Thomas, 1972a). The Parkwood Formation is defined as the sandstone and shale succession lying above a shale-dominated succession, the Floyd Shale. The contact between the Floyd and Parkwood is placed at the base of the lowermost sandstone in the Parkwood (Thomas, 1972a). Because the Parkwood sandstones prograde northeastward, the contact is diachronous (Thomas, 1972a; Mars, 1995; Mars and Thomas, 1999). Although the Floyd Shale is defined as a shale-dominated succession, sandstone units (Lewis and Evans) extend from the Pride

Mountain Formation southwestward into the lower part of the Floyd Shale. The toe of the Bangor ramp (Neal shale) extends into, and is undifferentiated from the Floyd Shale, resulting in Floyd Shale lying above and below the lower Bangor ramp in the southwest part of the basin (e.g., Fig. 2.7A).

The Floyd Shale is somewhat of a "catch-all" term for the southwestern part of the basin. This study proposes a revision of the stratigraphic subdivisions to better reflect facies relationships in the subsurface (Fig. 2.6, column 5). The Bangor Limestone has a laterally persistent basal limestone bed that can be identified on gamma ray-density logs and used as an easily identifiable correlation marker in the subsurface. Beyond the southwest limit of the limestone marker, a black shale unit (Neal shale) is a lateral and temporal equivalent to the lower Bangor (Mars and Thomas, 1999). This study finds that the Neal and Bangor have a laterally gradational relationship. The base of the lowermost limestone bed of the Bangor Limestone and the equivalent Neal shale are used as a stratigraphic marker in the subsurface to separate the underlying Pride Mountain/ Hartselle clastic tongue from the middle clastic tongue (Floyd Shale and lower Parkwood Formation) above. In this study, the beds below the lowermost Bangor Limestone are placed in the Pride Mountain Formation, with the exception of the Hartselle Sandstone, which will retain its original formation boundaries and name (e.g. Thomas, 1972a). Genetically, the Hartselle Sandstone is part of the same sandstone/shale succession and depositional system as the Pride Mountain Formation (Thomas, 1988; Stapor and Cleaves, 1992); however, the name is widely recognized and is in current use. The contact between the top of the black shale (Neal) and the base of the Floyd Shale is identified on the basis of color change (where core or cuttings samples are available), from black to gray, a change in lithology (p. 72, this study), and distinctive resistivity well-log signatures (Fig. 2.7). The Floyd Shale will now be defined as the shale unit lying above the toe of the Bangor Limestone ramp (Neal shale) in the southwestern part of the basin. The Floyd is genetically part of the Parkwood Formation stratigraphic package because it is part of the overall coarsening- and shallowing-upward sequence that led to the deposition of the lower Parkwood prograding deltaic succession.

Well 373m (Fig. 2.7) is the type section for the contact between the Floyd and Neal shale, as well as for the contact at the base of the Bangor which separates the Pride Mountain/Hartselle clastic tongue from the Floyd/lower Parkwood tongue. For example, in the existing stratigraphic subdivisions, the beds between the dashed line (base of Parkwood) and green line (top of Tuscumbia) in Figure 2.7A are all assigned to the Floyd Shale in the area southwest of the pinch out of the Hartselle Sandstone. Using the new subdivisions (Fig. 2.7B), the column is divided into the Floyd Shale, Bangor Limestone (Neal shale), and Pride Mountain Formation on the basis of characteristic gamma-ray, density and resistivity well-log signatures.

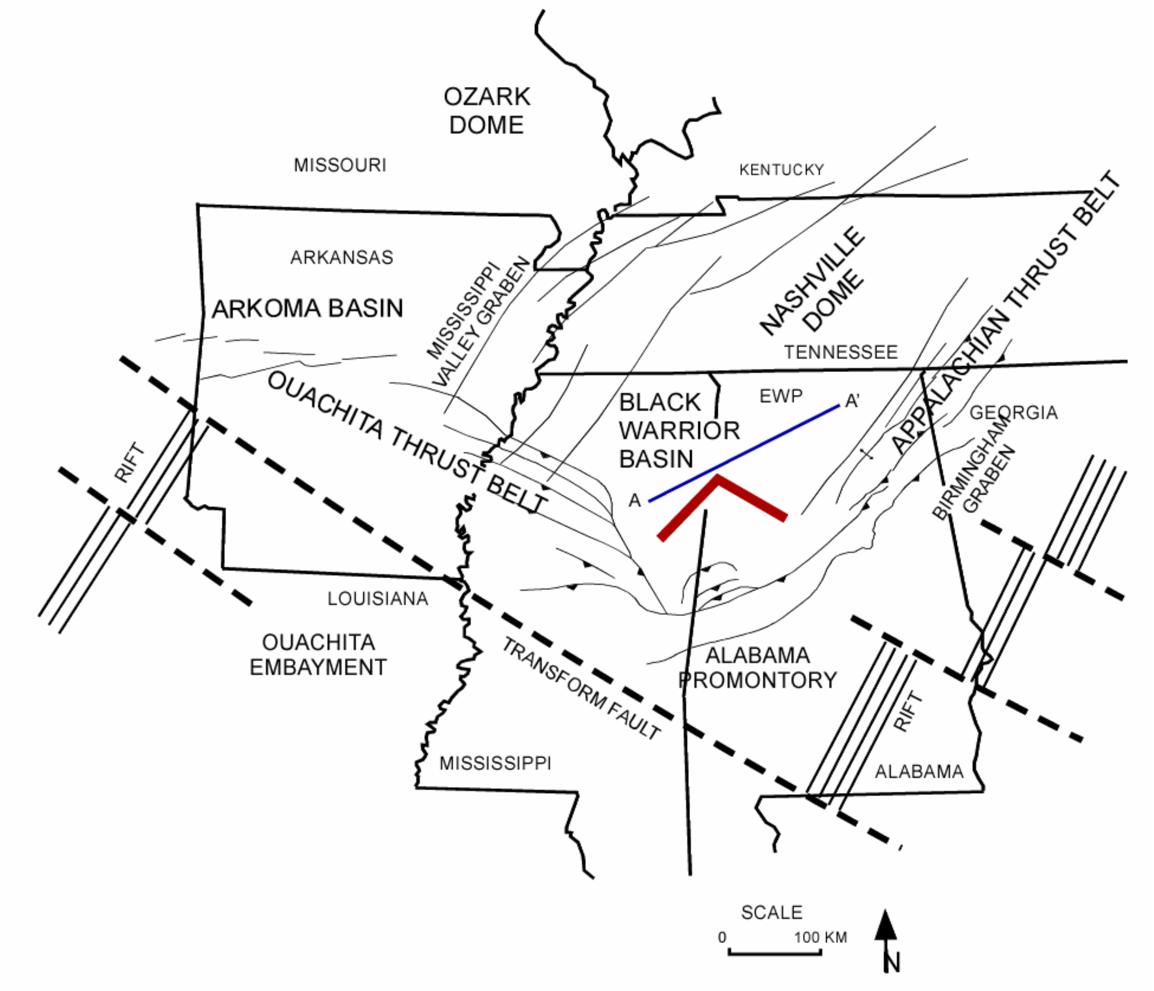

Figure 2.1: Location and structure of the Black Warrior basin. Approximate boundary of the Lowndes-Pickens block is in red. EWP=East Warrior platform. Modified from Thomas (1988, 1995)

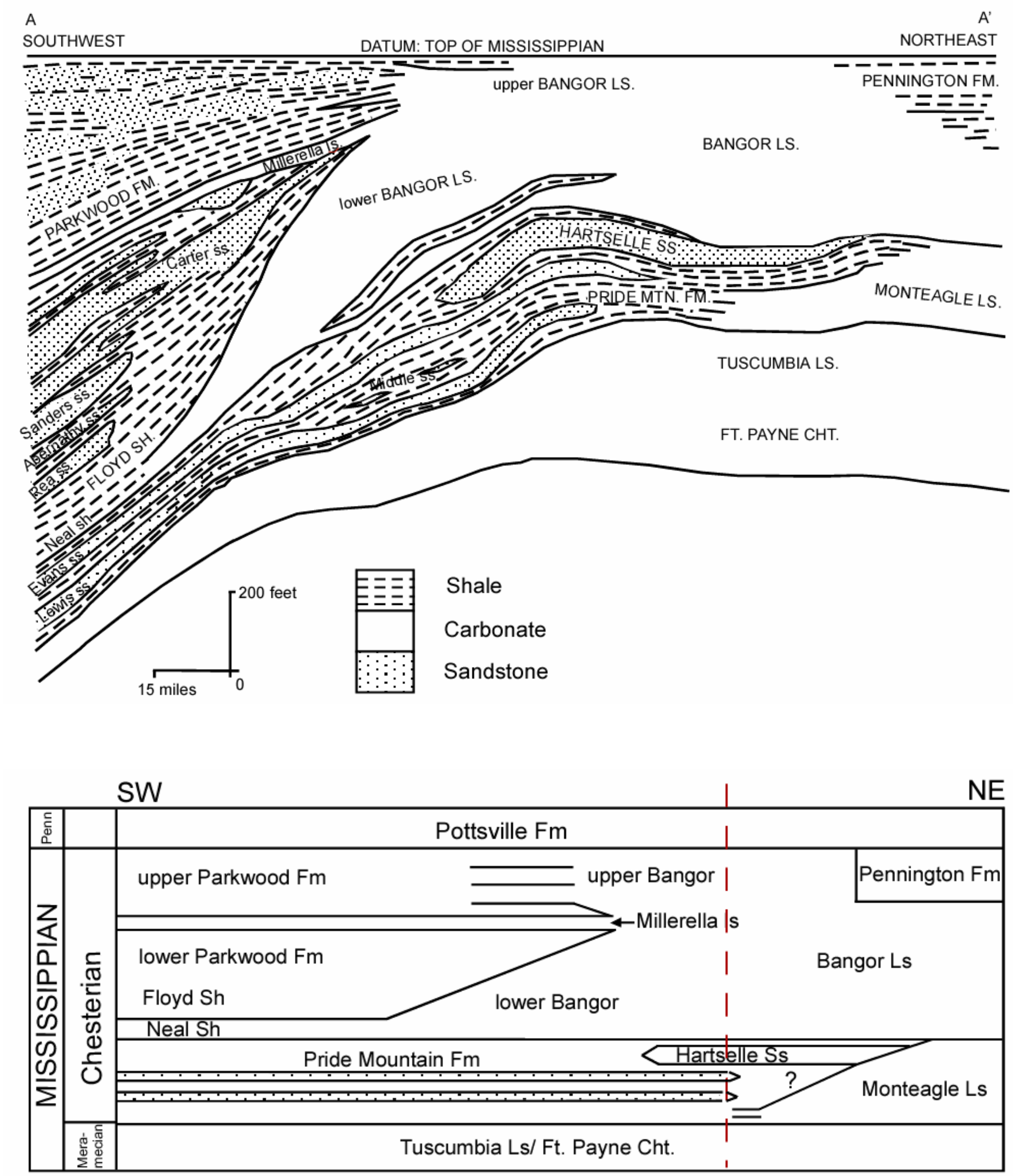

Figure 2.2: **Top**: Subsurface stratigraphy of the Upper Mississippian (Chesterian) rocks in northern Alabama. Modified from Hines and Thomas (1984).
**Bottom**: Schematic diagram of the Upper Mississippian rocks based on proportional thickness, but not to scale. This study encompasses the area southwestward of the red dashed line (above).

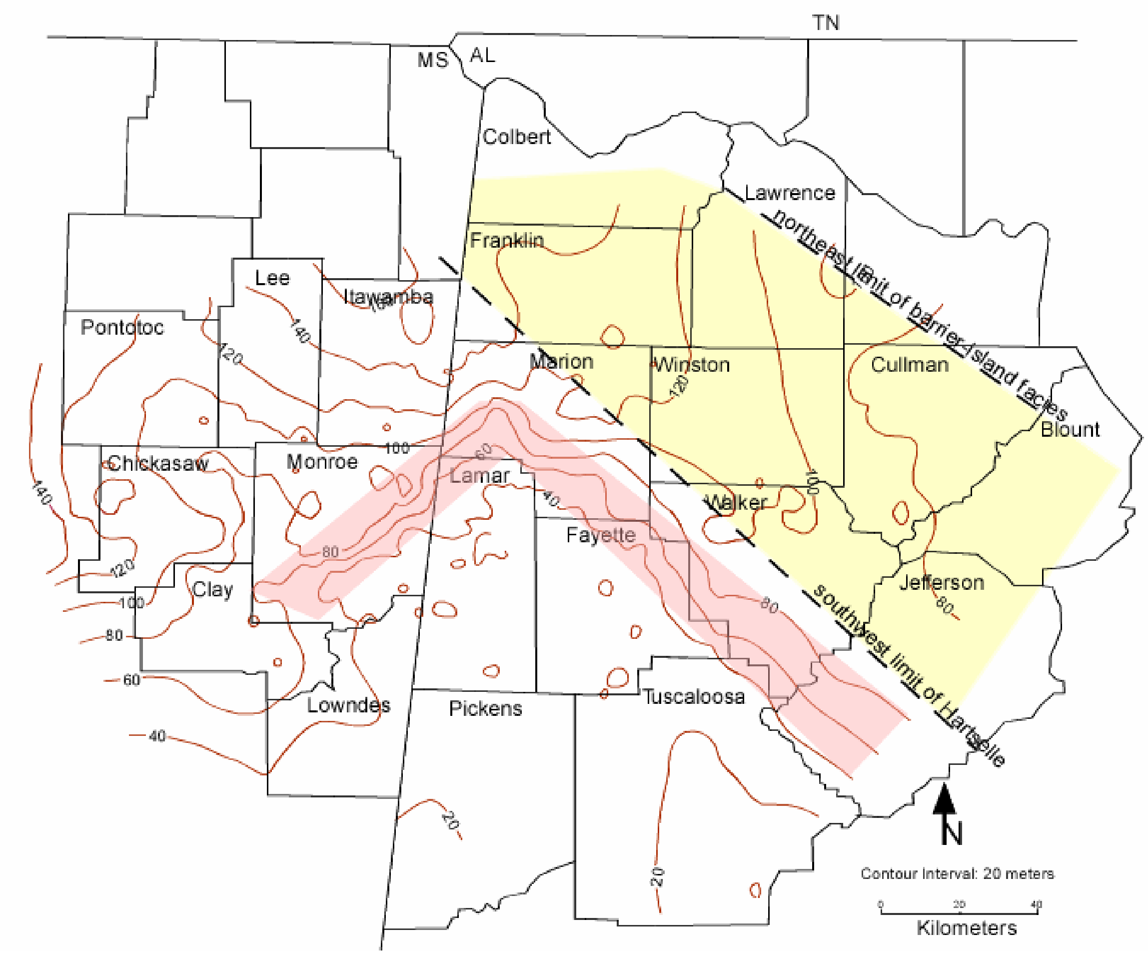

Figure 2.3: Isopach map of the Pride Mountain/Hartselle interval showing thinning to the south onto the Lowndes-Pickens block (modified unpublished maps by Thomas, Whiting, and Mars, 1995). Gradient of the block is shaded in pink. Extent of the Hartselle Sandstone is shaded in yellow.

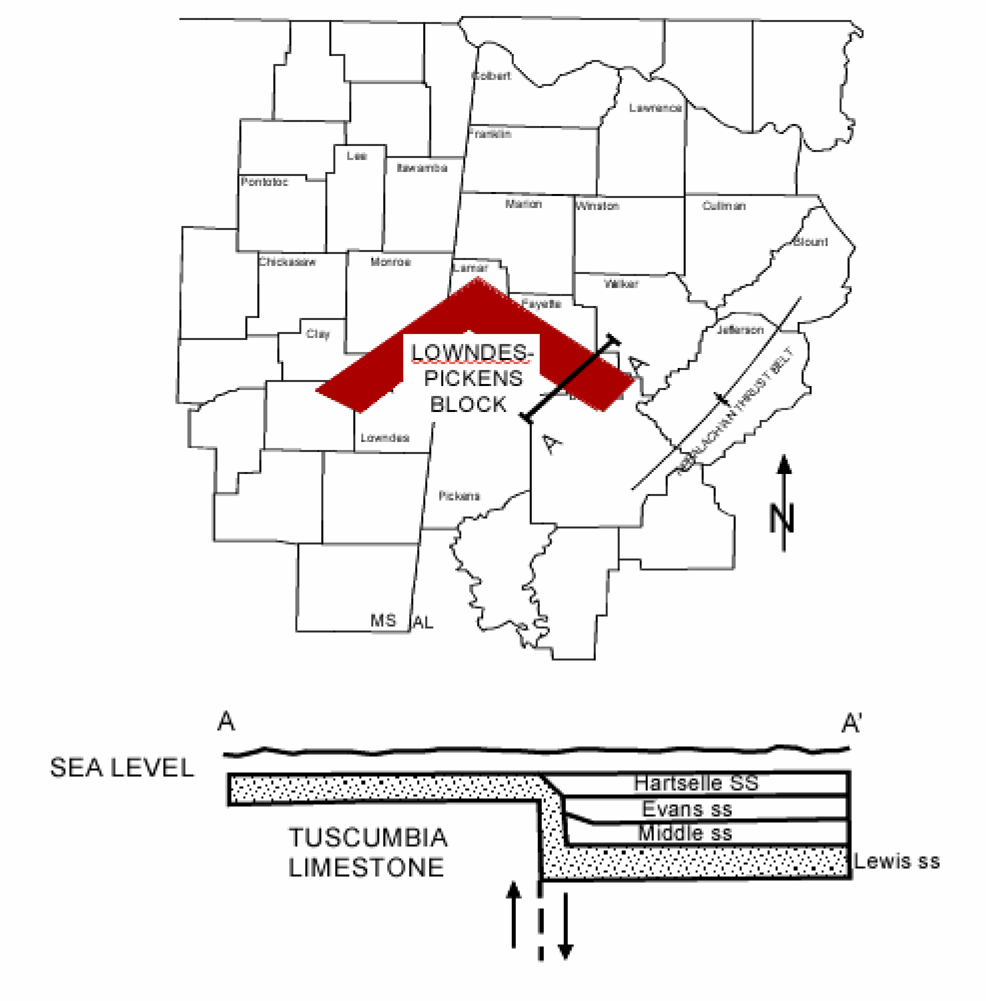

Figure 2.4: Cartoon illustrating the relationship between the Lowndes-Pickens block and the Pride Mountain/Hartselle interval. Gradient of the block in red. Cross section A not to scale. Modified from Higginbotham (1986).

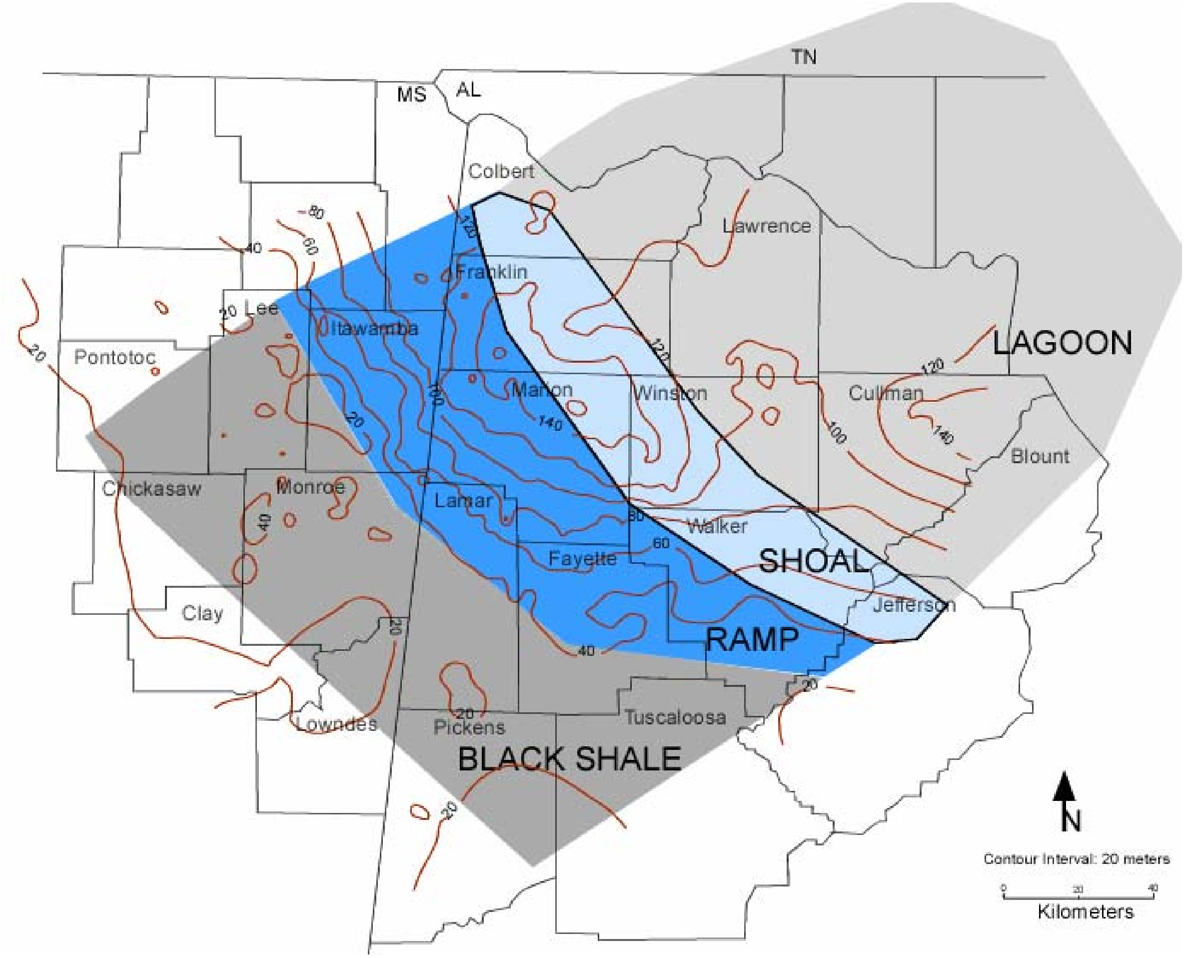

Figure 2.5: Isopach map of the Bangor Limestone ramp sediments thinning to the southwest (unpublished map by Thomas, Whiting, and Mars, 1995). Map also shows approximate extent of lagoon, shoal, ramp, and black shale facies. Thickness contours are in red.

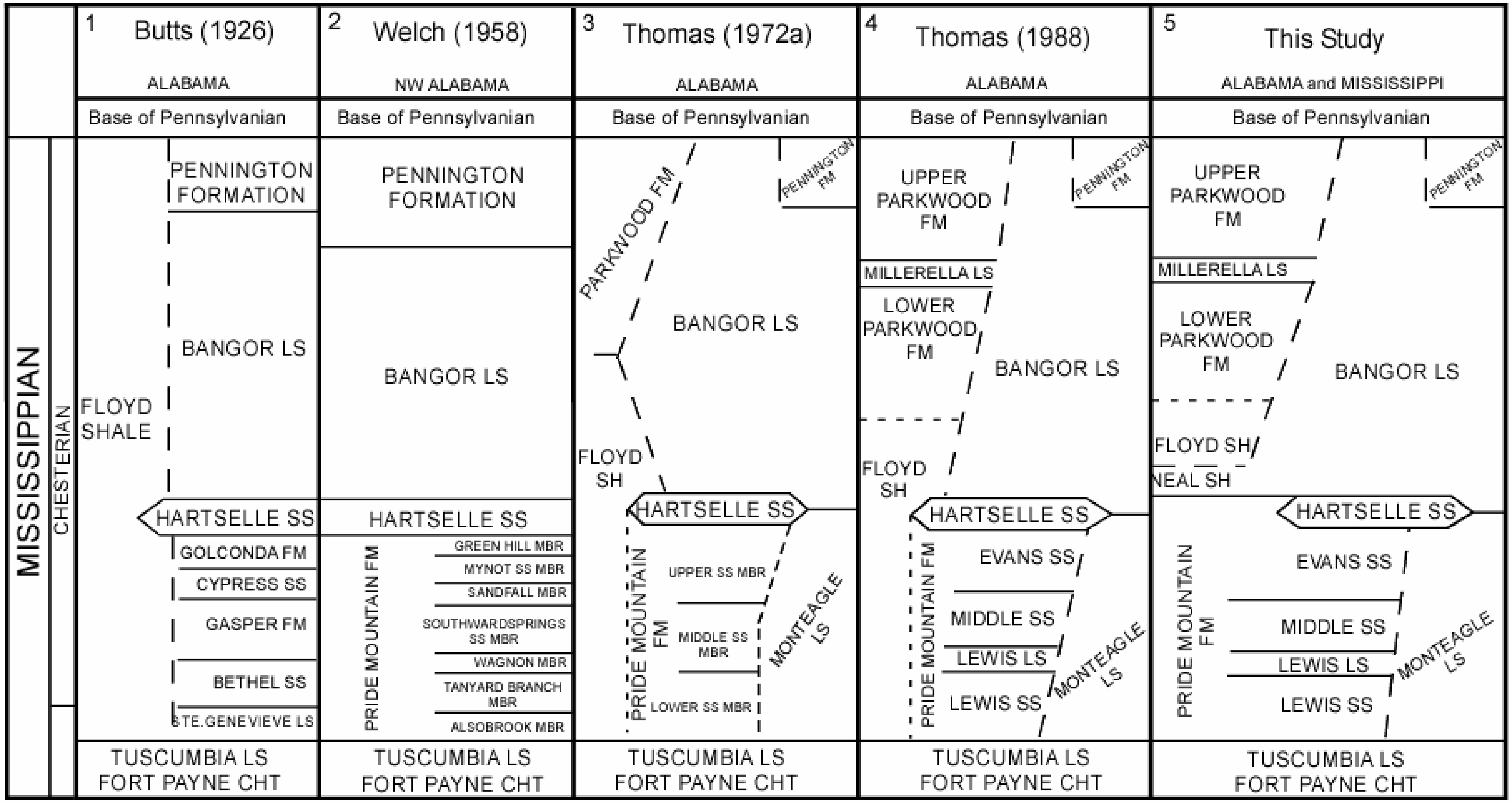

Figure 2.6: Evolution of the Mississippian stratigraphic subdivisions over the past 80 years. Dashed lines indicate unit boundaries. Dotted lines indicate arbitrary cutoffs between units.

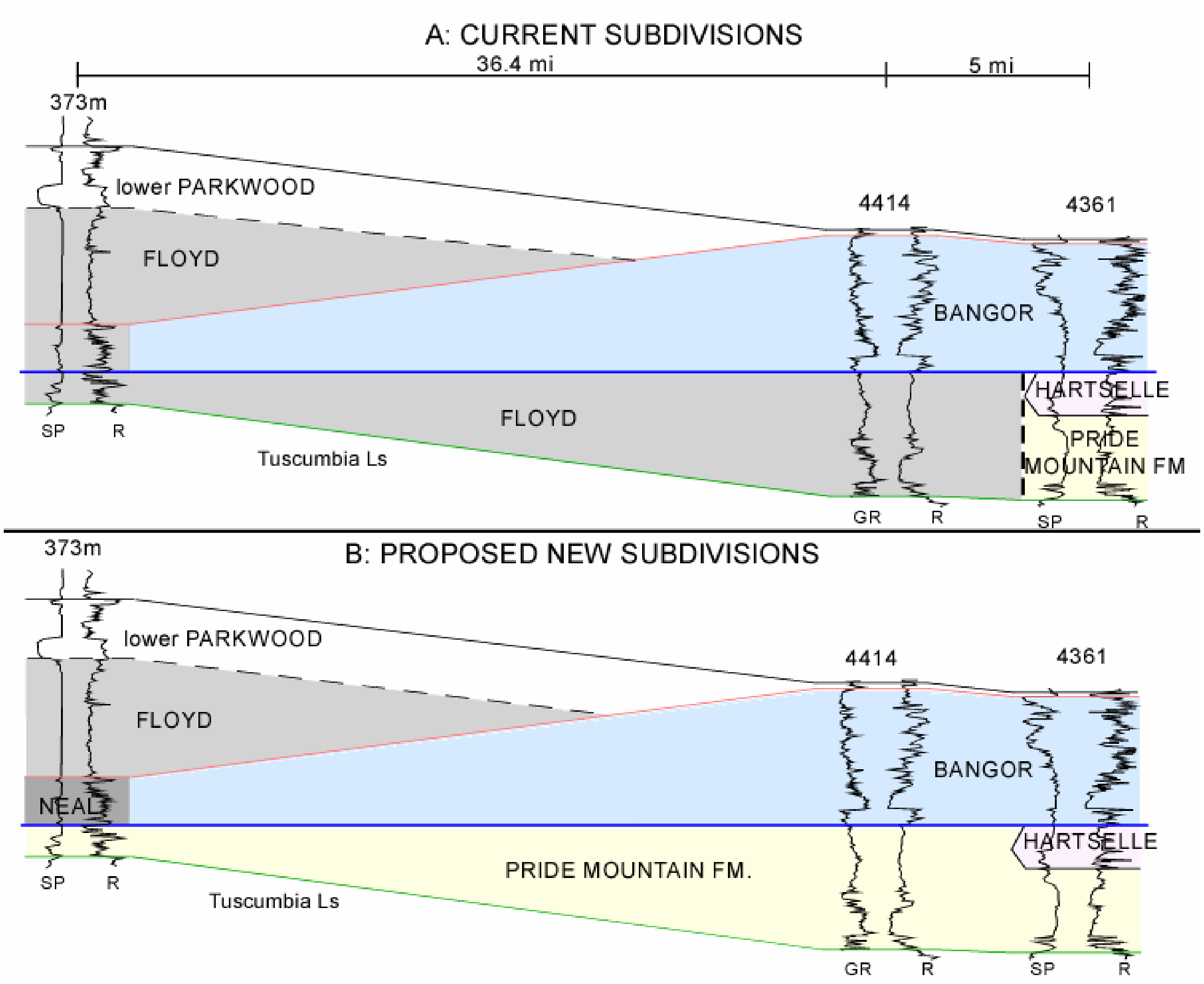

Figure 2.7: Example of current (A) (column 4, Fig. 2.6) and proposed (B) subsurface stratigraphic subdivisions.

# CHAPTER THREE
# LITERATURE REVIEW

## *Facies and Depositional Environments*

### Carbonates and associated facies

The Mississippian part of the Black Warrior basin fill is a clastic wedge composed of three clastic tongues (Pride Mountain and Hartselle, Floyd and lower Parkwood, and upper Parkwood), which pinch out into three carbonate units (Monteagle, lower Bangor Limestone, and upper Bangor Limestone) to the northeast. The oldest part of the basin fill rests on the Tuscumbia Limestone, which was the last sediment deposited as part of a passive-margin sequence (Thomas, 1972a). The Tuscumbia Limestone is an interbedded micrite, bioclastic (echinoderm-brachiopod) limestone, and chert, which was deposited in a shallow-marine shelf environment (Thomas, 1972a). It has a maximum thickness of approximately 200 feet and overlies the Fort Payne Chert (Thomas, 1972b). The Tuscumbia Limestone and Fort Payne Chert cannot be differentiated in the subsurface in the deeper part of the basin and are mapped as a single unit (Thomas, 1972b). These units form a carbonate platform that thins uniformly to the southwest, which resulted in a southwest-dipping paleoslope during Mississippian time (Pashin and Rindsberg, 1993).

The Monteagle Limestone is a shallow-water carbonate unit located in northeastern Alabama and southern Tennessee. The Monteagle thins southwestward from a maximum thickness of 250 feet and pinches out southwestward beyond Marshall County in northeastern Alabama (Thomas, 1972a). Handford (1978) identified six Monteagle lithofacies from 18 outcrop sections and one core in northeastern Alabama and southern Tennessee. The predominant lithology in the Monteagle is a fossiliferous packstone-grainstone facies which was deposited in subtidal environments on a shallow-marine shelf. Oolitic packstone and grainstone facies thin southwestward (>50) and are interpreted as tidal-bar deposits (Handford, 1978). Paleocurrent measurements from the oolitic limestone exhibit a dominantly bimodal northeast-southwest orientation interpreted to have formed through ebb and flood tidal currents (Handford, 1978). Dolomitic mudstone, pelletal wackestone, paleocaliche, and clay-shale facies typically directly overlie oolitic-bar facies and were deposited in peritidal environments on the crests of the oolitic bars (Handford, 1978).

The Monteagle Limestone is comprised of stacked shoaling-upward cycles (Handford, 1978). A typical shoaling-upward cycle in the Monteagle begins with fossiliferous marine-shelf limestones, followed by oolitic tidal-bar deposits, capped by a dolomitic lime mudstone supratidal deposit (Handford, 1978). The Monteagle Limestone is interpreted to reflect deposition on a carbonate ramp because of (1) the regional distribution of the oolitic deposits, which grade into deeper water packstone deposits and (2 ) the aggradational-facies stacking pattern (Stapor and Cleaves, 1992).

A study by Driese et al. (1994) suggested that a paleoweathering surface is present in the upper part of the Monteagle Limestone using data collected from 28 outcrops in northern Alabama and southern Tennessee. Petrographic evidence suggested for the surface includes micritization of allochems, clay/iron-filled root traces or burrows, micro-karst, and vadose silt. Grain dissolution, syntaxial sparry cement on echinoderm grains, and drusy to blocky, nonferroan calcite cement were suggested as evidence for meteoric diagenesis. The possible weathered surface was developed on a unit interpreted as a subtidal deposit (echinoderm-bryozoan packstone, similar to the subtidal deposits recognized by Handford (1978). The juxtaposition of facies suggests sea-level fall and subaereial exposure, which formed a regional disconformable surface. This surface, however, was recognized only in seven outcrop sections, and only two of these are in northern Alabama. It was not recognized in the study by Handford (1978). Thomas and Mack (1995) disagreed with the interpretation of the paleoweathering surface as a regional disconformable surface. They noted the surface is not preserved in a majority of the outcrops and, where present, it may not represent a consistent stratigraphic level. Thomas and Mack (1982) suggested that the surface in the upper Monteagle may have formed as a result of exposure on the crests of localized islands. Handford (1978), however, only identified bar deposits in oolitic facies, not subtidal packstone facies.

The lower Bangor Limestone is interpreted to reflect deposition on a carbonate ramp that extends into central Alabama and Mississippi (Thomas, 1972a). Lithofacies, depositional environments, and facies-stacking patterns of the lower Bangor are similar to those identified in the Monteagle. An oolitic grainstone facies, interpreted as a shoal deposit, extends northwestward from Jefferson to Colbert County, Alabama, and has a maximum thickness of 150 feet (Fig. 2.5) (Thomas, 1972a). The shoal deposit represents a rimmed shelf, with an open-marine-shelf environment to the northeast. Depositional environments interpreted from lower Bangor facies include open-marine shelf southwest of the shoal in northern Alabama and shallow-marine, lagoonal, and peritidal deposits northeast of the shoal deposits in southern Tennessee (Thomas, 1972a; Bronner, 1988; Algeo and Rich, 1992). Southwest of the shoal deposit, the lower Bangor Limestone grades from oolitic grainstone and bioclastic packstone into finer grained, muddy limestone (wackestone and micrite) and black shale at the toe of the ramp (Fig. 2.5) (Thomas, 1972a; Miesfeldt, 1985). The presence of more argillaceous limestone to the southwest indicates the transition to deeper, lower energy water resulting from subsidence of a shallow shelf (Miesfeldt, 1985; Mars and Thomas, 1999). A regionally extensive shale unit, approximately 20 feet thick, is recognized in cuttings and well logs close to the base of the Bangor (Miesfeldt, 1985). Cycles of limestone and siliciclastic mudstone have been noted in the lower Bangor and are interpreted to be a result of alternating delta progradation (shale) and periods of reduced clastic input (resulting in limestone deposition) (Miesfeldt, 1985). Individual limestone beds thin to the southwest, possibly because of siliciclastic influx that diluted carbonate production (Meisfeldt, 1985).

The Neal shale is an organic-rich, black shale interpreted to have been deposited under anoxic, sediment-starved conditions in the southwestern (deeper) part of the basin (Cleaves, 1983; Pashin, 1993). Oko (2006) investigated the mineralogical, geochemical, and petrophysical properties of the Floyd/Neal shale in order to evaluate its hydrocarbon and source-rock potential. The five samples selected for the analysis, however, were not taken from the organic-rich Neal shale, but rather were taken farther up the ramp in the Floyd Shale. The samples have a TOC>3.0% and are thermally mature, but Oko (2006) inferred that the succession lacks good confining units. Petroleum developers hoped that the Floyd/Neal shale was comparable to the Barnett Shale in the Fort Worth basin. The Barnett Shale is a thermally mature, 300-foot-thick, organic-rich (TOC between 3 and 13%) black shale (Montgomery et al., 2005). Although preliminary TOC measurements from the Floyd Shale are much lower than hoped for, higher TOC values may be discovered farther downdip from the Floyd in the Neal shale.

### Clastic facies

The Pride Mountain Formation is a succession of three quartzose sandstones (Lewis, “Middle”, and Evans, ascending order), mudstone, and minor amounts of interbedded limestone. Several studies (Moser and Thomas, 1967; Thomas, 1972a, 1972b; Pashin and Rindsberg, 1993) have collected abundant data on the Pride Mountain interval from outcrop descriptions in Colbert County, Alabama. The Lewis sandstone is a very fine- to medium-grained, cross-bedded quartzarenite which includes marine fossils and plant fossil fragments. It has a maximum thickness of 80 feet (Thomas, 1972a; Pashin and Rindsberg, 1993). The Middle sandstone is a very fine- to fine-grained, argillaceous sandstone containing abundant clay laminae. It has an average thickness of around 30 feet and is not a laterally extensive unit (Thomas, 1972a). The Evans sandstone is the uppermost sandstone in the Pride Mountain Formation. It is a very fine- to fine-grained, argillaceous sandstone and has a maximum thickness of 60 feet in outcrop (Thomas, 1972a). All three sandstones contain ripple laminae, crossbedding, bioturbation, localized channel-fill conglomerates at the base, evidence of marine reworking, and thin interbeds of sandy oolitic or bioclastic limestone (Thomas, 1972a, 1979). Shale units lying between the sandstone units typically contain abundant brachiopod and bryozoan fossils, indicating shallow-marine conditions (Thomas, 1989). The depositional environments in the Pride Mountain interval are interpreted as shallow marine (Thomas, 1972a; Cleaves and Bat, 1988; Pashin and Rindsberg, 1993).

The Hartselle Sandstone is a northwest-trending sandstone that has a maximum thickness of 150 feet in the northeastern part of the basin and pinches out to the southwest (Thomas, 1972a; Beavers and Boone, 1976). It is a quartzose, fine-grained, well-sorted sandstone which is calcareous in part. The unit is generally thick-bedded to massive with rare beds of sandy limestone (Thomas, 1979a). The Hartselle contains six lithofacies that can be placed into one of two larger lithofacies subdivisions: a clean, fine-grained, thick-bedded, cross-laminated facies and a fine-grained, thin-bedded, muddy facies (Thomas and Mack, 1982). Bedding structures include horizontal laminae, oscillation ripples, and polymodal cross beds. Tree-trunk fragments in sandstone, as well as root penetrations and plant-foliage fragments in mudstone are recognized in several outcrop localities (Thomas and Mack, 1982).

The provenance of the Pride Mountain Formation and Hartselle Sandstone is a debated subject. Thomas (1972a), Mack et al. (1981, 1983), Thomas and Mack (1982), and Higginbotham (1986) advocate an Ouachita orogenic source in the southwest. Depositional environments and sediment-dispersal patterns were interpreted from geophysical well logs and outcrop data, while sandstone petrography linked the lithic component of the sandstones to the orogenic belt to the southwest. Conversely, Cleaves (1983), Stapor and Cleaves (1992), Pashin and Rindsberg (1993), and Pashin and Ettensohn (1993) suggest a cratonic source with a northern provenance such as the Ozark dome or Illinois basin (Cleaves, 1983). Those studies primarily use sediment dispersal patterns interpreted from geophysical well logs and outcrop data, as well as sandstone petrography to support their interpretation for a non-orogenic source. Both groups cite roughly the same number of outcrop and well-log data points. Pashin (1993) also suggests that Pride Mountain and Hartselle sediments may have originally come from a cratonic source, but later switched to an orogenic source during Parkwood deposition. The interpretation of a switch in sources is based upon a change in sediment dispersal patterns, a southwest-dipping paleoslope, and a comparison to published information on the amount of time it would take for rising for mountains to gain enough relief to become active sources for sediment.

Those studies that interpret a cratonic source suggest that sediments prograded into the Black Warrior basin from the northwest (Cleaves, 1983; Stapor and Cleaves, 1992). Cleaves (1983) organized Lewis and Evans sandstone isopach data into “deltaic lobes” in northern Alabama and Mississippi using subsurface and outcrop data (Fig. 3.1). The study divided the Lewis delta into three to six highly constructive lobes and the Evans delta into five to eight cupsate, wave-dominated lobes. The distribution maps (Fig 3.1) show that the Lewis does not appear continuous and barely extends onto the Lowndes-Pickens block (Pickens Co., Alabama). The Evans delta only extends into Marion County, Alabama (Fig 3.1). Conversely, the Pride Mountain/Hartselle isopach map (Fig. 2.3, this study) shows that sandstone coverage is extensive throughout Alabama (discussed in Ch. 6).

A different hypothesis for the source of the basin’s clastic sediments was proposed by Driese et al. (1994). It suggests a northerly, unidentified, cratonic source for the Pride Mountain and Hartselle sandstones. Sediments were interpreted to have prograded from the northeast across the Monteagle Limestone based upon a proposed exposure surface (Driese et al., 1994). Driese et al. (1994) theorized that the sediments traveled across the ramp through incised valleys, created by fluvial processes, which were later destroyed by marine reworking. Handford (1978) suggested the Pride Mountain Formation and Monteagle were deposited contemporaneously; however, an interfingering relationship between the Pride Mountain clastic sediments and the Monteagle Limestone has yet to be recognized in outcrop. Thomas (personal communication) suggests that the Monteagle Limestone has a ramp geometry similar to that of the Bangor Limestone; and therefore, the Pride Mountain Formation and Hartselle Sandstone likely onlap the Monteagle ramp in the same fashion as the lower Parkwood Formation onlaps the lower Bangor ramp (Mars and Thomas, 1999).

The provenance and depositional environment of the Hartselle Sandstone is also debated. Thomas and Mack (1982) interpreted the Hartselle Sandstone to be a massive, northeast-facing, barrier-island complex. On the northeastern part of the thicker Hartselle, horizontally laminated sandstone and low-angle accretion deposits, resulting from swash and backwash, are interpreted as shoreline and beach facies. Farther to the northeast, sandstone containing sedimentary structures, such as oscillation ripples and ploymodal crossbeds, indicates a shallow-marine shelf environment northeast of the barrier facies (Thomas and Mack, 1982). Back-barrier deposits are recognized along the southwestern margin of the Hartselle. Tree-trunk fragments in sandstone, as well as root penetrations and plant-foliage fragments in mudstone interbeds indicate a subaerial barrier flat along the southwest side of the Hartselle barrier island. The cleaner facies are associated with beach, barrier-bar, and upper-shoreface facies; whereas, muddier facies were deposited in subtidal and lower shoreface environments (Thomas and Mack, 1982).

Alternatively, Driese et al. (1994, 1995) interpreted the Hartselle as a deltaic deposit. Hummocky stratified beds and graded storm deposits were identified in outcrop in north-central Alabama, which are interpreted to have been deposited in a lower shoreface to shelf environment proximal to the delta front. That study correlated 17 outcrop sections (average spacing 9.5 miles) in northwestern Alabama and interpreted three wave-dominated parasequences, downlapping onto flooding surfaces, which exhibit a southwestward progradation direction (Driese et al., 1995). This interpretation, however, would be more reliable if the data density were greater. The published cross section (Driese et al., 1995) interprets the Hartselle as backsteping onto the Monteagle ramp. This geometry implies deeper water to the southwest where tree fossils have previously been identified, which is problematic. The interpretation is not consistent with the exposure surface, interpreted from tree and plant fragments, on the Hartselle.

Pashin (1993) suggested that the Hartselle was a destructive-delta strandplain formed from transgressive reworking of the Evans delta system, which implies that the Evans and Hartselle are the same sandstone or that the Evans is the source of the Hartselle. This is unlikely because the Evans and the Hartselle are separated by shale and the Evans sandstone is much more extensive to the southwest of the basin.

### ***Sequence Stratigraphy***

Sequence stratigraphy has recently been applied to the Late Mississippian rocks in the Black Warrior foreland basin with some success (e.g., Pashin, 1994; Mars and Thomas, 1999). Clastic-wedge successions in foreland basins commonly are cyclic in nature, resulting from varying rates of tectonic subsidence, eustacy, and sedimentation rates (Mars and Thomas, 1999). Sequence stratigraphy provides a temporal framework for the filling of the basin (Mars and Thomas, 1999; Catuneanu, 2006).

Very few studies have focused on the sequence stratigraphy and cyclicity of the Pride Mountain/Hartselle/Bangor interval, and interpretations have been made largely from outcrop data (e.g., Stapor and Cleaves, 1992; Pashin, 1994). Pashin (1994) studied the frequency, composition, and stacking patterns of the strata between the top of the Tuscumbia and the base of the Pottsville. He identified 15 to 16 transgressive-regressive (third-order) cycles. Twelve cycles were recognized from the top of the Tuscumbia Limestone to the top of the Millerella limestone. Three of those cycles are present in the Pride Mountain/ Hartselle interval. Each Pride Mountain/Hartselle cycle typically includes four members: a basal shale, sandstone, an upper shale, and a limestone. Bangor Limestone cycles were not described. Pashin (1994) used the Harland et al. (1989) age estimation of 17 million years for the Chester to infer that the Pride Mountain/Hartselle cycles had an average duration of 1.1 million years.

Traditional sequence-stratigraphic divisions (system tracts) were applied to the Pride Mountain and Hartselle interval by Stapor and Cleaves (1992). The suggested disconformable surface at the top of the Monteagle Limestone was interpreted as a Vail third-order sequence boundary (Driese et al., 1994). The Monteagle Limestone carbonate ramp was interpreted to represent a highstand systems tract (Stapor and Cleaves, 1992).

The Pride Mountain Formation was interpreted as a lowstand wedge (lowstand systems tract) which prograded southwestward across the Monteagle ramp as sea level dropped (Stapor and Cleaves, 1992; Driese et al., 1994). The lowstand wedge is composed of multiple coarsening-upward limestone, shale, and sandstone deposits, which are interpreted to have been associated with southward prograding deltas (Stapor and Cleaves, 1992). The Hartselle Sandstone in northeastern Alabama and Tennessee was divided into three coarsening-upward transgressive or retrogradational parasequences based on correlations of widely spaced outcrop sections (Driese et al., 1995). The Hartselle Sandstone, in contrast, was interpreted to represent a transgressive systems tract because of the stacking pattern, facies relationships, and because the unit was interpreted to back step onto the Monteagle Limestone at the basin margin in extreme northeastern Alabama (Stapor and Cleaves, 1993; Driese et al., 1994; Driese et al., 1995). Thomas and Mack (1982), however, have identified an exposure surface, based upon plant roots and coaly beds, at the top of the Hartselle in north-central Alabama, which is not consistent with deposition in a transgressive systems tract. Interpretations made in northeastern Alabama and Tennessee are not consistent with what is seen in the Hartselle farther southwest.

Several studies (e.g., Bonner, 1988; Algeo and Rich, 1992; Stapor and North, 1999) have looked at the Bangor Limestone in terms of shallowing-upward cycles in outcrop. Unfortunately, each study has interpreted a different number of cycles for the Bangor. Bronner (1988) identified eight large-scale cycles composed of subtidal facies, capped by peritidal deposits in northern Alabama. The cycles have a calculated duration of 250,000 years each. Each of the eight cycles can be subdivided into two small-scale cycles composed only of subtidal deposits. The small-scale cycles have an approximate duration of 125,000 years each. The large-scale cycles were attributed to sea-level change and tectonic subsidence; whereas the small-scale cycles were interpreted to reflect Milankovitch cycles (Bonner, 1988). Algeo and Rich (1992) studied the cyclicity on the upper ramp of the Bangor Limestone in south-central Tennessee and northwest Georgia. Shallowing-upward cycles begin with open-marine facies, followed by a transgressive oolitic grainstone/packstone unit that grades upwards into restricted-marine facies (lagoonal and tidal flat). They concluded that the Bangor Limestone records one major marine transgression (likely caused by subsidence), accompanied by several minor transgressions (controlled by sea-level fluctuations). Mars and Thomas (1999) concluded that well logs of the oolitic shoal deposits in the Bangor Limestone show aggradational vertical stacking with evidence of lateral expansion of the upper ramp. Mars and Thomas (1999) also showed that individual beds can be traced laterally to the southwest. Not only does the entire limestone unit thin to the southwest, but the individual cycles within the unit also thin. The Millerella limestone is interpreted as a thin aggradational unit which represents transgression and a break in clastic sedimentation (Pashin, 1994).

A condensed interval is identified within the lowermost part of the Bangor Limestone extending from southern Tennessee into north-central Alabama (Stapor and North, 1999). The condensed interval was recognized in five outcrop sections throughout northern Alabama. It is described as an argillaceous wacke-packstone layer with increased conodont content compared to the rest of the Bangor. This unit divides the underlying transgressive systems tract, including the Hartselle Sandstone and lowermost 100 feet of the Bangor, from the overlying Bangor highstand systems tract (Stapor and North, 1999). The study also identified an average of nine shallowing-upward cycles, within the entire Bangor interval, composed of facies grading from micrite to grainstone, and capped by a flooding surface.

The lower Parkwood Formation is interpreted to contain three Galloway genetic sequences (Mars and Thomas, 1999). Parasequences are coarsening- and shallowing-upward successions bounded by marine-flooding surfaces; offlap and downlap patterns are recognized in cross section. The uppermost sequence may represent a time of no tectonic activity and sea-level transgression, which resulted in the deposition of the Millerella Limestone across the basin (Mars and Thomas, 1999). This study does not divide the lower Parkwood into T-R cycles, but does interpret it as a lowstand systems tract because of the progradational sandstone units which fill the basin.

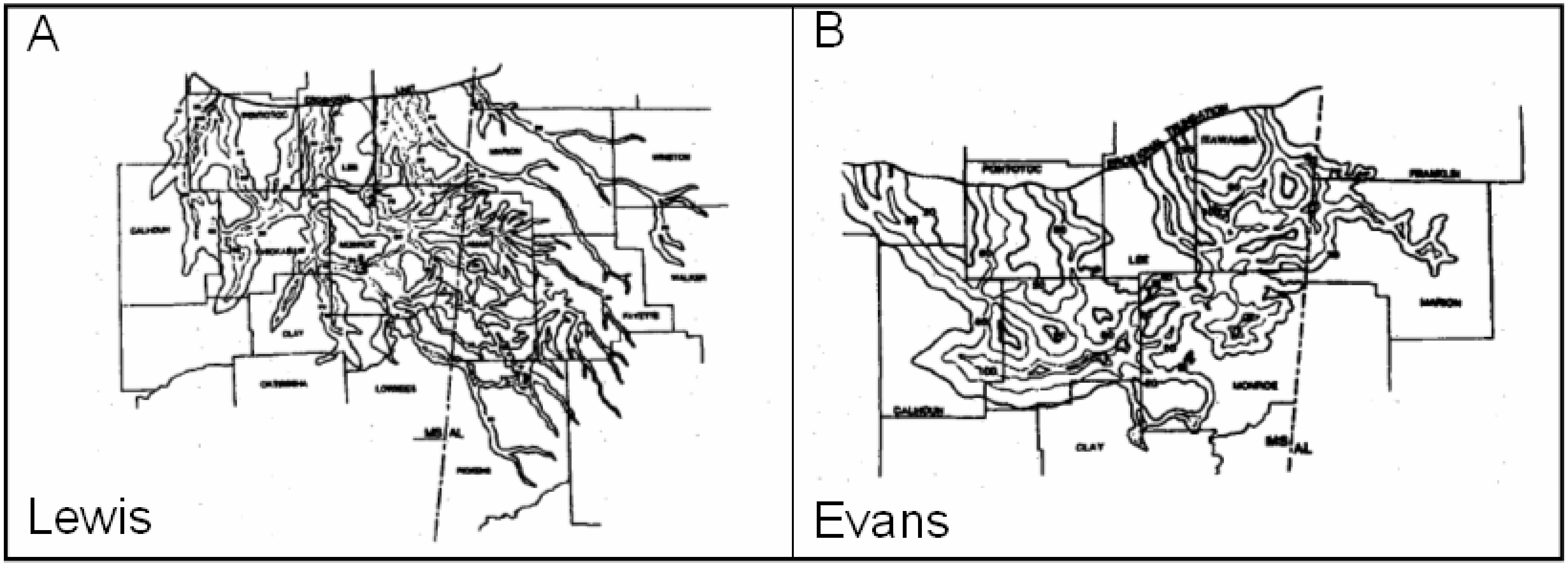

Figure 3.1: Cleaves' (1983) interpretation of Lewis (A) and Evans (B) sandstones as deltaic lobes based on subsurface mapping. Note the Lewis does not appear continuous on the Lowndes-Pickens block (Pickens County, Alabama) and the Evans does not extend into Alabama. Neither sandstone extends southwestward into central Mississippi. These patterns are in contrast to maps by this study (Figures 6.3 and 6.9)

# CHAPTER FOUR
# BASIN EVOLUTION

## *Foreland Basin Evolution*

Collisions at convergent plate margins result in lithospheric flexural downwarping and the creation of a foreland basin in front of the advancing orogen (Beaumont, 1981). The shape and evolution of a foreland basin are controlled by the buildup rate of the thrust-wedge tectonic load along the orogenic front and the flexural behavior of the underlying lithosphere (Flemings and Jordan, 1990). A peripheral bulge is formed as a result of flexural upwarping and migration of the lithosphere in advance of the thrust front (Flemings and Jordan, 1990).

Most studies infer a dominant sediment supply from the orogen; however, several studies have questioned the traditional orogenic source and have suggested erosion of the peripheral bulge as an alternative sediment source (e.g. Beaumont et al., 1988; Crampton and Allen, 1995; Bruhn and Steel, 2003). A peripheral bulge migrates cratonward as the tectonic load advances, and migrates back toward the thrust front as activity gradually slows and stops. Subaerial exposure of the peripheral bulge may result in the erosion of cratonic rocks and deposition in the adjacent basin. Narrowing and deepening of the basin adjacent to the thrust belt associated with bulge migration back towards the orogen, creates increased accommodation space, proximal to the orogenic belt, for sediments eroded from the orogenic belt (Flemings and Jordan, 1990).

Ettensohn and Pashin (1993) developed a flexural model for the Black Warrior basin that relates the stratigraphic succession in the basin to the different phases of Ouachita tectonism (Fig. 4.1). A possible localized Valmeyer-Chester unconformity was recognized at the top of the Tuscumbia Limestone and was suggested to have developed as a result of Ouachita bulge movement (Pashin and Rindsberg, 1992; Pashin and

Ettensohn, 1993). The unconformity at the top of the Tuscumbia Limestone was identified on the basis of the overlying limestone facies variations in outcrop and hummocky (~ 5 ft.) relief exhibited a the top of the Tuscumbia. Oolitic limestone, with a sharp basal scour surface, filled potential topographic lows and graded calcarenite beds accumulated on topographic highs in order to smooth pre-Lewis topography (Pashin and Rindsberg, 1993). No exposure surface was recognized; therefore, the unconformity was suggested to be the result of submarine erosion of the upper Tuscumbia ramp (Pashin and Rindsberg, 1993). In the Ettensohn and Pashin (1993) model, the black Floyd Shale is shown stratigraphically below the Pride Mountain Formation and unrelated to Bangor deposition. The Pride Mountain, Hartselle, lower Bangor, Floyd, and lower Parkwood represent initiation of subsidence and uplift and cratonward migration of the peripheral bulge. According to their model, the Millerella limestone was deposited during isostatic equilibrium. They concluded that tectonics, rather than eustacy, was the primary control on large-scale sedimentary sequences in the Black Warrior basin.

The Black Warrior basin formed as a result of loading by the Ouachita thrust load during Mississippian time and the Appalachian thrust load during Pennsylvanian time. Whiting and Thomas (1994) and Thomas and Whiting (1995) developed a quantitative model and a subsidence profile for the Black Warrior basin. Variations in the rate of subsidence are related to the proximity of rift and transform segments and intracratonic fault systems along the rifted continental margin (Thomas and Whiting, 1995). The model shows that subsidence was relatively slow during Mississippian time (~ 1,600 ft. over 20 m.y.) and increased rapidly during Pennsylvanian time (~ 5,000 ft. over 7 m.y.) toward the thrust front as the tectonic load increased and the basin filled with sediment (Whiting and Thomas, 1994; Thomas and Whiting, 1995).

As a foreland basin fills with sediment, it evolves from an “underfilled” state, to a “filled” state and lastly to an “overfilled” state when the basin is filled and sediment bypass begins. The stratigraphic architecture of an underfilled foreland basin can be divided into three depositional realms termed the “Underfilled Trinity” (Sinclair, 1997). The Underfilled Trinity consists of a lower carbonate unit deposited along the cratonic margin, a middle unit characterized by hemipelagic mud sedimentation in the deeper part of the basin, and an upper unit characterized by lithic (immature), turbiditic sandstones and mudstone derived from the orogenic belt. Deeper marine facies equate to underfilled basins; whereas, shallow-marine facies equate to a filled state and continental facies to an overfilled state (Sinclair, 1997).

The Underfilled Trinity model can be applied to the Black Warrior basin (Fig. 4.2). The Meramecian-Chesterian stratigraphy can be divided into two tectonostratigraphic units on the basis of how the major stratigraphic units fit into the model. Applying the model to the units between the top of the Tuscumbia and the base of the Bangor (first stage of filling, tectonostratigraphic unit 1), the Monteagle is the lower carbonate unit and the Pride Mountain and Hartselle are the upper unit. Several problems with this application of the model to these strata are evident. First, there does not appear to be a middle hemipelagic mud unit. The model predicts such a unit should exist at the toe of the Monteagle ramp; however, it is likely very thin, is not very extensive, and has limited exposure in outcrop which is why it has not been recognized. Another alternative is that the basin was very shallow and no hemipelagic mud unit was deposited. This idea is consistent with lower subsidence rates during Early Mississippian time (Whiting and Thomas, 1994), possibly resulting in a shallow basin during Pride Mountain/Hartselle deposition. The second problem involves the composition and source of the sandstones. Inherent in the model is that the upper unit is an immature sandstone facies derived from the adjacent orogen. Compositionally, the Pride Mountain and Hartselle sandstones are quartzarenites, not graywackes; although both the Pride Mountain and Hartselle sandstones contain evidence of extensive reworking (Thomas, 1972a; Mack et. al, 1981). If the Pride Mountain and Hartselle sediments came from the north, the model would not apply because the model is only applicable if sediments came from the adjacent orogen. Also, the Pride Mountain/Hartselle sandstones are interpreted to be shallow-marine deposits, and shallow-marine deposits correspond to filled basin depositional state, not an underfilled state.

The upper Chesterian rocks (second stage of filling, tectonostratigraphic unit 2) fit nicely into the Underfilled Trinity model (Fig. 4.2). The lower Bangor Limestone is the lower carbonate unit formed on the cratonic margin, the Neal/Floyd Shale is the middle hemipelegic mud unit, and the lower Parkwood Formation is the upper immature sandstone unit derived from the adjacent orogen. Again, there is a problem in detail with the application of the model to the upper unit. The depositional environment for both the Pride Mountain (tectonostratigraphic unit 1) and the lower Parkwood (tectonostratigraphic unit 2) are shallow marine and deltaic, respectively, not turbiditic as the model predicts for the upper unit. A modification of the model to include deltaic facies in the definition for the upper unit could be made to fit better with the stratigraphy in the Black Warrior basin. The turbiditic facies may not have been deposited as a result of slow rates of basin subsidence, high rates of sediment supply, and/or limited accommodation space. The overlying upper Parkwood Formation is composed of shale and shallow-marine sandstone units indicating a filled basin. The extensive shallow-water limestone deposits of the Millerella limestone also indicate a filled basin. The Pennsylvanian Pottsville Formation contains shallow-marine deposits, coal, and paleosols indicating a transition to terrestrial deposition, as well as the transition to an overfilled basin.

Application of the Underfilled Trinity model suggests two episodes of tectonic activity during the deposition of the Mississippian strata from the Pride Mountain Formation through the Millerella Limestone succession. The first pulse of tectonic activity produced a shallow basin which filled quickly; and the second pulse produced a deeper basin which gave rise to the traditional Underfilled Trinity sequence. These findings conform to previously published subsidence profiles of the Black Warrior basin by Whiting and Thomas (1994) and Thomas and Whiting (1995).

### ***Tectonic and Eustatic Controls on Sedimentation in the Black Warrior Basin***

The tectonic history of the Alabama promontory influenced the geometry and formation of the Black Warrior basin. During late Precambrian and Early Cambrian time, the Iapetus Ocean opened producing rift and transform segments along the continental margin (Thomas, 1989). The rift and transform segments act as boundaries for the Alabama promontory (Fig. 2.1) (Thomas, 1988). Deposition from Cambrian to Mississippian time was primarily a passive-margin carbonate succession, interrupted briefly by the influx of clastic sediments from the distal Taconic orogeny during Ordovician and Silurian time (Thomas, 1977a). The development of the Black Warrior basin began with the closing of an ocean basin accompanied by the destruction of the passive-margin sequence by Ouachita collisonal tectonics (Thomas, 1989; Pashin, 1993).

Climate and eustacy also heavily influenced sedimentation cycles in the basin. During Late Mississippian to Early Pennsylvanian time, Alabama and Mississippi were located near the equator in an embayment inundated by a shallow sea (Pashin, 1993). Climate changed from the end of the Mississippian time to the beginning of the Pennsylvanian time as the North American craton drifted from an arid trade wind belt northward toward the equator (Pashin, 1993). Meramecian to Chesterian strata were deposited as part of the Kaskaskia third-order depositional sequence in which the initial and episodic glaciation of Gondwana was the primary control on relative sea-level change (Pashin, 1993). Thick limestone, carbonate paleosols in the Tuscumbia and Bangor, and oxidized red paleosols and caliche documented in the Parkwood in Lamar County, Alabama, were deposited during Chesterian time and indicate an arid climate (Pashin and Kugler, 1992). The upper part of the Parkwood contains thin coal beds and abundant coal, and reduced paleosols in the Pottsville Formation indicate a change to a more humid climate close to the Mississippian-Pennsylvanian boundary (Pashin, 1993).

Tectonic loading determined the amount of accommodation space in the basin and controlled sediment dispersal while sea-level change influenced stacking patterns during Pride Mountain and Hartselle deposition (Pashin, 1994). Deposition of the lower Bangor represents the establishment of a carbonate ramp in the northeastern part of the basin (Miesfeldt, 1985). Southwest of the Bangor is a deep-water, starved basin (Neal shale) (Pashin, 1993; Mars and Thomas, 1999). Pashin (1993) attributed black-shale deposition to restricted circulation in the deeper part of the basin. Although, water circulation in the basin may have been restricted during this time, black-shale development is more likely a function of increased water depth caused by tectonic loading.

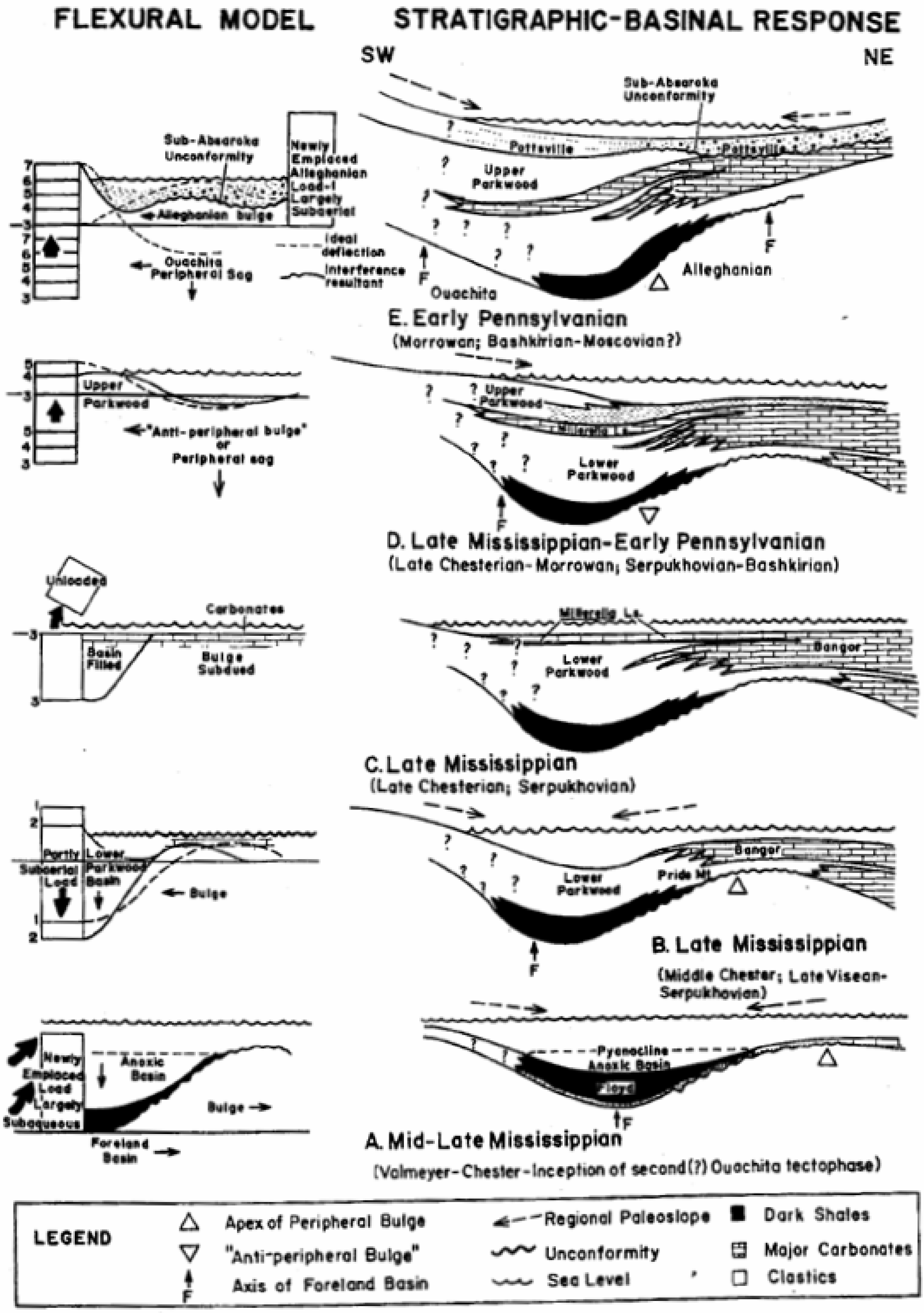

Figure 4.1: Model for stratigraphic responses to flexural changes in the Black Warrior basin (Ettensohn and Pashin, 1993).

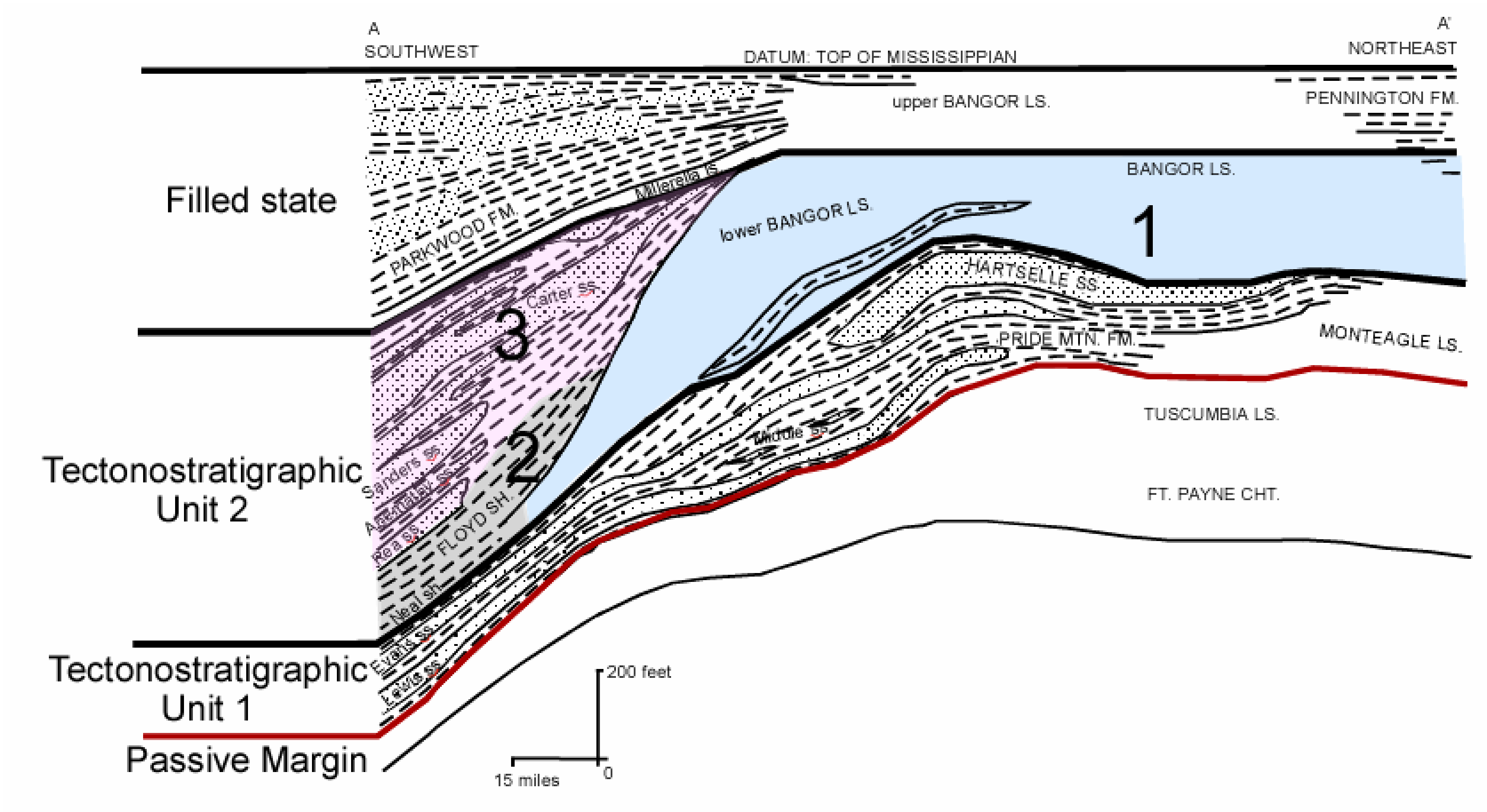

Figure 4.2: Application of the "Underfilled Trinity" model to the Black Warrior basin. The lower unit (1) is the lower Bangor Limestone (blue), the middle unit (2) is the Floyd Shale (gray), and the upper unit (3) is the lower Parkwood Formation (pink).

# CHAPTER FIVE
# METHODS

Geophysical well logs are the primary source of data for this study; cuttings and outcrop data are included for additional support. Most of the wells were drilled between 1970 and 1985 in Alabama and Mississippi. A comprehensive list of wells used to produce the cross sections and selected isopach maps can be found in *Appendix A*. Where referenced in this paper, Alabama wells are numbered with state permit numbers, and Mississippi wells have an arbitrarily assigned number followed by the letter "m."

To provide a complete stratigraphic framework for the basin, 140 wells were used to construct nine cross sections and form a grid for the basin (Plate 2). Four cross sections parallel the depositional strike of the Bangor Limestone (northwest-southeast), and five cross sections are perpendicular to the depositional strike of the Bangor Limestone. The basal limestone of the Bangor Limestone was used as the datum. Well spacing in the cross sections is not horizontally scaled. The straight-line distances (miles) between wells at the ends of the cross sections and the distances between wells in the cross sections are indicated at the top of the cross sections (Plate 1). The base of the Bangor was selected as the datum in order to investigate lateral stratigraphic relationships and illustrate thickness and facies variations of the Pride Mountain/Hartselle interval with respect to the Lowndes-Pickens block.

Geophysical logs were digitized in order to produce digital copies of the cross sections. Paper logs were scanned into the computer as bitmap images. Canvas 8 software was used to trace the bitmap log images to produce digital copies with the same scale as the original paper copy (1 in. = 100 ft.). The digitized logs were then arranged into the respective cross sections and correlated.

Approximately 200 additional wells were used to supplement correlations between and around cross section lines, as well as for isopach and facies maps. Isopach maps (modeled after the shaded distribution maps of Thomas, 1972a) were produced for selected intervals within the Pride Mountain Formation. Data used to create updated sandstone shaded distribution maps were taken from three sources. Ninety percent of the data was taken from subsurface well logs used in this study. Isopach data from Higginbotham (1986) were used to fill in data gaps in the northern counties of Mississippi. Outcrop data from Colbert, Blount, and Jefferson Counties, Alabama, came from various sources including Butts (1926), Welch (1958), Moser and Thomas (1967), Thomas (1972a), and Pashin and Rindsberg (1993).

### *Well-Log Interpretation and Cuttings Descriptions*

The tools included with the well logs are spontaneous potential (SP) and resistivity; a few logs include gamma ray, neutron, and density curves. The resolution of the tools allows for individual beds to be detected at a thickness of three feet. Depositional facies and environments can potentially be deduced from some well-log signatures; although without core or cuttings data, interpretations may be incorrect because different environments may produce similar well-curve signatures. Cant (1992) organized depositional environments into categories, using the typical vertical pattern recognized in SP, gamma, and resistivity curves (Fig. 5.1). Core, cuttings, and outcrop data must be used to correctly interpret facies successions, which may then be used to match a specific log curve to a specific depositional environment.

Well cuttings from Alabama and Mississippi were described in order to match facies with specific well-log signatures and provide lithologic evidence for the sequence stratigraphic interpretations. Samples from twelve wells, totaling 7,355 feet, from Alabama and three wells, totaling 1,935 feet, from Mississippi were described. The cuttings were described on the basis of color, lithology, fossil content, and small-scale sedimentary structures (laminae). A full description of well cuttings and strip logs can be found in *Appendix B*. Cores are rarely taken in the Black Warrior basin, and none were available for this study.

### *Sequence Stratigraphy*

Sloss (1963) defined the term ‘sequence’ as related stratigraphic units bounded by subaerial unconformities. The definition of sequence stratigraphy has been evolving since 1977. Originally developed by Exxon (Vail et al., 1977), a sequence was defined as ‘a stratigraphic unit composed of genetically related strata bounded by unconformities or their correlative surfaces.’ The definition of sequence stratigraphy has continued to evolve since 1977 to better express the relationship between depositional regimes and base-level change. Catuneanu (2006) defines sequence stratigraphy as the ‘sedimentary response to base-level changes, which can be analyzed on the scale of individual depositional systems to the scale of entire basins.’

Several methods/models have been developed for analyzing depositional sequences; these differ on the basis of what surface is used as the sequence boundary. The Exxon depositional model uses subaerial unconformities at basin margins and correlative conformities toward the center of the basin as sequence boundaries (Fig. 5.2). Galloway (1989) published an alternative ‘genetic sequence model’ which uses maximum flooding surfaces as sequence boundaries. The maximum flooding surface represents maximum shoreline transgression and slow rates of deposition in the deeper part of the basin. This surface is characterized by hemipelagic mud, radioactive black shales (condensed sections), or glauconite sands in shallow- to deep-marine settings (Galloway, 1989). Embry and Johannessen (1992) created the “transgressive-regressive (T-R) sequence’ model, which uses maximum flooding surfaces corresponding to a full cycle of transgressive and regressive shoreline shifts (Fig. 5.3).

A sequence can be divided into highstand, transgressive, and lowstand systems tracts on the basis of base-level change. A lowstand systems tract is deposited between the onset of base-level fall and the end of regression. Falling-stage systems tract (also known as the early lowstand systems tract) sediments are deposited on the basin margin during falling sea-level and high sedimentation rates. This results in a forced regression of the shoreline and the progradation of clinoforms across the basin (Catuneanu, 2006). A transgressive systems tract is deposited during sea-level rise, between the end of regression and the end of transgression. Transgressive deposits exhibit a retrogradational stacking pattern and a fining-upward facies succession. Sediment supply is limited during this time resulting in limited deposition on shallow-marine shelves (Catuneanu, 2006). A highstand systems tract includes all sediments deposited between the end of transgression and the onset of base-level fall. The shallow-marine deposits in a highstand systems tract exhibit coarsening-upward stacking patterns which are progradational or aggradational across the basin. The succession may be composed of higher-frequency transgressive-regressive packages caused by fluctuations in sea level and/or sedimentation rates. Systems tracts can be further subdivided into higher-frequency parasequences. Parasequences are defined as genetically related beds or bedsets, coarsening- or fining-upward, bounded by marine flooding surfaces (Catuneanu, 2006).

The T-R model differs from the genetic sequence model in that it uses only two systems tracts: regressive and transgressive. The transgressive systems tract corresponds to the transgressive systems tract of the other models, and the regressive systems tract incorporates the highstand and lowstand systems tracts into a regressive systems tract. The T-R model uses the maximum regressive surface and correlative unconformity as the sequence boundary (Embry, 2002). The maximum regressive surface (MRS) lies at the top of a coarsening-upward (regressive) cycle, marks the change between the shallowing-upward (regressive) and a deepening-upward (transgressive) systems tract, and was chosen as a sequence boundary because it is easily identifiable in well-log signatures (Embry, 2002).

This study uses the transgressive-regressive model for sequence interpretation. The transgressive-regressive model has not been previously applied to the Black Warrior basin. This model is more practical for interior basin analysis because marine flooding surfaces are more extensive in the central part of the basin and more reliably identified than erosional surfaces (Exxon model) which are found only on the basin margins. Also, it is more reliable to identify a flooding surface in geophysical well logs than an erosional surface where outcrop and core data are lacking. A depositional framework and basin-fill model for the basal Mississippian clastic wedge was constructed using sequence stratigraphic interpretations from the application of the “Underfilled Trinity” model (Fig. 4.2).

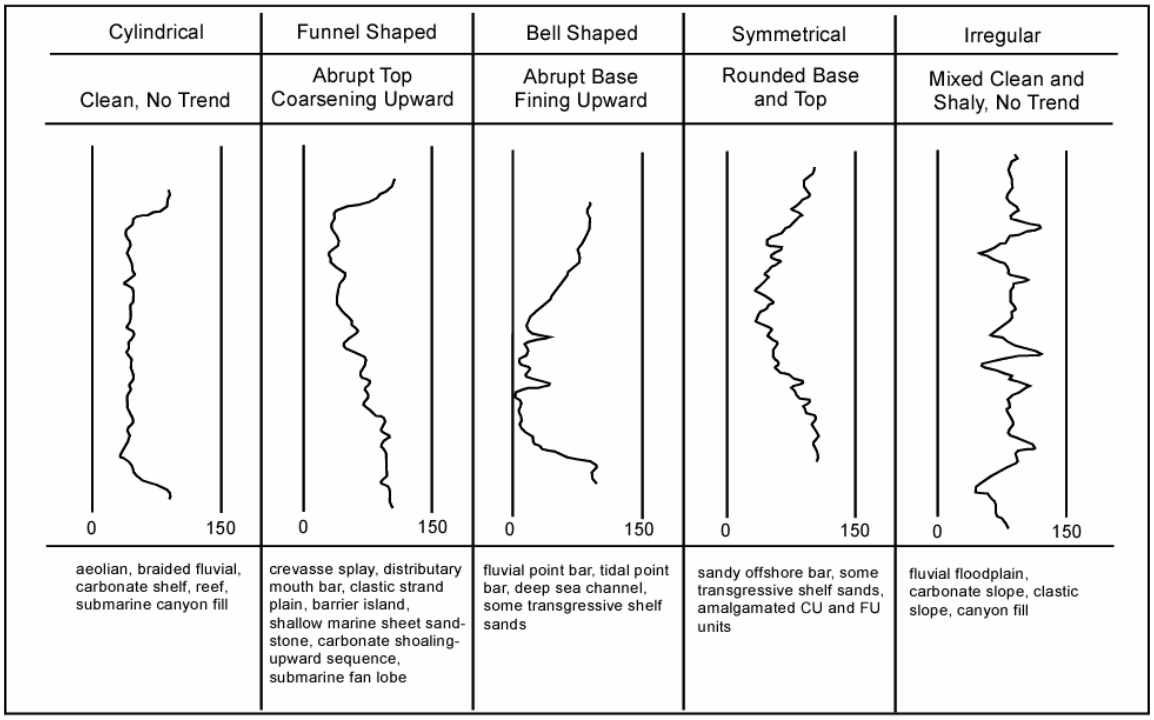

Figure 5.1: Typical vertical patterns recognized in well logs and lists of depositional environments capable of producing the curve (Cant, 1992).

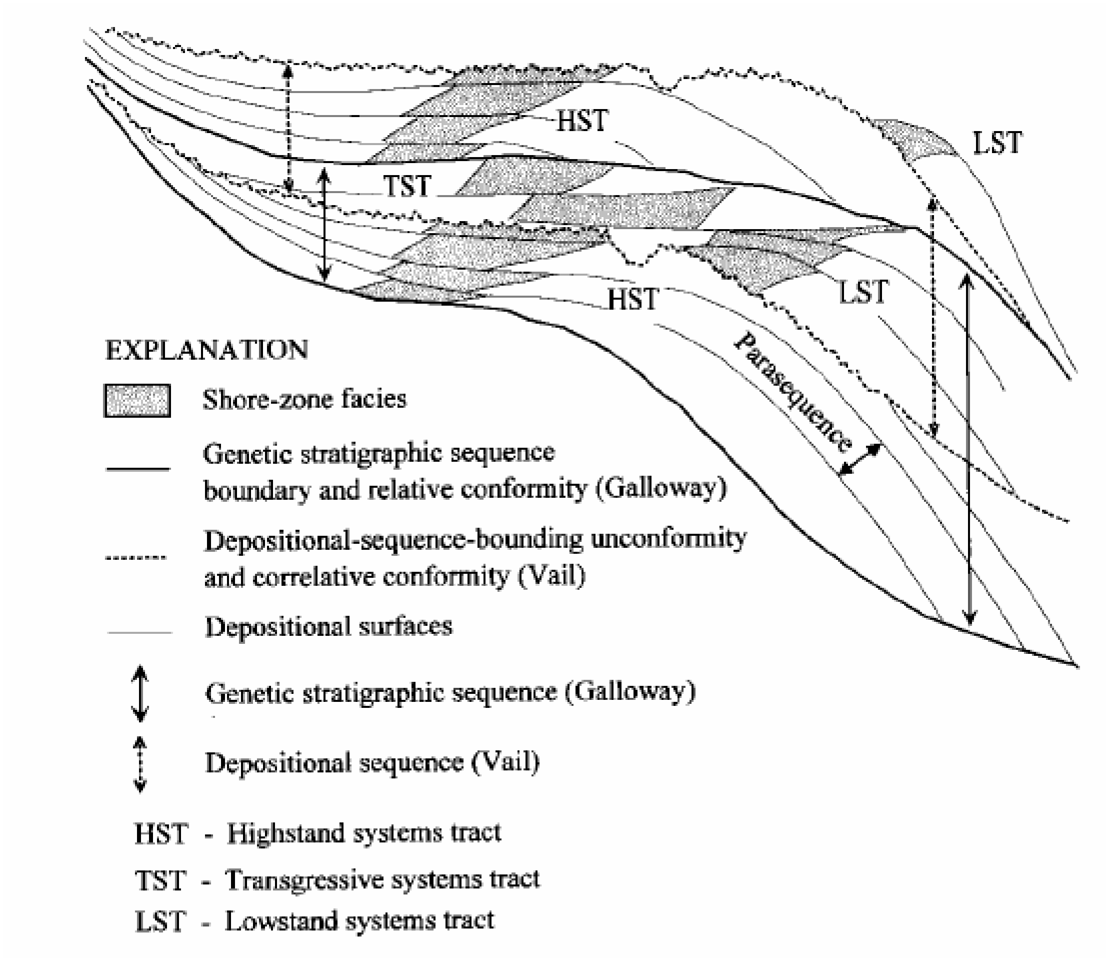

Figure 5.2: Cross section illustrating differences between Galloway and Vail sequence divisions (Mars and Thomas, 1999; modified from Galloway, 1989).

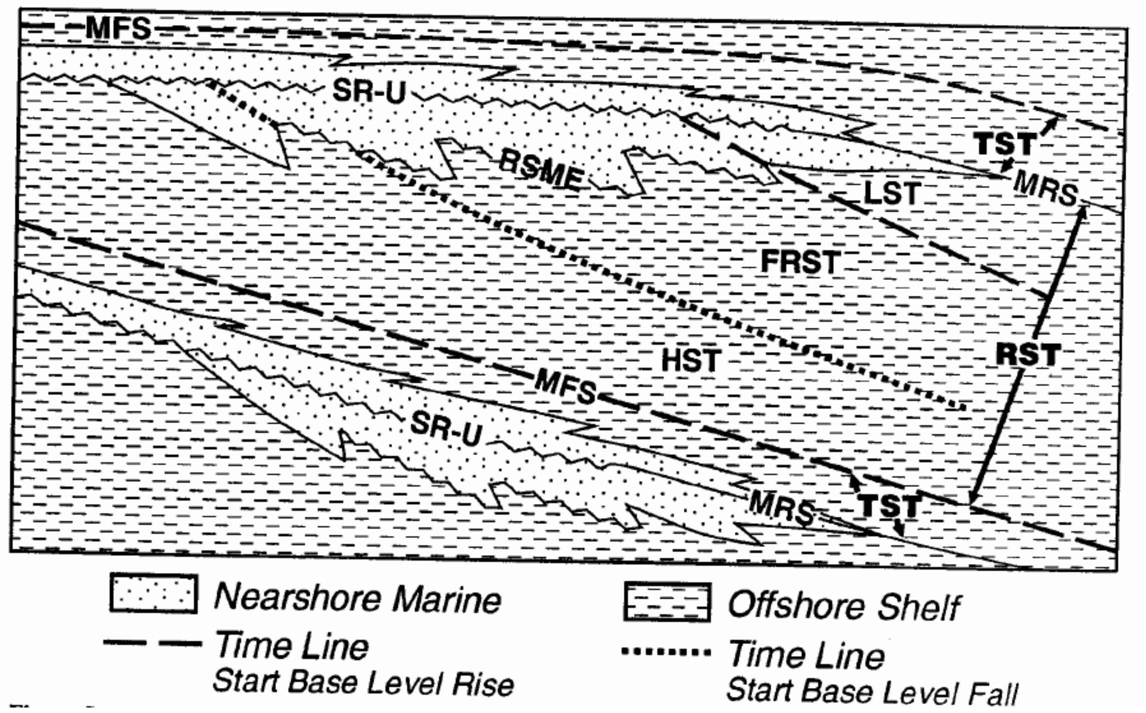

Figure 5.3: Transgressive-regressive model divisions (Embry, 2002). RST=regressive systems tract; TST=transgressive systems tract; LST=lowstand systems tract; HST=highstand systems tract; MRS=maximum regressive surface; MFS=maximum flooding surface; SR-U=shoreface ravinement-unconformable; RSME=regressive surface of marine erosion; FRST=forced regressive systems tract

# CHAPTER SIX
# RESULTS

## Cross Sections

In this chapter, units are characterized on the basis of lithology, well-log signature, distribution, and stratal relationships using data collected from well logs and cuttings descriptions. Figure 6.1 illustrates the typical SP and resistivity signatures of the units from the top of the Tuscumbia Limestone to the top of the Millerella limestone. In Figure 6.1, the top of the Tuscumbia is correlated with a green line, the base of the Bangor with a blue line, the top of the lower Bangor with a pink line, and the top of the Millerella with a black line. These units and colors are also used as correlation markers for a set of nine cross sections described in this chapter (Plate 1). Plate 2 is a location map, including well numbers, for the cross sections.

Cross sections are correlated by unit intervals (e.g., Lewis sandstone interval) and rock type. On the cross sections (Plate 1), the correlations of Pride Mountain/Hartselle unit intervals (Lewis sandstone, Lewis limestone, Middle sandstone, Evans sandstone, Pearce siltstone, and Hartselle Sandstone) are shown by thin black lines. Unit intervals in the cross sections are colored for the interpretation of the predominant rock type in the interval. For example, the Lewis interval shown on cross section 1 typically is composed of sandstone and consequently is colored yellow. The well-log signature and cuttings description, however, show a few interbeds of shale and limestone within the interval (wells 4324 to 3790, cross section 1, Plate 1). Where a facies change is evident within the interval, the interval is colored accordingly (e.g., change from sandstone to silty shale in wells 3670 to 3790, cross section 1, Plate 1). Shale and minor amounts of limestone commonly lie between the sandstone intervals.

Cross sections are oriented parallel and perpendicular to the strike of the Bangor Limestone in order to show thinning of the Bangor ramp to the southwest and thinning of the Pride Mountain/Hartselle clastic tongue onto the Lowndes-Pickens block. All of the cross sections in Plate 1 use the base of the Bangor as the datum line. A second version of cross section 2 uses the top of the Tuscumbia Limestone as the datum line (Fig. 6.2). In this cross section view, the Millerella limestone and Tuscumbia Limestone correlation lines (green and black) are roughly parallel. This view also shows the southwestward thinning of the Bangor ramp and thinning of the Pride Mountain/Hartselle clastic tongue to the southwest, but this datum obscures the context of the Lowndes-Pickens block, because of southwestward thickening of the Floyd-Parkwood between the lower Bangor and Millerella.

As shown by cross sections 2, 3, 4, 5, 6, and 7 (Plate 1), the Pride Mountain Formation thins onto the Lowndes-Pickens block. The Pride Mountain is approximately 400 feet thick at the northeastern ends of cross sections 2, 3, and 7 and has a maximum thickness around 500 feet on the northwestern end of cross section 4 (well 976m). Thinning of the Pride Mountain is more dramatic across the northwestern boundary of the block than the northeastern. The northeastern limb of the block has a gradient of approximately 13 feet/mile, whereas the northwestern limb of the block is much steeper with a gradient of 21 feet/mile. The stratigraphic section on the Lowndes-Pickens block ranges in thickness from 40 to 80 feet. West of the block, cross section 1 also shows a slight southwestward thinning of the Pride Mountain from 400 feet to around 250 feet.

## Description of Units

### Lewis sandstone

The Lewis sandstone is defined as the basal sandstone of the Pride Mountain Formation and includes any sandstone beneath the Lewis limestone, where present (Thomas, 1972a). In the subsurface, the thickness ranges from 10 feet in parts of northern Alabama and Mississippi to a maximum of approximately 80 feet in Monroe County, Mississippi, and Lamar County, Alabama (Fig. 6.3). A few thicker bands (~ 50 feet) of sandstone are also present in the southwest part of the basin in Chickasaw County, Mississippi. The sandstone is also slightly thicker (>20 feet, maximum around 50 feet) in a band in outcrop in northern Alabama (Thomas, 1972a). On the Lowndes-Pickens block (Fayette, Tuscaloosa, and Pickens Counties), the thickness of the Lewis is variable, ranging from 20 to 35 feet. The distribution map shows the Lewis sandstone is very persistent throughout the entire basin and extends across boundaries of the Lowndes-Pickens block without a systematic change in thickness.

Cuttings were described for the Lewis from several wells across the basin. On the Lowndes-Pickens block (well 1792), the Lewis is described as very fine, argillaceous, and locally glauconitic (Appendix B). North and west of the block, in wells 3790, 4324, and 14233m, the Lewis is described as a fine- to medium-grained (0.16 mm-0.25 mm), friable quartzarenite (Appendix B). It is locally calcareous and sparsely carbonaceous throughout. The cuttings for the Lewis increase in amounts of mud and silt and decrease in grain size up section.

In general, the spontaneous potential (SP) and resistivity signatures for the Lewis sandstone typically have fining-upward curves. North of the Lowndes-Pickens block, the Lewis sandstone interval is composed of thin beds (~5 feet each) of interbedded shale, sandstone, and minor amounts of limestone (Fig. 6.4A). On the block, the sandstone is cleaner and thicker (<35 feet) with no shaley interbeds (Fig. 6.4B). The sandstone on the Lowndes-Pickens block has a sharp basal contact and a slightly more gradational, but relatively abrupt, upper contact. In the western and southwestern part of the basin, the Lewis (Fig. 6.4C) has an SP and resistivity curve similar to that in Fig. 6.4B. The SP and resistivity curves show a sharp basal contact and a more gradational (fining-upward) upper contact with the overlying shale (Fig. 6.4C).

In Lamar County, Alabama, the SP and resistivity curves for the Lewis sandstone split into two distinct sandstones separated by a thin shale (Fig. 6.4D). The lower sandstone has an average thickness of 33 feet and the upper sandstone has an average thickness of 12 feet. The shale between the sandstones has a maximum thickness of 20 feet. This “double sand” pattern is recognized in more than 60 wells spread across two patches in Lamar County, Alabama: a south-trending patch on the northwestern corner and a southeast-trending patch on the southern part of the Lowndes-Pickens block (Fig. 6.5). Well logs show minor amounts of variation around edges of the two patches, making the unit gradational with the surrounding, more massive Lewis (e.g., Fig. 6.4B).

Two cuttings sections (wells 3586 and 2482) were described through the Lewis “double sand,” and cuttings, as well as log signatures, indicate a fining-upward relationship between the lower and upper sandstones (Appendix B). In well 3586, the lower sandstone ranges in grain size from 0.33 to 0.5 mm (fine to medium) and the upper between 0.16 and 0.25 mm (very fine to fine). Overall, the sandstone in well 2482 is finer, and grain size differs only slightly between the lower (0.33 mm) and upper (0.2 mm) sandstones. In both wells, the upper sandstone is more argillaceous and poorly sorted. In well 4425, the cuttings show the upper sandstone unit is actually sandy limestone.   Therefore, the upper sandstone may gradationally change laterally from sandstone to sandy limestone or limestone.

The Lewis sandstone is laterally continuous in all of the cross sections, except locally in cross section 3 (well 782) and at the southwest end of cross section 1 where it pinches out (Plate 1).  Cross section 3 (Plate 1) shows the Lewis grading from sandstone into siltstone and limestone where it extends southwestward across the Lowndes-Pickens block gradient, but the sandstone covers the block. The correlations in cross section 3 between wells 782 and 4224 are unclear because not enough well data are available.  The southwest end of cross section 1 (well 1508m through 79m), northwest of the Lowndes-Pickens block gradient, also shows that the Lewis grades laterally into silty shale and pinches out into shale.

Well-log signatures on the northeastern ends of cross sections 1, 2, 7, and 3 and along cross section 8 all show the Lewis as interbedded shale with sandstone and/or limestone.  Cuttings from wells 4361 and 1838 (cross section 2) show the shale interbedded with sandstone; whereas, well 3790 (cross section 1) shows the Lewis interval as limestone.

The cuttings descriptions from well 3790 (Appendix B), show no change in lithology from the Lewis interval downward into the Tuscumbia Limestone as shown by well logs, but cuttings described from the equivalent interval in well 1838 and 4361 are sandstone.  Therefore, the cuttings samples for the interval in well 3790 (cross section 2) may have been incorrectly collected or otherwise mixed.  The northwestern end of cross section 4 (well 976m) has a very thick section of sandstone; elsewhere in the north the unit is thin and interbedded.   Well logs in the southeastern part of cross section 4, on the

Lowndes-Pickens block, indicate the Lewis sandstone interval grades laterally into limestone.

### Lewis limestone

The Lewis limestone, which is defined as the limestone that lies directly above the Lewis sandstone (Thomas, 1972a), is very persistent on the Lowndes-Pickens block and has a patchy distribution in the deeper parts of the basin to the north and west of the block (Fig. 6.6). On the block, the thickness is consistently between 3 and 7 feet. North and west of the block, the limestone, where present, has a variable thickness between 5 and 30 feet in the subsurface and as much as 30 feet thick in outcrop in northwestern Alabama (Pashin and Rindsberg, 1993).

The Lewis limestone is described as a light olive gray, sparsely oolitic (with quartz nuclei in well 2482), fossiliferous packstone from cuttings on the block. Fossils identified in this unit include echinoderms, gastropods, and shell fragments. West of the block in wells 4324, 10107m, and 1262m, the limestone is a light olive to medium gray wackestone/micrite. Cuttings descriptions indicate fossils (echinoderms and shell fragments) are very sparse in the Lewis limestone in the deeper part of the basin.

A strong kick in the resistivity curve is indicative of the Lewis limestone (Fig. 6.4C and D). The Lewis limestone is very persistent in the southwestern ends of cross sections 2 and 3 and the southeastern ends of cross sections 4 and 5. It has a patchy distribution in the northeast ends of cross sections 1, 2, 3, and 7.

Some well logs (e.g., cross section 8) exhibit a weak resistivity signature in the stratigraphic position of the Lewis limestone; however, it is uncertain whether these represent the Lewis limestone because the logs lack the characteristic resistivity kick and the lithology is unknown. In cross section 4, the Lewis can be correlated from the block to the deeper part of the basin. It also appears, however, that the limestone can be correlated across the top of the Pride Mountain Formation and Hartselle Sandstone in cross section 3 (well 782 to 4224).

### Middle sandstone

The Middle sandstone lies between the Lewis and Evans sandstones and has patchy distribution in outcrop in northern Alabama (Thomas, 1972a). The Middle sandstone is laterally discontinuous and distributed primarily in Chickasaw, Monroe, and Itawamba Counties, Mississippi, and Marion and Lamar Counties, Alabama (Fig. 6.7). A shaded distribution map shows the area of approximately 35 wells in which the Middle sandstone is identified. The thickest body of sandstone is in Itawamba County, Mississippi, and Marion County, Alabama. In Marion County, Alabama, the sandstone has a maximum thickness of 70 feet (well 5187, Fig. 6.8A). The average thickness of the unit is less than 20 feet throughout the rest of the basin. The sandstone pinches out against the gradient of the Lowndes-Pickens block (Fig. 6.7).

Cuttings from the Middle sandstone were described from wells 4324 and 4361, which provide different lithologic descriptions of the Middle sandstone. In well 4361, the Middle sandstone is very fine grained (~0.125 mm) and very argillaceous, and is interbedded with green claystone and shale; whereas, in well 4324, the sandstone is a slightly coarser (<0.25 mm) quartzarenite (Appendix B). Cuttings were not described from well 5187, but well 4324 is close in proximity to well 5187 (Fig.6.8A), and is likely comparable in lithology.

The Middle sandstone typically has a coarsening-upward SP and resistivity signature (Fig. 6.8A and B). In Marion County, where the sandstone is thickest, the well-log signature shows approximately 40 feet of clean sandstone with a gradational basal contact and a sharp upper contact (Fig. 6.8A); whereas, east of Figure 6.8A, the Middle sandstone is thin (<10 feet) and interbedded with claystone or shale (Fig. 6.8B). The

Middle sandstone has a fining-upward SP and resistivity pattern locally in a few places (Fig. 6.8C).

A patchy distribution for the Middle sandstone is evident in the cross sections (Plate 1). The Middle sandstone near the northeastern end of cross section 2 (well 4361 and 2292) grades laterally northeastward into silty shale and pinches out northeastward. Cross section 1 (well 946m through 3790) shows the sandstone grading laterally between sandstone and limestone facies. An alternative interpretation for this interval is that the Middle sandstone rests directly on the Lewis limestone. Cross sections 4 and 1 have one common well (1008m). In cross section 4, the Lewis limestone can be traced laterally from the northwest into well 1008m and appears to lie beneath the Middle sandstone interval. Therefore, the Middle sandstone interval may include interbedded limestone. In cross section 4, the Middle sandstone interval is found in three wells (1008m, 944m, and 4821) and grades laterally from sandstone into limestone where it pinches out on the gradient of the Lowndes-Pickens block. The Middle sandstone is not recognized in the southwestern part of the basin in cross sections 5, 6, and 9 or in the northeastern ends of cross sections 3 and 7.

### Evans sandstone

The Evans sandstone is the third sandstone upward above the Tuscumbia Limestone (Thomas, 1972). The Evans sandstone is laterally continuous in a linear area that extends northeastward from the southwest part of the basin, wraps around the northern corner of the Lowndes-Pickens block, and continues in a southeasterly direction sub-parallel to the western margin of the block (Fig. 6.9). The Evans sandstone has a maximum thickness of roughly 100 feet in Marion County, Alabama. The distribution map shows that the thickest band of Evans sandstone pinches out to the southwest and southeast against the Lowndes-Pickens block. Like the Lewis sandstone, the Evans sandstone is thicker (~50 feet) in Chickasaw County, Mississippi, and locally in outcrop in Colbert County, Alabama.

Cuttings descriptions from the Evans reveal that the unit typically is less argillaceous upward and grades up-section from very fine-grained (~0.125 mm) to fine-grained sandstone (0.16- 0.25 mm). Sandstone described from the southwest part of the basin (wells 1262m and 14233m) appears to be less argillaceous than sandstone farther north (wells 18 and 3790) (Appendix B). The underlying shale is calcareous and commonly contains pyrite, sulfur, and rare shell fragments.

The Evans sandstone typically has a coarsening-upward well-log signature. The lower boundary with a is gradational with the underlying shale (Fig. 6.10). The coarsening-upward signature is more gradual in the southwest part of the basin (Fig. 6.10A); whereas, in the northern part of the basin, the signature is more abrupt (Fig. 6.10B and C). Where the Evans is more massive (Fig. 6.10A and B), the top of the sandstone has an abrupt contact with the overlying shale. In the northwestern part of the basin, the Evans sandstone interval is less massive and is divided into three distinct sandstone units separated by thin siltstones or argillaceous sandstones (Fig. 6.10C). The Evans fines upward from a thick bottom sandstone into two siltstone/sandstone packages totaling 10 feet each.

The Evans sandstone interval is very persistent, excluding the surface of the Lowndes-Pickens block, in all of the cross sections. In cross sections 2, 3, and 7 (Plate 1), the Evans thins to the southwest and pinches out against the Lowndes-Pickens block. Cross sections 4, 5, and 6 show the Evans pinching out southeastward against the northwestern gradient of the Lowndes-Pickens block. Off the block on the northeastern end of cross section 1, the sandstone grades into siltstone and shale to the northeast. Cross section 1 shows that clean sandstone in the Evans sandstone thins to the southwest, even though the total interval retains a constant thickness from northeast to southwest.

The siltstone/sandstone ratio of the Evans interval increases to the southwest. In the southwest, the clean sandstone averages 40 feet; whereas, in the north/northeast subsurface it averages between 60 and 80 feet. The siltstone/sandstone ratio in the Evans interval in the northwestern end of cross section 5 is comparable to the southwest end of cross section 1. Cross sections 2 and 3 show limestone units overlying the Evans (well 3772, cross section 2; well 4224, cross section 3). The well-log signature of the Evans shown in Figure 6.10C is isolated to the northwestern end of cross section 4. The northwestern end of cross section 6 (well 826m) transects one of the thicker bands of sandstone in Chickasaw County, Mississippi.

### Hartselle Sandstone

In northern Alabama, the northwest-striking, linear body of the Hartselle Sandstone abruptly pinches out to the southwest in Franklin, Marion, Winston, and Walker Counties (Thomas, 1972a). The sandstone extends southeastward into the Appalachian thrust belt (St. Clair County, Alabama) where it pinches out at a southeastern limit (Mack and Thomas, 1982). In the subsurface, the Hartselle is variable, generally ranging in thickness from 60 to 90 feet, and has a maximum thickness of 165 feet in Franklin County, Alabama. The Hartselle is described as a friable quartzarenite with grain size ranging from fine to medium grained (0.16-0.5 mm) (wells 18, 4361, and 3790) (Appendix B). It contains shale or limestone interbeds in wells 18 and 4361. In well 4361, a thick limestone (~ 30 feet) described as a micrite, lies directly above the Hartselle.

The Hartselle sandstone SP and resistivity signatures generally have a sharp basal contact and a slightly gradational, but generally abrupt, fining-upward upper contact evident in the well-log curves (Fig. 6.11A and B). The unit fines upward (uppermost 5 feet of unit) as the sandstone grades into overlying shale. In rare wells, the Hartselle has a coarsening-upward succession capped by shale at the upper contact as in Figure 6.11C. Some well-log signatures also show that the sandstone is interbedded with limestone and shale (Fig. 6.11D). A thin shale unit commonly lies between the Hartselle and Evans. The Hartselle extends into the northeastern ends of cross sections 1, 2, 3, and 7, perpendicular to depositional/isopach strike and close to the southwestern limit of the unit. Cross section 8 crosses through the Hartselle, parallel to depositional strike. Cross sections 2, 3, and 7 show a limestone (<35 feet) overlying the Hartselle.

### Pearce siltstone

A previously unnamed unit, found only in the subsurface, is recognized in approximately 50 wells in Itawamba County, Mississippi, and in Marion and Walker Counties, Alabama. This unit is named here informally as the Pearce siltstone after Alabama well 5187 (PEARCE TRUST #8-12). The Pearce is part of the Pride Mountain Formation.

Cuttings from more than 500 feet of section, from four different wells which contain the Pearce, were described (wells 4324, 1838, 2143, and 10107m) (Appendix B). Lithologically, the Pearce is a very muddy, limey siltstone. Fossils are rare in the unit, and only a few cephalopod fragments, unidentifiable shell fragments, and two tiny clam shells were found. The unit commonly contains carbonaceous material, pyrite, and sulfur. The shale units lying directly above and below the Pearce commonly contain a higher diversity of fossils, including brachiopods, bryozoans, and echinoderms, as well as sparse carbonaceous material. Sparse bryozoans were identified in well 3772 in laterally equivalent shale northwest of the Pearce siltstone.

The Pearce SP and resistivity curve signatures generally show an “hour glass” or aggradational “blocky” shape (Fig. 6.12A and B). Looking at only the SP and resistivity log signatures, the unit appears to be calcareous shale; however, the gamma ray signature indicates the unit has a silty component (Fig. 16.12A). Where the Pearce is thin (cross section 4) the log signature fines upward into overlying shale (Fig. 6.12C). The Pearce lies directly over the Evans sandstone, and occupies the area southwestward of the southwestern limit of the Hartselle Sandstone.

In an isopach map of data from 47 wells in which the Pearce signature was identified (Fig. 6.13), thickness ranges from 0 to a maximum of 300 feet in Marion

County, Alabama.  The unit may be laterally equivalent to the Hartselle; however, the thickest Pearce is approximately 150 feet thicker than the thickest Hartselle.  The linear outline of the unit has a northwest-southeast strike and is wedged between the northeastern boundary of the Lowndes-Pickens block and the southwestern limit of the Hartselle Sandstone (Fig. 6.13).  The isopach contours extend approximately one-third of the way up the gradient of the northeastern boundary Lowndes-Pickens block, showing a pinch out against the block.  The northwestern end of the unit appears to wrap around the corner of the block and parallels the northwestern boundary for a short distance. The northwestern end of the unit also widens slightly where it grades into shale and pinches out northwestward.

The siltstone unit is present in wells in cross sections 1, 2, 7, and 4 (Plate 1).  It pinches out to the southeast, and does not extend to cross section 3.  The lateral relationship between Hartselle and Pearce is unknown.  A supplementary cross section (A) (Fig 6.14) provides the only additional well data for the unit.  Figure 6.14 shows that a shale facies intervenes between the Pearce and Hartselle and suggests no direct interaction or intertonguing between the units.  The resistivity signature in well 853 (Fig. 6.14) suggests that shale separates the Pearce and Hartselle.  Additional well data are unavailable in the area for better resolution of the lateral relationship.

## Bangor Limestone

The lower Bangor Limestone is more than 400 feet thick in Marion, Winston, and Walker Counties, Alabama; and in the geometry of a carbonate ramp, it thins southwestward to less than 100 feet in central Mississippi, where it grades into the Neal shale (Fig. 2.5). Where the Bangor thins to the southwest, the gradient of the ramp is relatively consistent at approximately 13 feet/mile. Cross sections 1, 2, and 3 (Plate 1), show the southwestward thinning of lower Bangor ramp carbonates and cross section 4 parallels the middle of the lower Bangor ramp section. Cross section 1 shows an unusually thin interval (<20 feet) of the Bangor in wells 81m and 79m. An effort was made to trace out the lateral continuity of this thin interval; however, the signature is found in only three adjacent wells (76m, 78m, and 82m, wells not in cross sections) suggesting a very localized expression.

Cuttings descriptions show a gradation in facies from the upper part of the ramp to the lower part of the ramp (Appendix B). Upper ramp facies are light in color (light olive gray to light gray) and range from oolitic grainstones to bioclastic packstones. Fossils identified in upper ramp facies include echinoderms, brachiopods, gastropods, mollusks, and bryozoans (wells 3790, 4361, 3772, and 18). Middle ramp facies are darker in color (medium to dark gray) and include pelloidal packstones and wackestones, as well as an increase in shale interbeds (wells 2482, 432, and 4425). Lower ramp facies are predominantly dark gray micrite and black shale (wells 1792, 81, and 14233m). Well 3790 (cross section 1, Plate 1) exhibits strong cyclicity in the lower 80 feet. Each cycle is approximately 30 feet thick. Each cycle begins with a basal shale, overlain by a micrite or wackestone, which grades upward into a fossiliferous packstone.

Spontaneous potential and resistivity well-log curves show that the lower Bangor Limestone on the ramp is composed of interbedded shale and limestone (Fig. 6.15). The cross sections correlate individual limestone beds, as well as recognizable packages of resistivity peaks. The lower Bangor Limestone is laterally continuous along stratigraphic strike on the upper and middle part of the ramp (e.g., unit shaded blue in cross section 4, Plate 1). Figure 6.15 provides a closer look at the correlation of individual limestone beds, limestone packages, and shale the upper ramp settings.

Wells in the northeastern ends of cross sections 1, 2, 3, and 7 have SP expressions indicative of oolitic grainstone deposits in the uppermost Bangor. The oolitic deposits in the subsurface can be correlated to shoal deposits recognized farther to the north in Franklin and Colbert Counties, Alabama (Thomas, 1972a). Cuttings descriptions though the upper limestone units include interbedded oolitic grainstone and fossiliferous packstone beds (wells 18, 3790, and 4361).

Logs indicate that a thick shale unit overlies the basal limestone bed of the Bangor limestone (e.g., unit shaded in light gray in cross section 2, Plate 1). The shale maintains a consistent thickness of roughly 20 feet (maximum of 50 feet) in the center of the basin (Marion, Walker, Winston, Fayette, and Lamar counties) and thins in all directions (Fig. 6.16).

### Floyd/Neal Shale

Cuttings from the Neal shale were described from well 14233m (Appendix B). The lowermost 30 feet of the Floyd Shale (above the Neal) is dark gray, micaceous, and sideritic shale. The Neal is a black, noncalcareous shale containing pyrite. The color change is fairly abrupt, indicating a relatively sharp contact between the Floyd and Neal.

Cross sections 5 and 6 parallel the northwest trend of the Neal in the southwestern part of the basin. The Neal has a high resistivity signature similar to that of the lower Bangor Limestone. For example, the Neal resistivity signature can be traced northeastward from well 540m to 5255, up the Bangor ramp (unit shaded in dark gray in cross section 2, Plate 1). The lateral contact between the Neal and lower Bangor Limestone is gradational. More detailed petrographic studies need to be completed in order to determine where the lithology of the Neal black shale grades into the Bangor limestone. Because the Neal retains the signature of the lower Bangor ramp facies, well logs are not good indicators of this facies change because it is very subtle. For example, northeast of cross section 5, the Neal resistivity signature changes slightly, but it is not known if the lithology changes at that point (e.g., wells 597m and 373m, cross section 2).

The Neal shale is between 60 and 100 feet thick and may be as thick as 140 feet just northeast of cross section 5 if the lithology there is black shale. An isopach map shows the distribution of the typical Neal shale signature from 45 wells (Fig. 6.17). Cross section 5 was used as an arbitrary northern limit for the shale because the exact lithology northeast of this line is uncertain in terms of contrast of black shale and limestone. The distribution map shows the thickest Neal in Clay County, Mississippi (Fig 6.17). Thick patches (<100 ft.) of Neal are also present in Chickasaw and Pontotoc Counties, Mississippi, and in Pickens County, Alabama.

The isopach map of the Neal shale created for this study differs from a previously published isopach by Cleaves and Bat (1988). That study did not provide a well log of the typical Neal signature, indicating the Neal shale was thought of as a much thinner interval which extended farther to the north, beyond cross section 5 (this study).

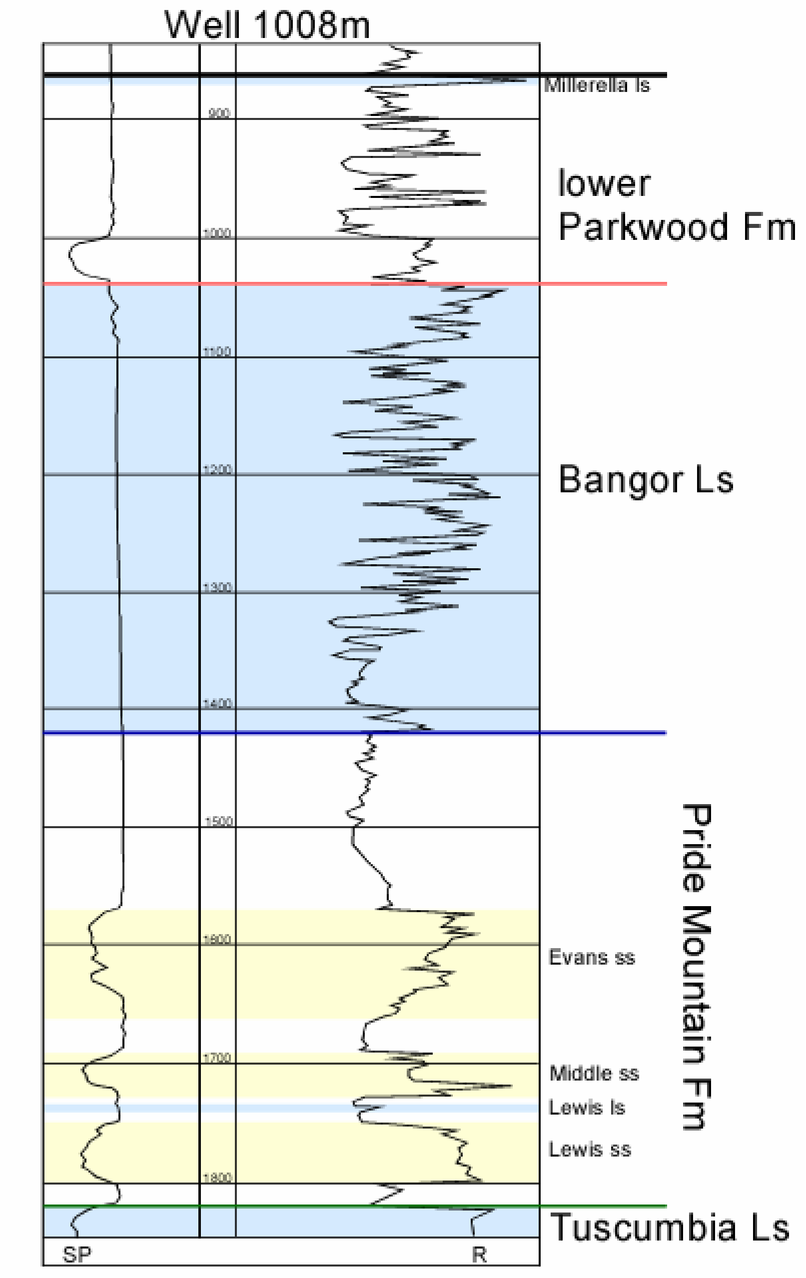

Figure 6.1: Typical spontaneous potential and resistivity responses for the stratigraphic section from the top of the Tuscumbia Limestone to the top of the Millerella limestone. Explanation of colors: yellow/sandstone, blue/limestone

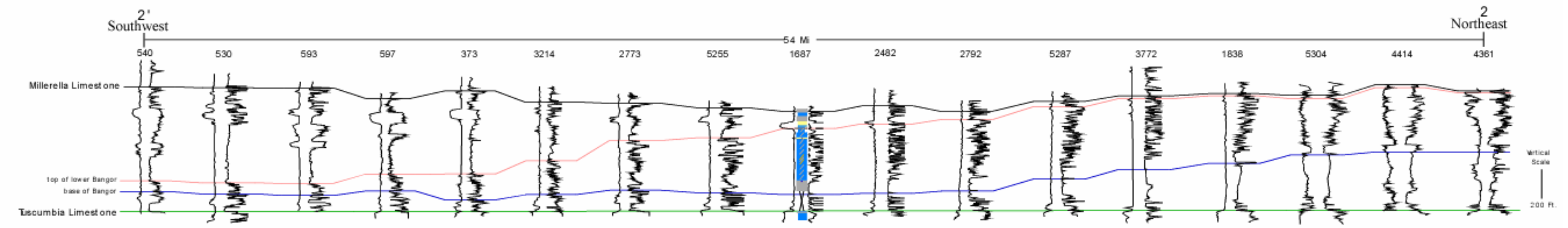

Figure 6.2: Cross section 2 using the top of the Tuscumbia Limestone as the datum. The Millerella limestone (black line) and top of the Tuscumbia Limestone (green line) are roughly parallel.

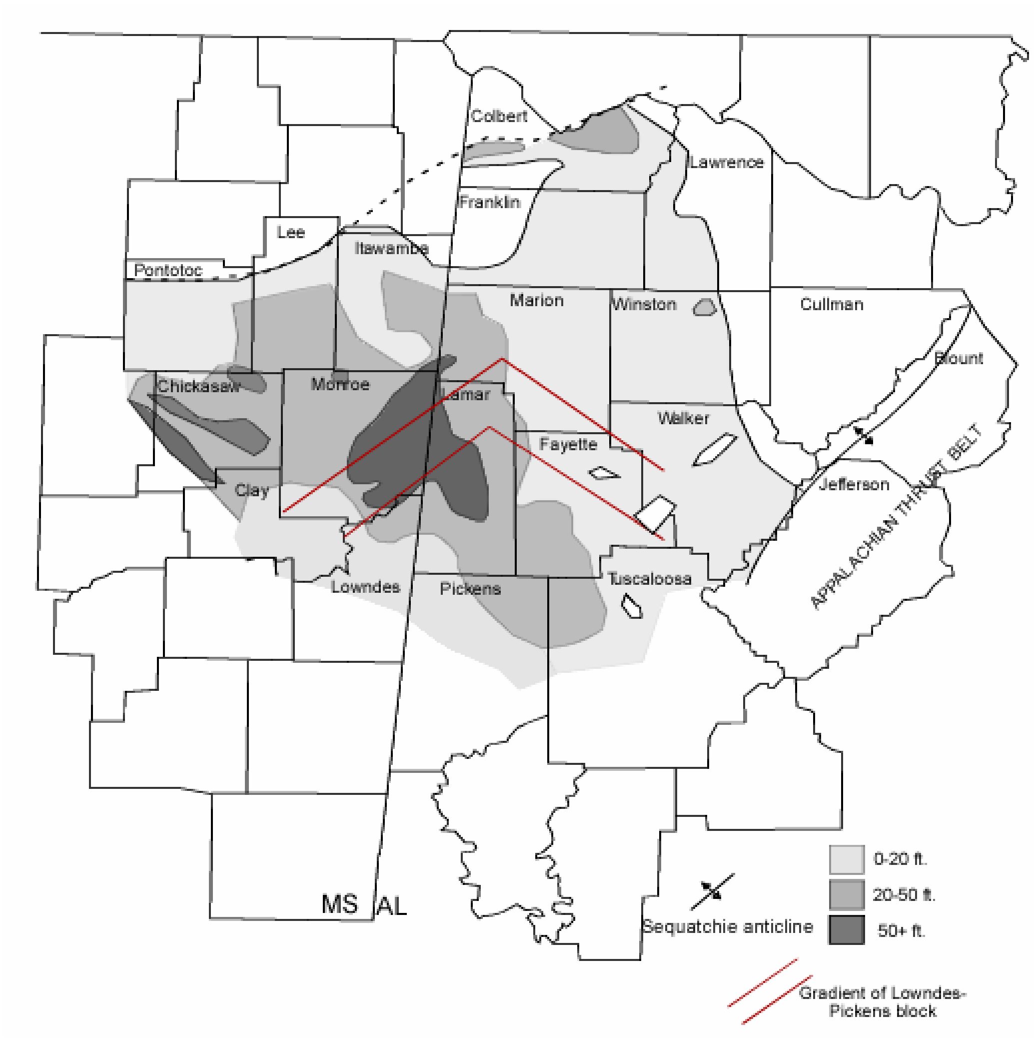

Figure 6.3: Shaded distribution map for the Lewis sandstone showing no change in thickness across boundary of Lowndes-Pickens block. Black line is zero sand, edge of shaded area (without line) is the limit of the data, and dashed line is erosional limit.

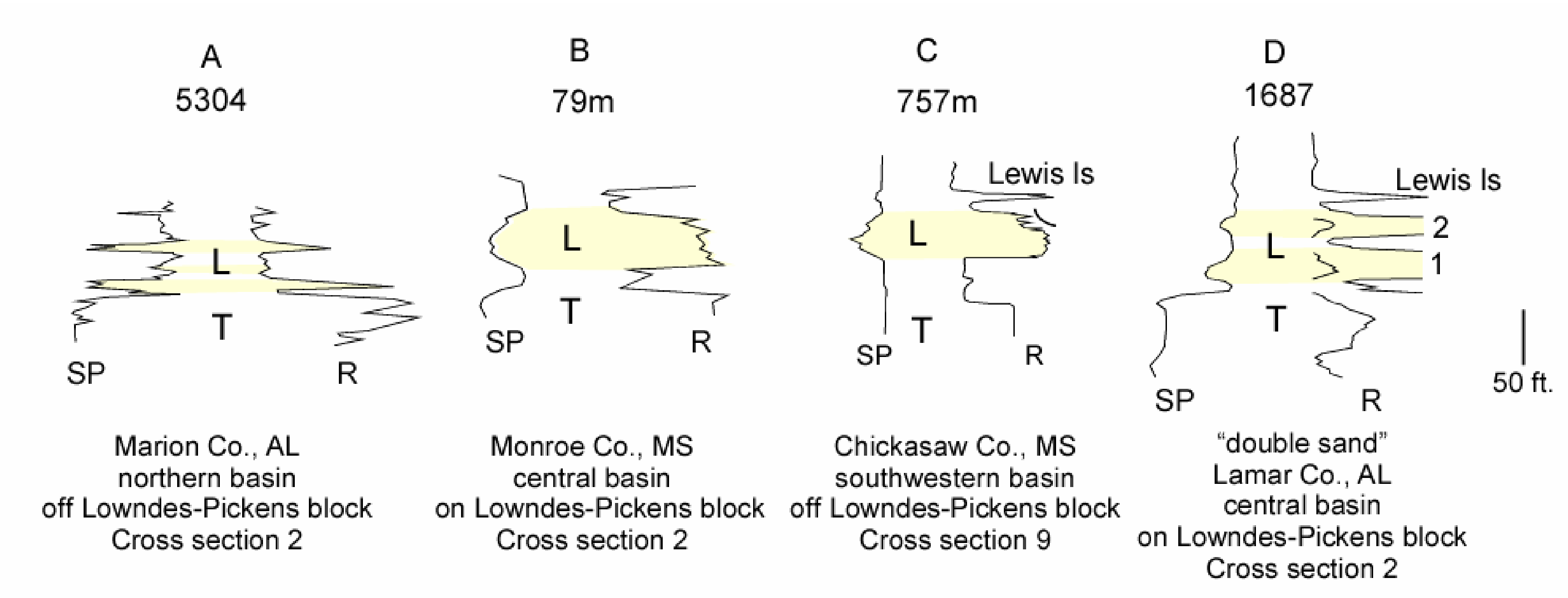

Figure 6.4: Typical spontaneous potential and resistivity curve response for the Lewis sandstone. L-Lewis, T-Tuscumbia

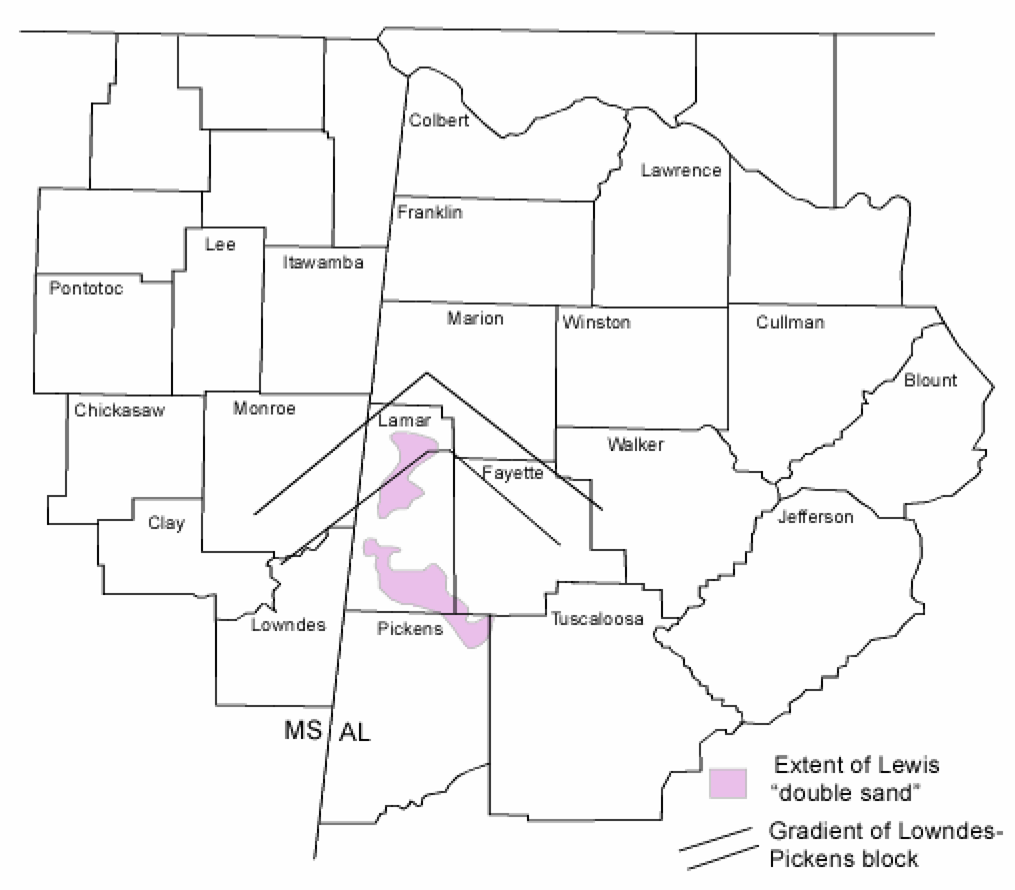

Figure 6.5: Map extent of the Lewis "double sand" signature in relation to the gradient of the Lowndes-Pickens block.

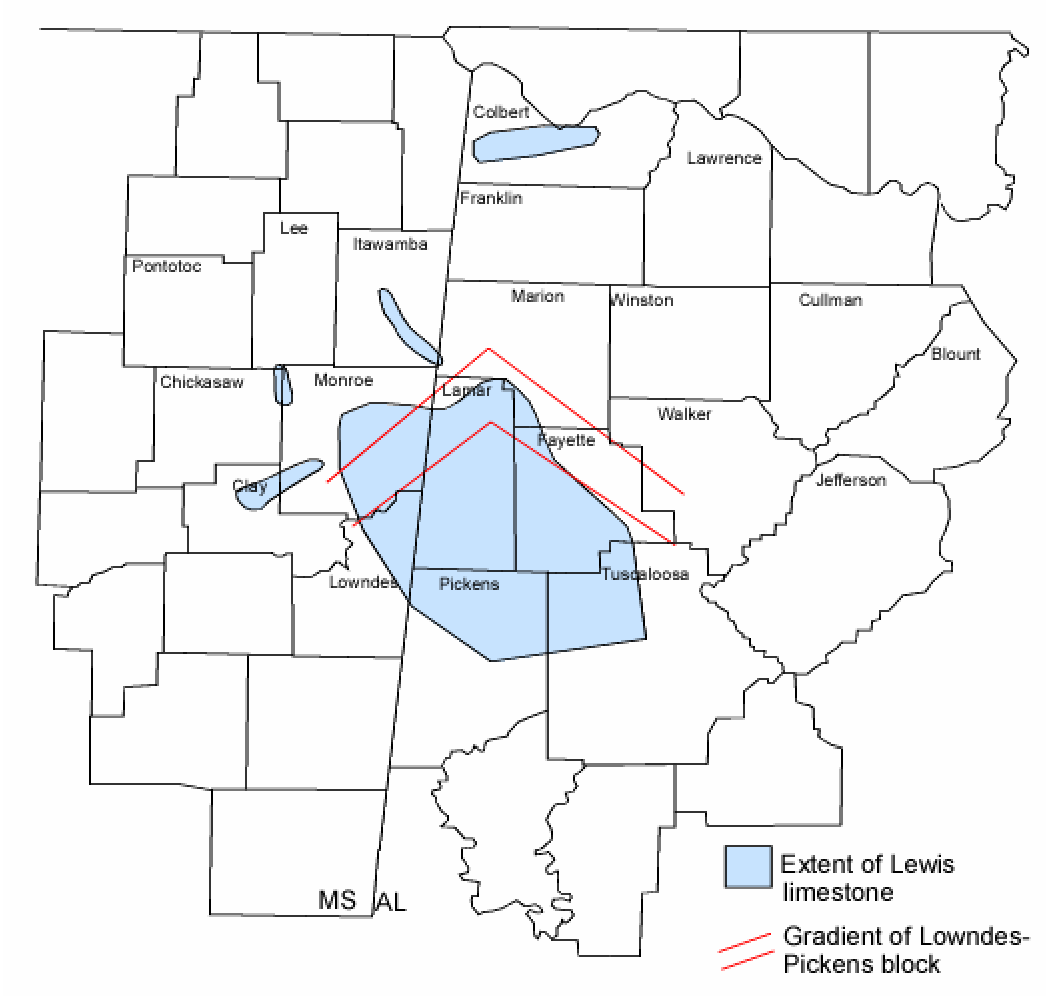

Figure 6.6: Map distribution of the Lewis limestone directly overlying the Lewis sandstone in relation to the gradient of the Lowndes-Pickens block. Black line represents zero limestone.

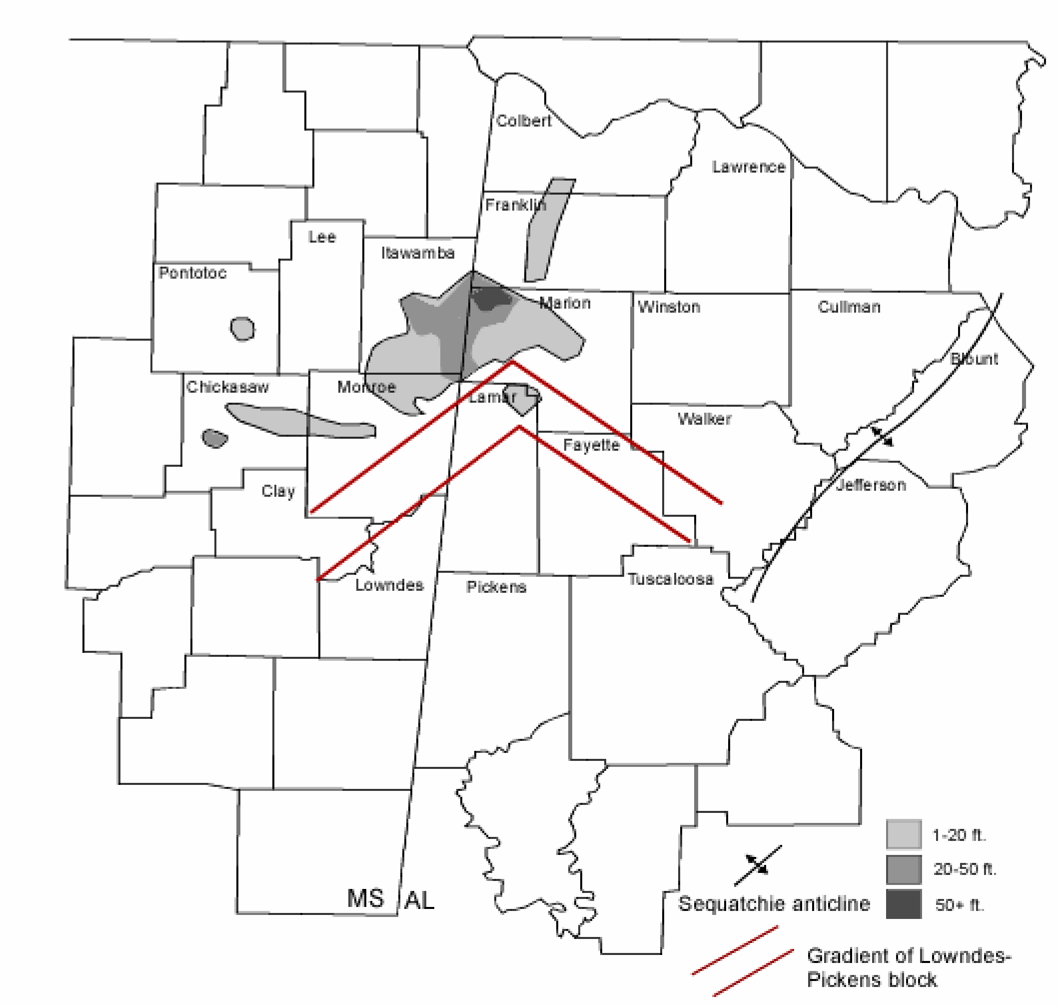

Figure 6.7: Shaded distribution map for the Middle sandstone showing a patchy distribution in the northern part of the basin. Black line is zero sand

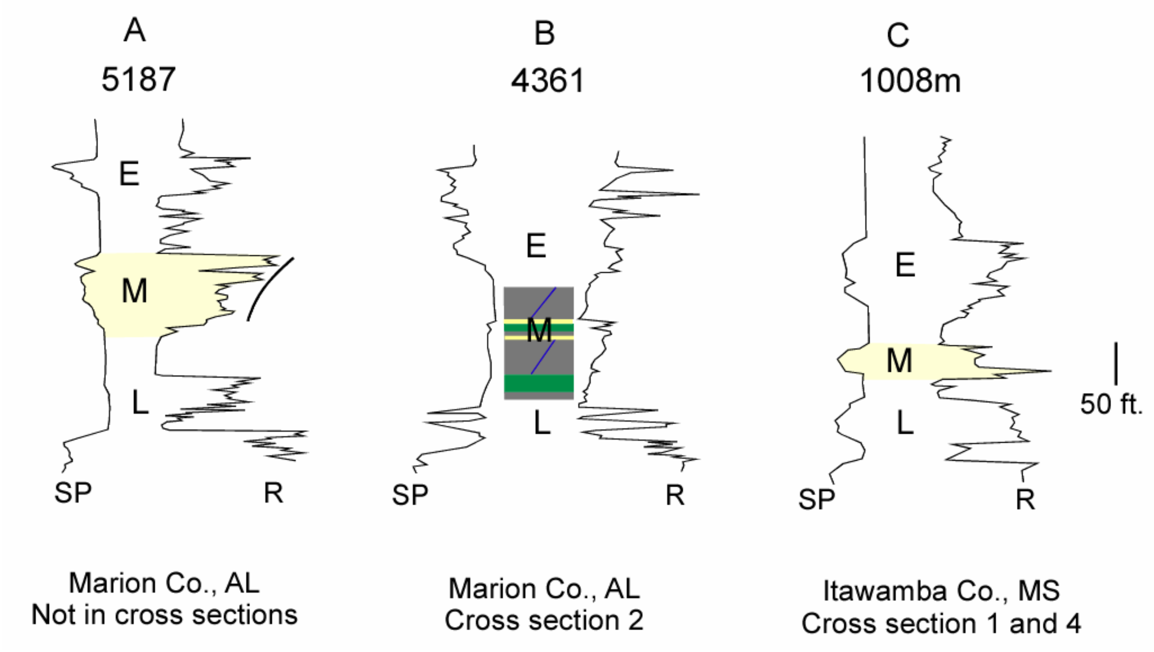

Figure 6.8: Typical spontaneous potential and resistivity curve response for the Middle sandstone. L-Lewis, M-Middle, E-Evans

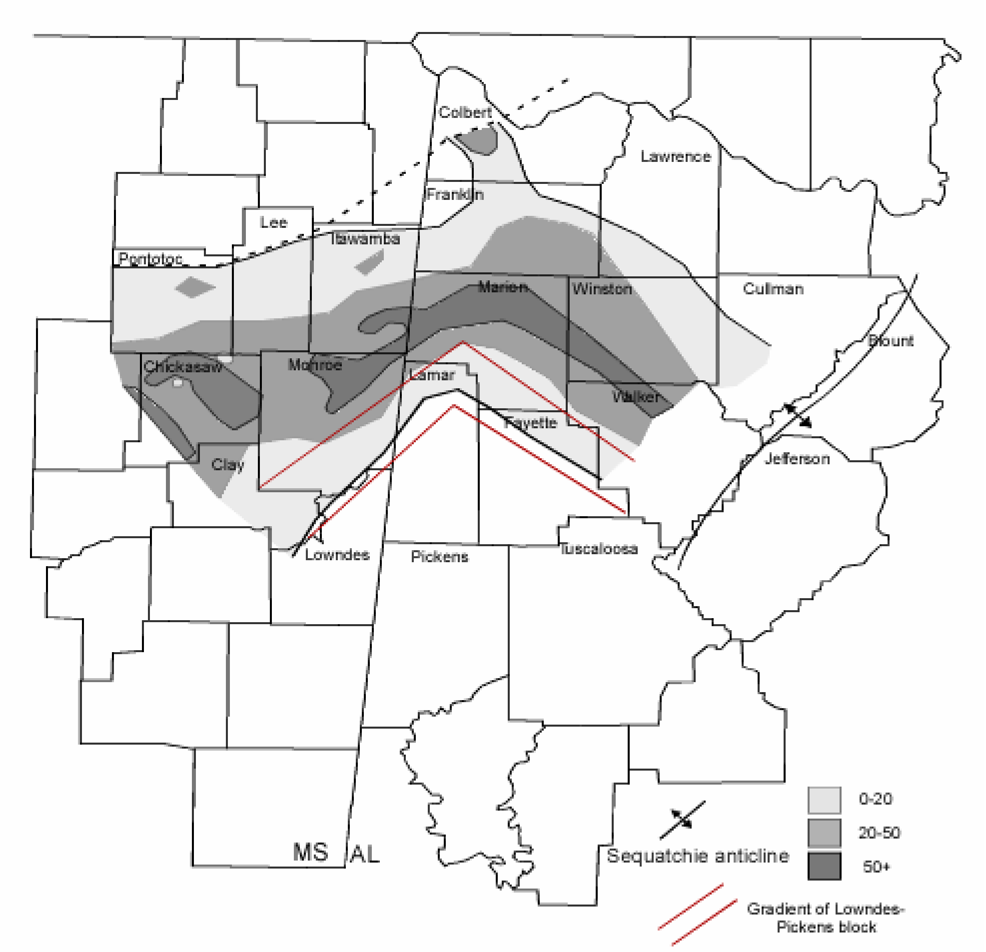

Figure 6.9: Shaded distribution map for the Evans sandstone. Map shows unit wraps around the Lowndes-Pickens block boundary and pinches out on the gradient of the block. Black line is zero sand, edge of shaded area (without line) is the limit of the data, and the dashed line is the erosional extent.

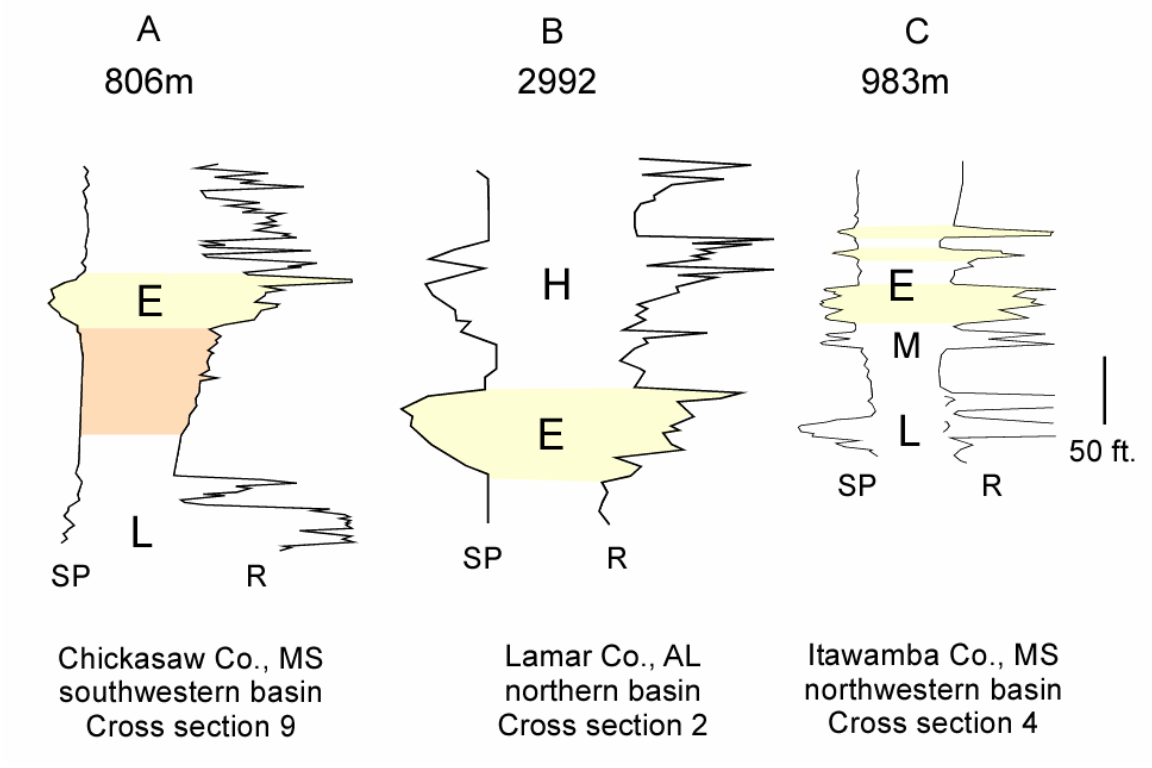

Figure 6.10: Typical spontaneous potential and resistivity curve response for the Evans sandstone. L-Lewis, M-Middle, E-Evans, H-Hartselle

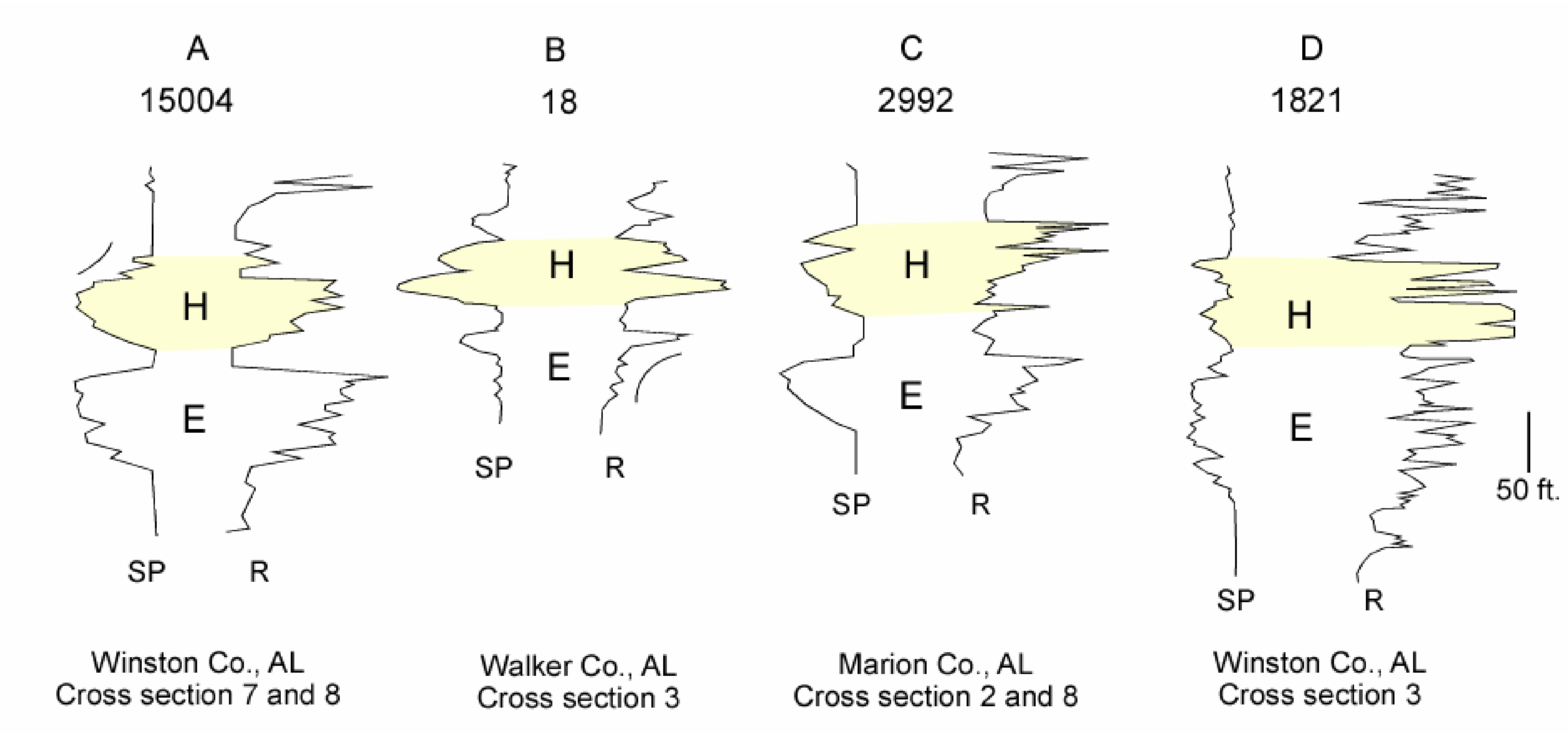

Figure 6.11: Typical spontaneous potential and resistivity curve response for the Hartselle Sandstone. H-Hartselle, E-Evans

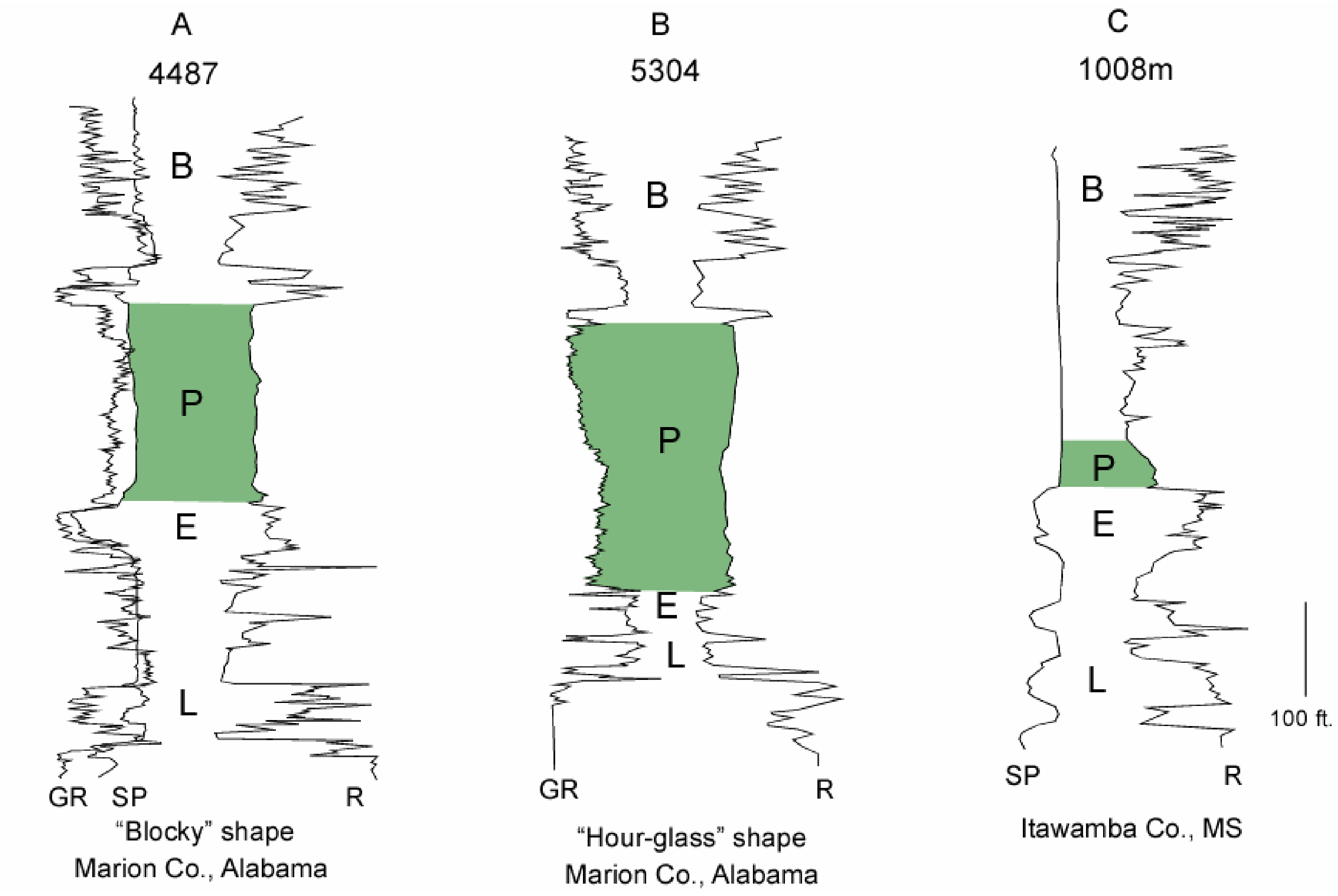

Figure 6.12: Typical spontaneous potential, resistivity, and gamma curve responses for the Pearce siltstone (green). Well locations indicated by red dots on Figure 6.13

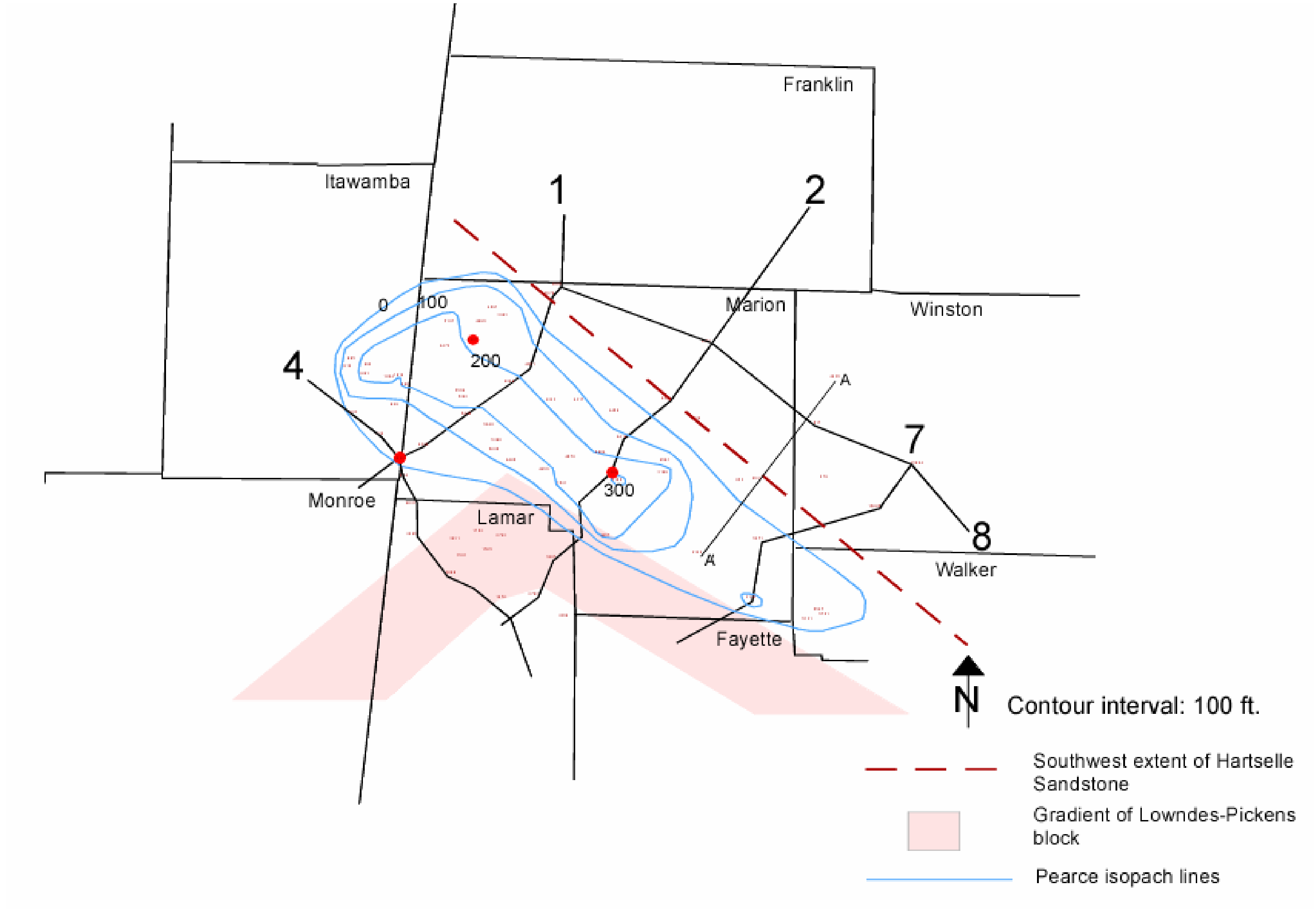

Figure 6.13: Isopach of the Pearce siltstone wedged in between the Lowndes-Pickens block and the Hartselle Sandstone. Red dots indicate well locations for Figure 6.12.

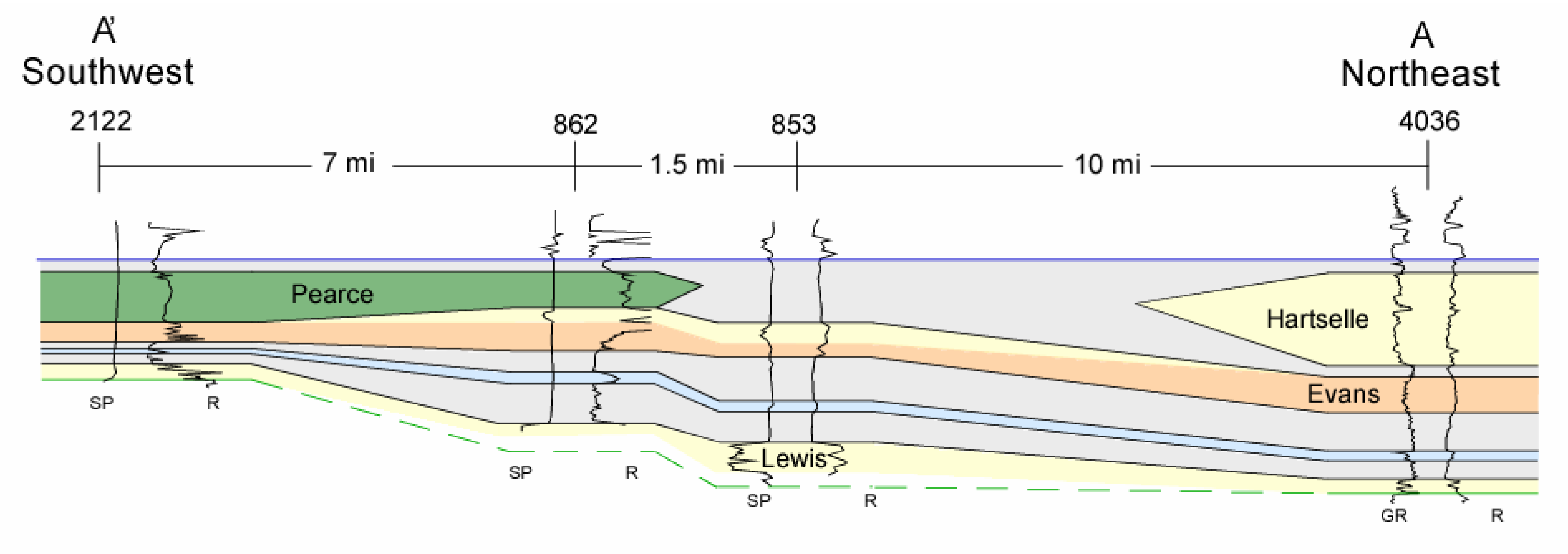

Figure 6.14: Supplemental cross section detailing lateral relationship between the Hartselle, Evans, and Pearce in the northeastern part of the basin. Cross section shows the area between cross sections 7 and 2, shown on Figure 6.13. Lithology key same as in Figure 6.2.

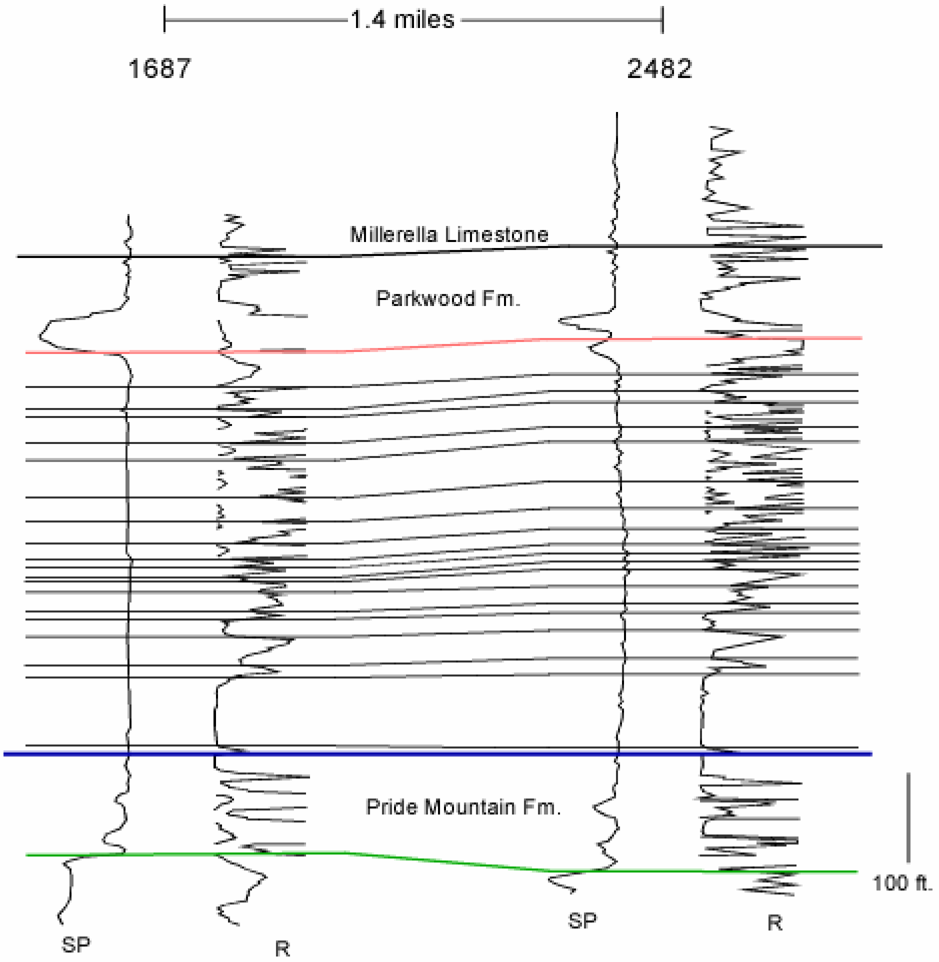

Figure 6.15: Diagram providing a closer look at lower Bangor correlations and lateral continuity of beds across the upper part of the ramp. Lower Bangor is the interval between blue and pink lines.

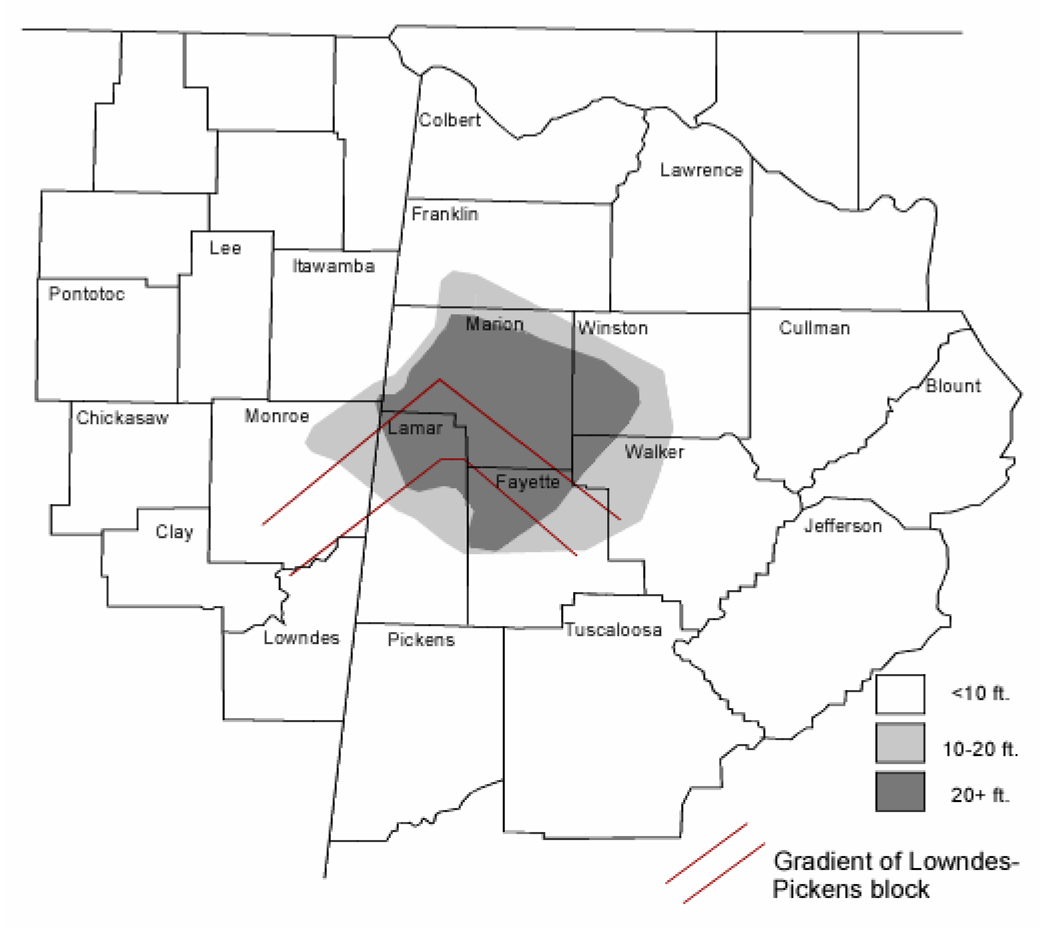

Figure 6.16: Isopach and distribution map of the lower Bangor shale. Interval has a maximum thickness of approximately 50 feet.

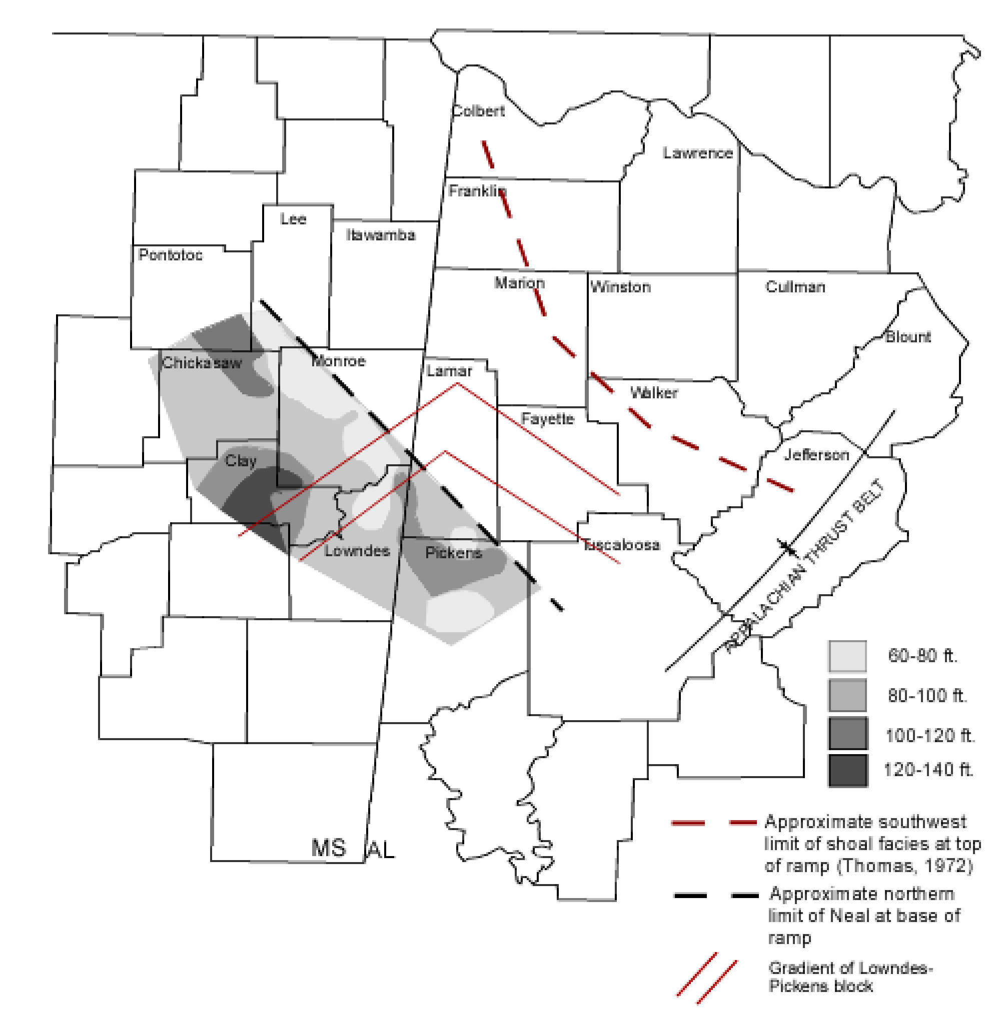

Figure 6.17: Isopach map of the Neal shale indicating thickening to the southwest. Edge of shaded area is the limit of the data.

# CHAPTER SEVEN
# INTERPRETATION AND DISCUSSION OF CROSS SECTIONS

## *Pride Mountain Formation and Hartselle Sandstone*

Because the Mississippian stratigraphic units extend widely in the subsurface, it is unreliable to make generalizations about the entire basin on the basis of observations in the outcrop around the northeastern part of the basin. Several previously published interpretations (e.g., Cleaves and Bat, 1988; Driese et al., 1994) of depositional systems for the Pride Mountain/Hartselle clastic tongue, interpreted from outcrop data, are not compatible with the subsurface distributions and are not applicable across the entire basin. For example, in outcrop, the Lewis sandstone is in discontinuous lenses; the Lewis limestone is laterally persistent; and the Middle and Evans sandstones are generally represented by limestone (Thomas, 1972a). The subsurface framework constructed in this study, however, shows that the Lewis and Evans are laterally continuous sandstones and the Lewis limestone is discontinuous throughout most of the basin, excluding on the Lowndes-Pickens block.

Well-log and cuttings data for this study agree with previous interpretations that the Pride Mountain Formation and Hartselle Sandstone were deposited in a shallow-marine environment. The Lewis, Middle, and Evans sandstones typically are represented by a coarsening-upward well-log signature, which suggests progradational deposits such as shallow-marine bars that have been interpreted throughout the basin (Higginbotham, 1986). Thin, sandy/oolitic limestone beds and sub-rounded quartz grains in the sandstones, suggestive of wave reworking, indicate that the Pride Mountain Formation and Hartselle Sandstone were deposited in shallow water. In northern Alabama (northern Marion, Fayette, Walker, and Winston Counties), interbedded shale within the Lewis and Evans sandstone intervals indicates fluctuating energy conditions or a decreased supply of clastic sediment in the northern part of the basin; whereas to the southwest, the resistivity signatures of both the Evans and Lewis sandstone intervals are progressively more massive.

The Lewis sandstone is an extensive sheet across the basin and commonly has a well-log signature indicative of marine-bar deposition. A “double sand” signature on the Lowndes-Pickens block in the Lewis sandstone is interpreted to represent stacked marine-bar sandstones on the basis of stacked coarsening-upward well-log signatures. The shale separation in the double sandstone may represent a single eustatic event, which possibly submerged the western side of the Lowndes-Pickens block resulting in a shale break within the sandstone. The distribution map (Fig. 6.5) and cross sections, however, show that the shale is localized and is laterally gradational into the more massive sandstone facies, where no break in the resistivity signature is visible. This suggests that the shale break is more localized and did not form as a result of a basin-wide event.

Cuttings descriptions indicate that the lithology of the Lewis limestone on the block differs from the limestone north and west (off) of the block. Micrite and wackestone facies are found in the northern and western part of the basin, off the block; whereas, fossiliferous and oolitic packstone deposits are more common on the block and in outcrops farther to the north. Pashin and Rindsburg (1993) suggested limestone deposition in the north was restricted to topographic highs (<20ft) inherited from the Tuscumbia ramp, which may explain why limestone distribution in the deeper parts of the basin is patchy if deposition was limited to topographic highs.

Two possible interpretations for the distribution pattern of Lewis limestone have implications for when the timing of deposition occurred. The first interpretation is that the Lewis limestone on the Lowndes-Pickens block was deposited concurrently with and is equivalent to the limestone in the deeper part of the basin (e.g., distribution pattern of Fig. 6.6). This interpretation suggests the Lowndes-Pickens block began moving sometime before the deposition of the limestone, as evidenced by the oolitic shallow-water facies on the block and the wackestone deeper water facies off the block. This interpretation would also imply that limited carbonate production and shale were the only deposition that occurred on the surface of the block during the deposition of the rest of the Pride Mountain and Hartselle interval. The Lewis limestone can be correlated from the northwestern deeper part of the basin onto the block in cross section 4. Other cross sections cannot confirm that the Lewis limestone on and off the block is laterally continuous, and therefore, the limestone on the block may be younger than the limestone off the block.

Another possible interpretation for the Lewis limestone on the block is that it is younger than the Lewis limestone off the block and was deposited along with the uppermost part of the Pride Mountain Formation and the Hartselle Sandstone. Cross section 3 (Plate 1) suggests that the limestone unit on the block can possibly be correlated northeastward where it overlies the Pride Mountain and Hartselle intervals (Fig. 7.1). Thus, the limestone is a “pseudo-Lewis” limestone because it only fits the definition of the Lewis limestone where present on the block and does not fit the definition elsewhere in the basin. Limestone distribution is patchy at the top of the Pride Mountain and Hartselle in the northwestern and western part of the basin; only the southwestern part of the basin is somewhat extensively covered by limestone (Fig. 7.1). The limestone may have been deposited in the shallowest parts of the basin, while shale was deposited in the slightly deeper areas, such as the sub-basin in the northwest. The pseudo-Lewis does not represent the earliest limestone deposition of the Bangor Limestone. The earliest Bangor deposit is an extensive limestone package which covers the entire basin and is a recognizable correlation marker. The pseudo-Lewis is a separate unit because it is present only in parts of the basin directly overlying part of the Hartselle; recognizable Bangor deposits overlie the pseudo-Lewis. The pseudo-Lewis was the last unit in the Pride Mountain Formation to be deposited. The pseudo-Lewis is comparable to the Millerella limestone, which overlies the lower Parkwood, in that it is a rather extensive, transgressive limestone unit that represents a decrease in tectonic subsidence or sediment supply and eustatic sea-level rise (Mars and Thomas, 1999).

Unlike the Lewis and Evans sandstones, which are extensive, the Middle sandstone has a limited distribution and is restricted to the northern part of the basin (Fig. 6.7). The limited distribution and coarsening-upward well-log signature suggest marine-bar deposition. The source of the quartzose sediment for the Middle may have either been reworked from the Lewis sandstone, the initial influx of sediment for the Evans interval, or possibly may represent a time with much less sand input between two big pulses of sand supply. Sparse evidence of reworking may be present in places where the Lewis sandstone thins and is replaced by a limestone (e.g., well 482m, cross section 1, Plate 1). Thick shale units, however, commonly lie both above and below the Middle, and the sandstone cannot be correlated directly to either the Lewis or Evans interval.

A small sub-basin has been identified in the Pride Mountain/Hartselle interval (Fig. 7.1). Overlying the typical coarsening-upward signature of the Evans sandstone in the northwestern part of the basin, are 2 to 4 thinner sandstones interbedded with silty shale and a thick shale found only in the northwestern part of the basin (Fig. 7.2) (cross section 4, Plate 1). The thick shale section is laterally equivalent to the Hartselle Sandstone and Pearce siltstone. The thick shale and thin sandstones above the Evans interval represent the fill of a small “Hartselle sub-basin” which formed as a result of the overall filling of the larger basin on the southwest and uplift of the Lowndes-Pickens block in the southeast.

The cross sections show the Pride Mountain sandstones thicken to the west and southwest and pinch out to the north. The overall Pride Mountain interval, however, appears to thicken to the north in the isopach map (Fig. 2.3) because of the thick shale interval that overlies the Evans sandstone. The regional distribution and thickness trends of the Lewis and Evans sandstones suggest deposition in an active tectonic setting with high sediment input into a shallow-marine environment. Wave reworking in shallow water of the marine-bar sediment could have resulted in the deposition of basin-wide sheet sandstones (Lewis and Evans).

### *Lowndes-Pickens Block*

Several studies have failed to recognize the Lowndes-Pickens block as a structural feature capable of influencing sediment dispersal in Alabama and Mississippi, most likely because these studies did not include well data from the southern part of the basin. The Pride Mountain/Hartselle isopach map (Fig. 2.3) shows the sediment dispersal pattern of the clastic tongue thinning onto a structure in the southern part of the basin. The Pride Mountain/Hartselle isopach map indicates that the structure in the southern part of the basin has relatively straight boundaries with uniform gradients that meet at an orthogonal junction in Marion County, Alabama. Sediment dispersal patterns indicate the block had some control in the southern part of the basin as previously interpreted by Higginbotham (1986).

The relationship of the Lowndes-Pickens block movement to sediment dispersal is clearly seen in (1) the distribution pattern and pinch out of the Middle and Evans sandstones against the northern margins of the block and (2) the elongate trend of the Pearce siltstone onto the northeastern limb of the block. The relationship of block movement to the Lewis sandstone is less obvious; although, a regional facies distribution pattern can be identified on the block. Higginbotham (1986) determined that the Lowndes-Pickens block did not affect the sediment dispersal of the Lewis sandstone because the sandstone did not change thickness across the block. Well-log signatures on the southeastern end of cross section 4 (wells 1769 to 2546, Plate 1), however, illustrate that the Lewis sandstone does not blanket the entire surface of the block, but rather, grades into sandy limestone or limestone on the southeastern part of the block. Also, little Lewis sandstone is found in the Appalachian thrust belt (Thomas, 1972a). The upward movement of the block may have resulted in a decreased amount of sediment transported to the block, resulting in widespread limestone deposition. Alternatively, the block may not have affected sediment dispersal, and clastic sediments simply were not transported to the southeastern part of the block or may have been reworked and transported to specific areas on the western side of the block.

This study prefers the pseudo-Lewis limestone interpretation. It is more likely that the Lewis sandstone was being reworked on the surface of the Lowndes-Pickens block during late Pride Mountain and Hartselle deposition than of a very thin shale and limestone bed (<10 feet) during the rest of Pride Mountain and Hartselle deposition. The pseudo-Lewis interpretation implies that during the deposition of the Middle, Evans, and Hartselle sandstones, the Lewis sandstone was the only unit being deposited on the Lowndes-Pickens block. The surface of the Lowndes-Pickens block was likely under shallow water, influenced by wave-reworking, winnowing of mud, reworking of sediment, and received little clastic input after the original influx of sediment. The “pseudo-Lewis” limestone prograded over the Pride Mountain/Hartselle clastic tongue and the block during a rise in sea level shortly before Bangor deposition began (Fig. 7.1). This interpretation cannot constrain exactly when the block began moving; although, the Middle sandstone onlaps the block, which indicates it must have began moving shortly after Lewis sandstone deposition at the latest.

### *Pearce Siltstone*

Abundant organic indicators (carbonaceous plant material, pyrite, and sulfur) and limited fossil quantity and diversity (few tiny bivalves and cephalopods?) within the Pearce siltstone suggest the unit was deposited in a restricted environment. Shale and limestone units directly overlying the Pearce (e.g., well 1838, cross section 2, Plate 1) contain a higher diversity and abundance of fossils (shell fragments, echinoderms, and bryozoans), which suggests more normal marine or less restricted conditions. Cuttings show an upward change in lithology from muddy, limey siltstone to more fissile, non-silty shale above, also suggesting the end of restriction. The sharp contact between the restricted and normal marine units, recognized in well logs (cross section 2, well 1838) and in cuttings, suggests the environment changed fairly rapidly.

Pearce siltstone deposition was a result of restricted circulation produced by a structural barrier, the Lowndes-Pickens block, to the southwest and the Hartselle Sandstone to the northeast. The Pearce isopach (Fig. 6.13) shows that the northwest part of the unit seems to spread out, wrap around, and pinch out beyond the control of the northeastern boundary of the block. The isopach map also shows the Pearce thins southwestward and pinches out against the block. The close influence on deposition indicates a strong relationship between Pearce distribution and facies to the shape of the block. The northeastern limit of the Pearce unit parallels the southwestern edge of the Hartselle Sandstone resulting in a northwest-southeast elongate body of Pearce. The Pearce lies in the same stratigraphic position southwestward of the Hartselle suggesting that Hartselle and Pearce deposition was occurring concurrently.

Although the Pearce is laterally equivalent to the Hartselle Sandstone, no evidence of interaction (continuity or interbedding) between the units is recognized in cuttings or well logs. Cross section A (Fig. 6.14) suggests that the shale laterally separates the Pearce from the Hartselle, and cuttings descriptions demonstrate no lateral interaction between the units, although sampling was limited. The Pearce unit is thicker than the Hartselle interval; increased accommodation space, possibly created during the movement of the Lowndes-Pickens block, may account for the increased thickness of the Pearce.

The Pearce does not appear to be laterally equivalent to lower units of the Pride Mountain Formation (Lewis through Evans section). The cross section correlations show the Evans as a separate unit beneath the Pearce, a unit which grades into limestone and pinches out on the gradient of the Lowndes-Pickens block. This suggests that the deposition of the Pearce is not directly related to the deposition of the Evans and must be interpreted within the context of the Hartselle.

The Pearce siltstone contributes to the resolution of the two conflicting depositional system interpretations (barrier-island or delta) for the Hartselle Sandstone. The straight, elongate geometry of both the Pearce and Hartselle units suggests they were deposited as part of a barrier-island system, rather than wave-dominated delta system, which would not produce an elongate geometry. The restricted facies also suggest back barrier deposition rather than delta front deposition, which would be expected to exhibit normal-marine facies. The vertical facies succession and limited lateral interaction between the Pearce and Hartselle are also not indicative of a delta front, which would produce a coarsening-upward sequence as the Hartselle delta prograded southward.

Considering the Hartselle to be a northeast-facing barrier island, any unit at that stratigraphic level to the southwest is in the setting of a restricted back-barrier deposit. The lateral equivalent of the Pearce to the northwest, however, has a normal shale signature in well logs.  Cuttings should be described in the shale unit to determine if it is also a restricted facies.  The Pearce may represent an area of further restriction within the back barrier created by the Lowndes-Pickens block.  The restricted lagoon might connect northwestward to more open marine waters.

### ***Bangor Limestone and Floyd/Neal Shale***

The lower Bangor Limestone fits a traditional carbonate ramp model as indicated by the facies stacking pattern and gradation of environments from oolitic shoal to basinal shale as interpreted by previous studies (Miesfeldt, 1985; Thomas, 1988). The thickest part of the lower Bangor is in Marion County, Alabama, and formed in response to either sea level rise and/or basin subsidence, resulting in a thick carbonate buildup. Fossils (brachiopods, bryozoans, echinoderms, and gastropods) identified in the lower Bangor are consistent with shallow, open-marine shelf deposition. Cuttings descriptions indicate the negative SP kick in the upper part of the lower Bangor ramp (northeastern end of cross sections 1 and 2, Plate 1) is produced by both oolitic grainstone and fossiliferous packstone. Thin beds of packstone and grainstone indicate the cross sections do not extend northeastward to the shoal deposits, in which individual units are more than 20 feet thick in outcrop (Thomas, 1972a). Therefore, the grainstone facies are interpreted as wash-over beds close to the southwestern boundary of the shoal. The accumulation of pelloidal packstone and wackestone southwestward on the middle to lower part of the ramp indicates deepening water and the addition of mud. The lateral gradation into black shale at the toe of the ramp suggests slow deposition in deeper water where little coarser sediment was washed down from the upper ramp. A local, abnormally thin section of Bangor on the lower part of the ramp (well 79m, cross section 1, Plate 1) is interpreted as a small scour channel or pit.

Both the cross sections and Bangor isopach map (Fig. 2.5) indicate that movement of the Lowndes-Pickens block did not affect Bangor deposition. The Bangor ramp uniformly thins to the southwest and does not change in thickness across the northeastern boundary of the block (cross section 2). Similarly, the northwest-southeast striking

Neal/Floyd shale also maintains a constant thickness across the northwestern boundary of the block (cross section 5). The return to normal-marine and unrestricted conditions immediately after deposition of the Pearce siltstone suggests that the end of Pearce deposition coincides with the end of block movement. Shallow-marine limestone and shale, laterally equivalent to the shale overlying the Pearce, directly overlie the Hartselle Sandstone suggesting a basin-wide, sea-level event. The sharp contact indicates a rapid increase in water depth or subsidence resulting in a blanket of shallow-marine shale and limestone across the entire basin, marking the beginning of Bangor deposition. The results of this study agree with Higginbotham (1986) that the Lowndes-Pickens block moved during a short period of time beginning sometime during the deposition of the Lewis sandstone and had finished moving before deposition of the Bangor Limestone.

### ***Summary of Basin Fill***

The stratigraphic framework of the basin is used to establish the sequence of events during the Pride Mountain, Hartselle, and Bangor time of basin fill. As the basin began to subside, the Monteagle carbonate ramp sediments were deposited on the northeastern margin of the basin. Pride Mountain clastic sedimentation began to fill the basin concurrently with the start of movement of the Lowndes-Pickens block. Shallow-water wave reworking of the marine-bar sediment of the Lewis and Evans sandstones resulted in the deposition of basin-wide sheet sandstones. The basin filled first in the southwest resulting in the creation of the Hartselle sub-basin in the north shortly after Evans deposition. The sub-basin is bounded by the Hartselle Sandstone barrier island on the north and is occupied by the Pearce siltstone in the east; thick shale overlies the Evans in the west. The pseudo-Lewis limestone prograded over the Pride Mountain and Hartselle shortly before Bangor deposition began.

A second phase of subsidence initiated the start of Bangor carbonate deposition on the northern margin and the Neal black shale deposition in the southwestern part of the basin. The Lowndes-Pickens block had stopped moving by this time and no longer affected sediment dispersal thereafter. The change from the Pearce/Hartselle clastic deposition to the Bangor carbonate ramp reestablished the basin geometry with shallow-marine waters across the basin (which deepened as subsidence rates increased during Bangor deposition) and clastic sediment deposition in the southwestern part of the basin.

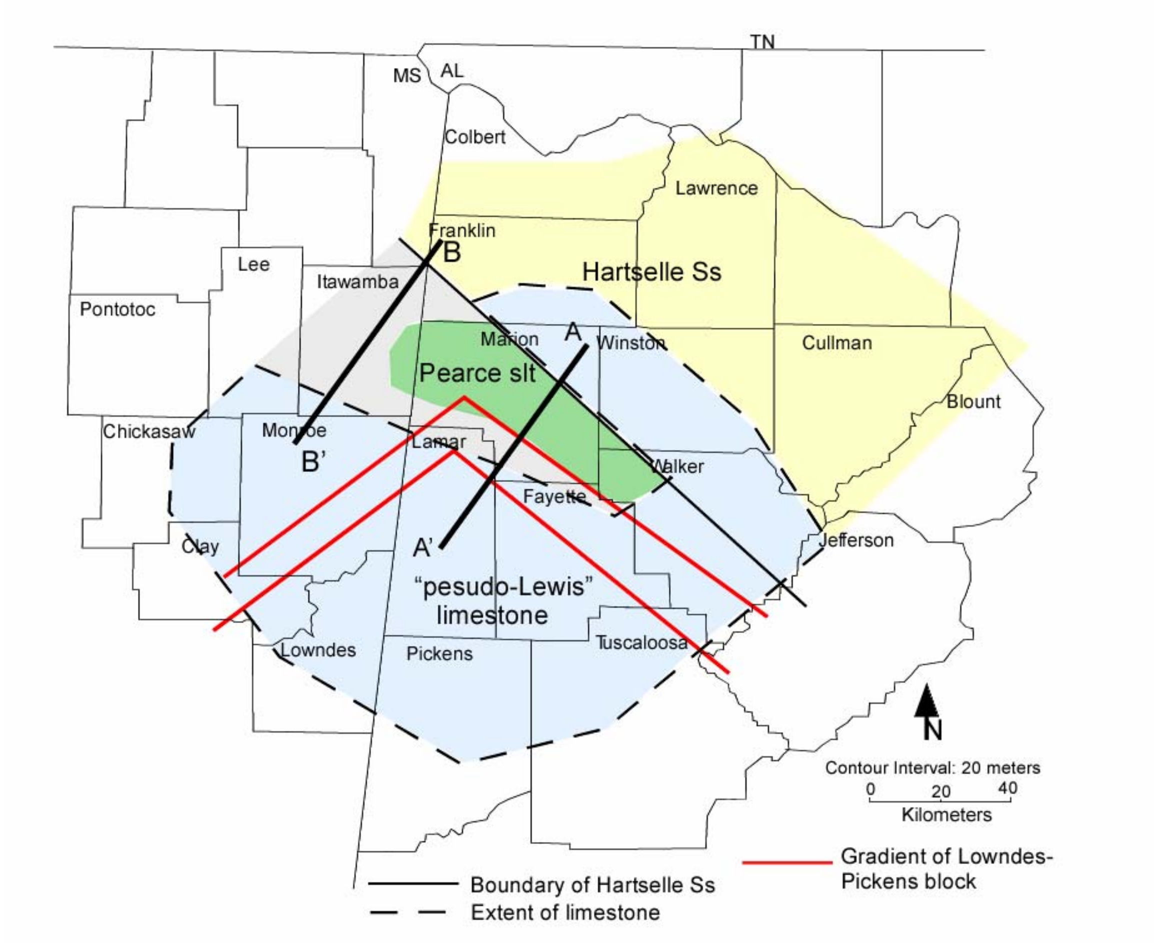

Figure 7.1: Facies distribution map of Hartselle sub-basin. Distribution pattern of the "pseudo-Lewis" limestone (blue) extends from the southwest to overlie the Hartselle sandstone in the northeastern part of the basin.
yellow-sandstone, green-Pearce, gray-shale

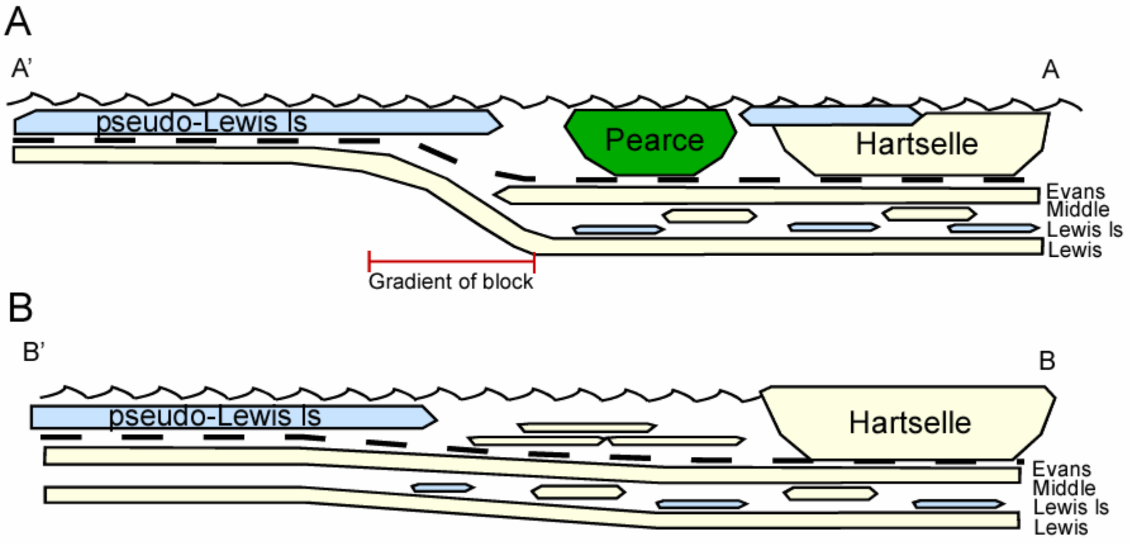

Figure 7.2: A. Cross section A-A' through central Hartselle sub-basin. Modeled after cross section 2 (Plate 1). Black dashed line represents boundary between the deposits filling the Hartselle sub-basin (above line) and Pride Mountain deposits (below line). Unit thickness and horizontal distance not to scale.

B. Cross section B-B' through western Hartselle sub-basin. Modeled after interpretation of what lies westward of Pearce siltstone and northwestern end of cross section 4 (plate 1). Unit thickness and horizontal distance not to scale.

# CHAPTER EIGHT
# SEQUENCE STRATIGRAPHY

In this chapter, cross sections 2 and 4 (Plate 3) are used to divide the Pride Mountain Formation, Hartselle Sandstone, and lower Bangor Limestone into coarsening (regressive)- and fining (transgressive)-upward cycles. Large-scale cycles, shown by red triangles on Plate 3, represent basin-wide large-scale events. Pride Mountain and Hartselle cycles, shown by black triangles on Plate 3, represent coarsening-upward shale to sandstone cycles, each capped by a flooding surface. The lower Bangor Limestone is divided into shoaling-upward cycles on the basis of resistivity expression, shown by blue triangles on Plate 3. Internal divisions, shale or limestone interbeds marked by resistivity spikes, within the sandstone intervals are marked with black dashed lines. The sections in this chapter are organized by systems tracts, and the last section describes the application of the transgressive-regressive sequence model.

### ***Monteagle Limestone Highstand Systems Tract***

The Monteagle Limestone has previously been interpreted as a highstand systems tract on the basis of the exhibited carbonate-ramp geometry and the cyclic coarsening-upward facies stacking patterns (Stapor and Cleaves, 1992). This study agrees with the interpretation that the buildup of a carbonate ramp on the basin margin occurred during sea-level highstand. The Underfilled Trinity model predicted that black shale may have been deposited at the toe of the carbonate ramp. Black shale commonly represents a condensed section indicating sea-level transgression before highstand deposition. A geographically limited exposure surface at the top of the Monteagle was identified in northern Alabama and southern Tennessee, which indicates sea level fall after the deposition of the Monteagle. Falling sea level exposed Monteagle subtidal deposits (Driese et al., 1994).

### *Pride Mountain Formation and Hartselle Sandstone Falling-Stage Systems Tract*

Falling-stage systems tracts are deposited on the basin margin during base-level fall when the sedimentation rate outpaces the fall in sea level, resulting in sandstone progradation across the basin and normal regression of the shoreline (Catuneanu, 2006). This study interprets the Pride Mountain Formation as a falling-stage systems tract because (1) the location of the deposits in relation to the basin margin, (2) the progradational and shallowing-upward nature of the sandstone cycles, and (3) the fact that sea-level must have already been falling in order to produce the exposure surface at the top of the Monteagle Limestone. Sea-level fall is also indicated by a coarsening-upward grain size in each cycle from the Lewis to the Hartselle, and stacked progradational and shallowing-upward sandstone/shale cycles capped by an exposure surface at the top of the Hartselle indicating sea regression (e.g., well 4361, cross section 2, red triangle, Plate 3). This study disagrees with Stapor and Cleaves (1992) that the Pride Mountain Formation was deposited as a lowstand wedge. A classic lowstand wedge is deposited as turbidites off the shelf edge (Catuneanu, 2006); this is not the depositional environment of the Pride Mountain.

Tree trunk fragments, root penetrations, and plant-foliage fragments identified at the top of the Hartselle Sandstone (Thomas and Mack, 1982), indicate subaerial exposure and are interpreted to mark the surface of maximum sea-level regression (maximum regressive surface, MRS). This study suggests that the Hartselle is part of the same depositional package as the Pride Mountain Formation and, therefore, is part of the falling-stage systems tract. A possible exposure surface, developed in subtidal deposits, at the top of the Monteagle Limestone indicates sea-level regression (Driese et al., 1994) and could be the northeastward expression of the maximum regressive surface interpreted at the top of the Hartselle. These interpretations conflict with the interpretations of Stapor and Cleaves (1992) that the Hartselle Sandstone represents a transgressive systems tract. The exposure surface present at the top of the Hartselle cannot have been formed during sea-level transgression.

Higher frequency subdivisions are identified in the Lewis, Evans, and Hartselle sandstone intervals on the basis of resistivity pattern (black triangles and dashed lines on Plate 3). Each black-triangle cycle begins with a basal marine shale followed by an overlying progradational sandstone unit indicating a coarsening- and shallowing-upward facies stacking pattern. The contact between the sandstone unit and the overlying marine shale is interpreted as a flooding surface. Four flooding surfaces are evidenced by a sharp contact with an overlying marine shale at the top of the Lewis, Middle, Evans, and Hartselle sandstones, respectively. Flooding surfaces are the results of either subsidence outpacing sea level drop or static sea level drop accompanied by changes in sedimentation rates in which less clastic sediment is deposited resulting in the end of the shallowing-upward cycle. The limited lateral extent of the Middle sandstone suggests the overlying flooding surface may not be a true flooding surface, but a continuation of the flooding event overlying the Lewis sandstone interval punctuated by a small influx of sediment.

On the northeast-southwest trending cross sections, the Lewis and Evans units are not at consistent stratigraphic levels; whereas, on the northwest-southeast striking cross sections (parallel to depositional strike), in the southwestern part of the basin, the sandstones exhibit “railroad track” geometry, where not influenced by the Lowndes-Pickens block. North of the Lowndes-Pickens block, the shale above the Evans increases in thickness to the northwest (cross section 4 and 6, Plate 1) and the Evans descends in the section, which indicates the parasequences downlap toward the north. The stratigraphic architecture of the clastic tongue also exhibits an offlap pattern to the north. The main depocenter of the basin was pushed to the north from the time of Evans deposition to Hartselle deposition.

The typical hour-glass shape of the Pearce siltstone resistivity curve shows an internal coarsening-upward expression stacked on top of a fining-upward expression, within the siltstone facies, possibly resulting from a change in sea level (e.g., wells 1838 through 4414, cross section 2, Plate 3). Cross section correlations show the Evans as a separate unit beneath the Pearce, which implies that the Pearce is not a lateral equivalent to the lower units of the Pride Mountain and, therefore, is not part of the parasequence framework interpreted for the Pride Mountain sandstones. It is unclear how the internal divisions of the Pearce relate to the Hartselle because cross sections do not show any direct relationship between the internal divisions of the Pearce and Hartselle.

### *Transgressive Systems Tract and Neal Shale Condensed Section*

The “pseudo-Lewis” limestone, overlying part of the basin (Fig. 7.1), represents sea-level transgression over the top of the Pride Mountain and Hartselle clastic tongue and is interpreted as the start of a major basin-wide transgression. After the initial transgression over the clastic interval, sea level continued to rise and deposition of a condensed interval, recognized by Stapor and North (1999), in the lowermost part of the Bangor began. The Neal shale is interpreted as a condensed section at the base of the Bangor ramp in the southwestern part of the basin. Cross section 2 (Plate 3) demonstrates that the condensed interval recognized in the lower part of the Bangor by Stapor and North (1999) can be traced southwestward into the Neal shale. The transgressive systems tract begins with the deposition of the “pseudo-Lewis” limestone over the Pride Mountain/Hartselle interval and ends with the deposition of the condensed interval in the lower Bangor marking the point of maximum sea-level transgression.

### *Bangor Limestone Highstand Systems Tract*

Cross section 2, perpendicular to the depositional strike of the Bangor Limestone, and cross section 4, parallel to the depositional strike across the middle of the ramp, are used as representative sections for counting coarsening-upward cycles in the lower Bangor Limestone (Plate 3). The lateral continuity of individual beds recognized in the middle and upper Bangor ramp suggests that the number of larger scale coarsening-upward cycles should not differ between cross sections. Cross section 4 is oblique to strike of the ramp southeast of well 1648 as a result of the ramp curving slightly northeastward, which accounts for thinning to the southeast shown in the cross section. Cycles were not counted southeast of well 1648 in cross section 4 for that reason. Cross sections 5, 6, and 9 depict the Neal shale which is not divided into cycles.

As shown in cross section 4 (red triangles, Plate 3), the stratigraphic section from slightly below the base of the lower Bangor ramp to the top of the lower Bangor is composed of two large-scale transgressive-regressive sequences (red triangles). The lowermost large-scale coarsening (shoaling)-upward cycle on the upper part of the ramp (measured at northeastern end of cross section 2 and northwestern end of cross section 4, Plate 3) varies in thickness between 230 and 300 feet (averaging 274 feet) and the overlying fining-upward (transgressive) cycle averages around 70 feet. The northeastern end of cross section 2 (well 2992 to 2550, Plate 3) shows a similar transgressive-regressive cycle distribution in the upper and middle part of the lower Bangor ramp as seen in the middle part of the ramp represented by cross section 4.

The Bangor ramp was divided into high-frequency shoaling-upward (regressive) sequences on the basis of resistivity log signatures and the lateral continuity of each cycle. Each cycle begins with a basal shaly zone followed by a coarsening-upward resistivity expression of the limestone, also recognizable in cuttings. The cycle ends upward where the resistivity signature reaches a maximum followed by either a change to fining-upward pattern or an abrupt contact with an overlying shaly unit. Six to seven higher frequency shoaling-upward cycles, or parasequences, are identified within the lower Bangor Limestone. The top of each cycle is shown by a thin black line (Plate 3), each marking a basin-wide flooding surface. The uppermost cycle has a maximum thickness of 67 feet (ranging between 40 and 100 feet) and the underlying three cycles are 45 feet thick on average. Southwestward along cross section 2, the coarsening-upward cycles thin and decrease to only two recognizable cycles at the toe of the ramp (southwest of well 5255, Plate 3).

Continued tectonic subsidence would have eventually outpaced carbonate production and led to a flooding surface. This is evident in well logs and cuttings where facies-stacking patterns show a coarsening-upward succession capped by a shaly deposit on a flooding surface indicating termination of carbonate production related to an increase in water depth. The number of shoaling-upward cycles decreases to the southwest indicating a stable region of deeper water in which deposition was unaffected by subsidence rates or carbonate production. Limited clastic influx and carbonate production in the southwest allowed for the deposition of the black shale.

Both the flooding surfaces and the large-scale transgressive-regressive cycles (red triangles, Plate 3) are basin wide and could have been produced by either episodes of tectonic subsidence or sea-level fluctuations. A study by Ross and Ross (1988) suggests that the Chesterian series contains seven third-order sea-level cycles. This study has shown the Pride Mountain through lower Bangor Limestone stratigraphy, excluding the

Parkwood Formation, contains approximately 11 cycles. Therefore, cycle formation may be the result of both eustacy and tectonism.

Limestone beds in the upper part of the Bangor ramp exhibit an aggradational stacking pattern (e.g., northeastern end of cross section 2, Plate 3). The lower Bangor ramp is composed of clinoforms which thin and pinch out into the Neal shale at the toe of the ramp. Each clinoform grades from oolitic grainstone into packstone, wackestone, and mudstone southwestward down the ramp, resulting in uniform facies belts on the ramp (e.g., Fig. 2.5). The entire thickness of the lower Bangor stratigraphic section (approximately 400 feet) thins southwestward and is equivalent to the 100 feet of Neal shale. Therefore, the top of the Neal shale is coeval with the top of the lower Bangor.

Maximum sea-level transgression was reached during the deposition of the condensed section in the lower Bangor Limestone, and sea-level remained at a highstand for the rest of lower Bangor deposition. Subsidence increased rapidly toward the end of the Mississippian (Whiting and Thomas, 1994) which resulted in increased accommodation space and led to thick carbonate buildup on the basin margin. Prodelta muds of the Floyd Shale terminated black-shale deposition in the southwest and added mud to the lower part of the carbonate ramp as Bangor deposition ended.

### *Application of T-R Model*

The transgressive-regressive (T-R) sequence model (Embry and Johannessen, 1992) is applied to the stratigraphic section from the top of the Tuscumbia through the Millerella limestone (Fig. 8.1). The T-R model was used for this study because the Pride Mountain and Hartselle are mostly shallow-marine deposits, and marine-flooding surfaces are more extensive in the central part of the basin and more reliable to identify in geophysical well logs. One partial T-R sequence (sequence A) and one complete T-R sequence (sequence B) are identified in the Pride Mountain Formation, Hartselle Sandstone, and lower Bangor Limestone interval.

Sequence A contains only the regressive part of the T-R sequence. Sequence A is considered a partial sequence on the basis that the transgressive systems tract represented by the black shale at the toe of the Monteagle carbonate ramp has not yet been identified in outcrop, only suspected to be present. Therefore, no lower maximum regressive surface sequence boundary is identified. The Monteagle Limestone carbonate ramp is interpreted to be a highstand systems tract deposit. The Pride Mountain Formation and Hartselle Sandstone are interpreted as a falling-stage systems tract on the basis of progradational facies stacking patterns and deposition on the basin margin. Together the Pride Mountain/Hartselle falling-stage systems tract and the Monteagle highstand systems tract are interpreted as a regressive systems tract under T-R sequence model terminology (Fig. 8.1). The upper sequence boundary is the maximum regressive surface (MRS) identified at the top of the Hartselle Sandstone and Monteagle Limestone.

Sequence B is a full transgressive-regressive sequence (Fig. 8.1). The lower boundary of the sequence is the Hartselle/Monteagle maximum regressive surface. The limestone overlying the Hartselle and the condensed interval in the lower Bangor represent sea-level rise and are interpreted to be a transgressive systems tract. The top of the condensed interval within the basal shale of the lower Bangor and the equivalent part of the Neal shale (cross section 2, Plate 3) is interpreted as a maximum flooding surface. The maximum flooding surface separates the transgressive sequence tract from the overlying Bangor highstand systems tract (Stapor and North, 1999). The regressive systems tract in Sequence B includes the lower Bangor highstand systems tract and the lower Parkwood Formation lowstand systems tract. The upper MRS sequence boundary has not been identified and may lie somewhere near the top of the lower Parkwood formation. Millerella limestone, above the lower Parkwood, is widely recognized as a basin-wide transgressive unit deposited in shallow water (Thomas, 1972a).

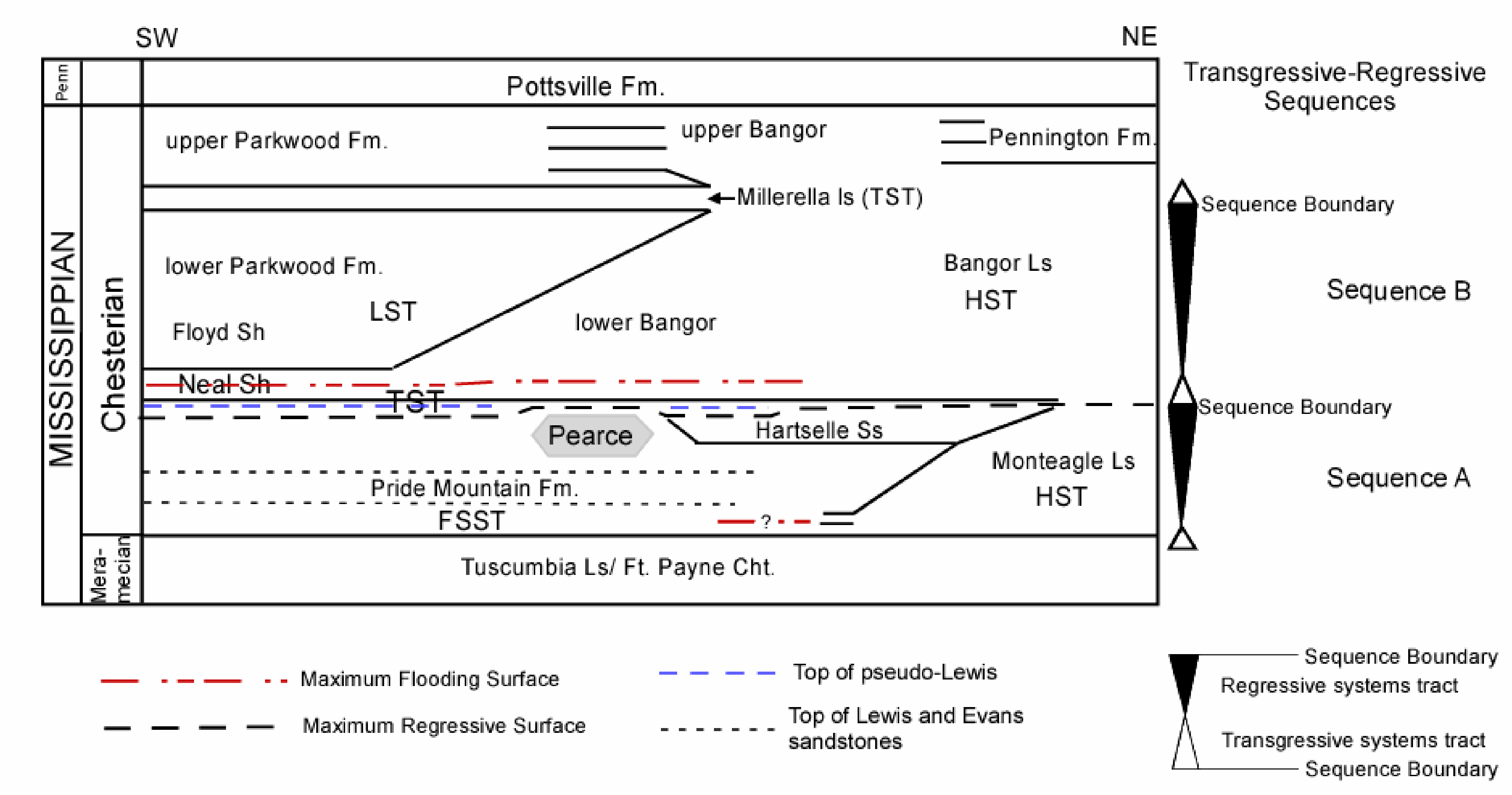

Figure 8.1: Diagrammatic representation of thickness and sequence subdivisions. Time lines are represented by solid black lines. Diagram is a mix of transgressive-regressive model (Sequence A and B) and systems tract divisions from traditional sequence stratigraphy terminology. TST=transgressive systems tract; FSST=falling-stage systems tract; HST=highstand systems tract; LST=lowstand systems tract.

# CHAPTER NINE
# SUMMARY AND CONCLUSIONS

The Mississippian part of the synorogenic clastic wedge (Pride Mountain Formation, Hartselle Sandstone, lower Bangor Limestone, Floyd/Neal Shale, and Parkwood Formation) in the Black Warrior basin contains two “Underfilled Trinities” representing two pulses of tectonic activity. The application of the Underfilled Trinity model links the stratal architecture of the basin fill to the quantitative subsidence history calculated by previously published studies (e.g., Thomas and Whiting, 1995). Both the conceptual and quantitative models conclude that the Pride Mountain/Hartselle clastic tongue reflects deposition in a slowly subsiding basin with limited accommodation space; whereas, the lower Parkwood clastic tongue was deposited during a time of higher subsidence rates and greater accommodation space.

Cuttings descriptions and well-log pattern interpretations indicate that the sandstone, limestone, and shale succession in the Pride Mountain Formation and Hartselle Sandstone was deposited in shallow-water environments. Marine-bar deposits are recognized in the Lewis, Middle, and Evans sandstones interpreted from a coarsening-upward resistivity signature. The elongate geometry and vertical facies successions in the Hartselle Sandstone indicate deposition of a barrier-island system.

This study has further constrained the duration of movement for the Lowndes-Pickens block and its effects on the stratigraphic architecture of the Pride Mountain/ Hartselle clastic tongue. The Lewis sandstone was reworked by the shallow waters on the surface of the block during the deposition of the remainder of the Pride Mountain Formation. Distribution and facies variations within the Lewis limestone suggest that the limestone on the block may be younger than the limestone off of the block. It is unknown if block movement began during or shortly after Lewis sandstone deposition; although, it must have been moving in order for the Middle sandstone to onlap the block. The thick shale above the Evans suggests the southwest part of the basin filled first and shifted the main depocenter to the north-central part of the basin which resulted in the formation of the Hartselle sub-basin. The Pearce siltstone, a previously unnamed unit deposited between the northeastern limb of the Lowndes-Pickens block and the southwestern limit of the Hartselle Sandstone, represents deposition in an area of restricted circulation created by the block in the eastern part of the Hartselle sub-basin. The end of block movement was coincident with the end of Pearce deposition as evidenced by a return to normal, non-restricted, marine conditions in the shale and limestone overlying the Pearce.

Sediment dispersal patterns and parasequence progradation direction suggest the clastic sediments for the Pride Mountain/Hartselle clastic tongue entered the basin from the southwest. The Pride Mountain/Hartselle isopach map, sandstone distribution maps, and the distribution of marine-bar facies suggest accommodation space was greater in the western and north-central part of the basin than in the south, largely as a result of the Lowndes-Pickens block. The southwestern part of the basin filled first and shifted the main depocenter to the north-central part of the basin which resulted in the formation of the Hartselle sub-basin.

Fossils and the gradation of facies from oolitic grainstones to micrite and basinal black shale (Neal) within the lower Bangor Limestone are consistent with models for deposition on a carbonate ramp with deepening water to the southwest. The lower

Bangor ramp is composed of clinoforms which thin and pinch out into the Neal black shale, lowermost part of the Floyd Shale. The entire thickness of the lower Bangor stratigraphic section thins southwestward and is equivalent to 60 feet of Neal shale at the toe of the ramp. Further work needs to be conducted on the facies change between the black shale and limestone facies to better draw a boundary between the black shale, which is an unconventional gas play, and the dark lower Bangor carbonate facies. The stratigraphic architecture (both thickness and lateral extent) defines the area of prospective shale gas. Cross sections indicate the movement of the Lowndes-Pickens block did not affect the deposition of the Bangor Limestone or Neal shale.

The fill of the Black Warrior basin records the interplay between basin subsidence and eustacy. The interval from the top of the Tuscumbia Limestone to the base of the Millerella limestone contains one partial and one complete transgressive-regressive stratigraphic sequence. The Pride Mountain and Hartselle contain four progradational sandstone parasequences, two of which are basin wide and two of which are located in the northern part of the basin. The Pride Mountain/Hartselle falling-stage systems tract and the Monteagle Limestone highstand systems tract together compose a regressive systems tract capped by a maximum regressive surface at the top of the Hartselle and Monteagle. The complete T-R sequence begins with the transgressive systems tract, identified as the limestone and shale overlying the Hartselle and Evans, respectively, and the condensed interval in the lower Bangor Limestone. A maximum flooding surface, recognized in outcrop in Alabama, separates the transgressive systems tract from the overlying Bangor highstand systems tract (Stapor and North, 1999). The number of cycles in the upper part of the lower Bangor ramp indicates both eustacy and subsidence played a role in the formation of the ramp. The lower Bangor ramp contains six to seven basin-wide coarsening-upward parasequences capped by basin-wide flooding surfaces. The Neal shale is a lateral and temporal equivalent of the lower Bangor deposited at the toe of the ramp as a condensed section.

# APPENDIX A

A-1 Alabama wells
A-2 Mississippi wells*
A-3 Well data for Pearce siltstone

* Mississippi well numbers are followed by an “m” in text and plates

**A-1: ALABAMA Wells**

| WELL # | WELL OPERATOR | WELL NAME | T | R | Sec. | COUNTY | STATE |
|---|---|---|---|---|---|---|---|
| 18 | SUPERIOR OIL CO., THE | MOSS & MCCORMACK #1 | 14S | 9W | 14 | Walker | AL |
| 699 | DUFFY, JAMES L. & ROWE, FRANK H., JR. | HESTER-WHITE #1 | 8S | 12W | 34 | Franklin | AL |
| 782 | PEAVEY PETROLEUM CO. | J.L. GARRISON ESTATE#1 | 15S | 11W | 36 | Fayette | AL |
| 1648 | SKELTON OPERATING CO., INC. | F. C. HOLLIS #1 | 14S | 14W | 5 | Lamar | AL |
| 1687 | SKELTON OPERATING CO., INC. | A.F. MIXON #1 | 13S | 15W | 13 | Lamar | AL |
| 1769 | WARRIOR DRILLING AND ENGINEERING COMPNAY INC. | #1 R.G. GRIFFIN | 15S | 13W | 26 | Fayette | AL |
| 1780 | SHELL OIL COMPANY | SHELL HOLLIMAN #13-16 | 20S | 15W | 13 | Pickens | AL |
| 1792 | SHELL OIL CO. | B.E. TURNER #32-10 | 18S | 13W | 32 | Pickens | AL |
| 1803 | SHENANDOAH OIL CORP. | FNBB 7-1 #1 | 13S | 8W | 7 | Walker | AL |
| 1813 | SHENANDOAH OIL CORP. | W.W. WORTHINGTON ESTATE #4-4 #1 | 12S | 8W | 4 | Winston | AL |
| 1821 | ENERGY EXPLORATIONS, INC. | FIRST NATIONAL BANK #17-16 | 12S | 8W | 17 | Winston | AL |
| 1838 | MCMORAN EXPLORATION CO. | H.W. MATTHEWS 25-1 | 11S | 14W | 25 | Marion | AL |
| 2038 | WILLIAM A. BREWER & BRYANT A FEHLMAN | VERDNER THORNE #1 | 6S | 14W | 13 | Franklin | AL |
| 2139 | WARRIOR DRILLING & ENGINEERING CO. | BATTLE-PINKERTON #1 | 16S | 11W | 7 | Fayette | AL |

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|---|---|---|---|---|---|---|---|
| 2143 | BURNS, R.L. CORP. | PEARCE 4 #1 | 13S | 11W | 4 | Marion | AL |
| 2167 | TERRA RESOURCES, INC. | SAM FRIEDMAN #1 | 19S | 10W | 36 | Tuscaloosa | AL |
| 2194 | SHENANDOAH OIL CORP. | JOHN KILGORE ESTATE #35-15 #1 | 11S | 8W | 35 | Winston | AL |
| 2278 | AROC (TEXAS), INC. | A.M. GRIMSLEY #2 | 15S | 13W | 6 | Fayette | AL |
| 2292 | MWJ PRODUCING CO. | KNIGHT-ALLMAN UNIT #1 | 12S | 16W | 34 | Lamar | AL |
| 2423 | ENSERCH EXPLORATION, INC. | CLEVELAND LUMBER CO. #1 | 14S | 10W | 34 | Fayette | AL |
| 2482 | ROUNDTREE & ASSOCIATES, INC. | FLOYD WHITE 7-12 #1 | 13S | 14W | 7 | Lamar | AL |
| 2546 | SKELTON OPERATING CO., INC. | ROBBIE DENNIS UNIT #1 | 12S | 15W | 34 | Lamar | AL |
| 2550 | SOUTHLAND ROYALTY CO. & MOON & HINES | L.A. WILDER 16-15 #1 | 13S | 15W | 16 | Lamar | AL |
| 2594 | SOUTHLAND ROYALTY CO. | #1 J.E. BOGGES 8--10 | 18S | 16W | 8 | Pickens | AL |
| 2637 | WARRIOR DRILLING & ENGINEERING CO. | AUBURN EXPERIMENTAL LAND #29-15 | 14S | 12W | 29 | Fayette | AL |
| 2643 | PACIFIC ENTERPRISES OIL CO. | WATT #9-1 | 17S | 12W | 9 | Fayette | AL |
| 2771 | SOUTHLAND ROYALTY CO. | E.O. RODGERS 2-7 #1 | 17S | 15W | 2 | Lamar | AL |
| 2773 | HUGHES & HUGHES-WARRIOR DRILLING & ENGINEERING CO. | ODGEN UNIT 14-1 #1 | 14S | 16W | 14 | Lamar | AL |
| 2792 | HUGHES & HUGHES-WARRIOR DRILLING &ENGINEERING CO. | VICK 4-3 #1 | 13S | 14W | 4 | Lamar | AL |

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|---|---|---|---|---|---|---|---|
| 2806 | MOON & HINES | SPRUIELL-METCALFE #1 | 12S | 16W | 11 | Lamar | AL |
| 2833 | STRAHAN OIL &GAS CO | NEAL WILLIAMS #2 | 7S | 10W | 3 | Franklin | AL |
| 2944 | MOON & HINES | NORTHINGTON-THOMPSON 13-13 #1 | 12S | 16W | 13 | Lamar | AL |
| 2992 | MARION CORP. | CLABORN 14-16 #1 | 9S | 12W | 14 | Marion | AL |
| 3005 | PRUET PRODUCTION COMPANY | #1 BLAKENEY 19-8 | 17S | 15W | 19 | Lamar | AL |
| 3009 | SOUTHLAND ROYALTY CO. | S. PRIDDY 30-8 #1 | 12S | 15W | 30 | Lamar | AL |
| 3170 | AMERICAN QUASAR PETROLEUM CO. | GEORGE S. WRIGHT ET AL18-2 #1 | 19S | 10W | 18 | Tuscaloosa | AL |
| 3214 | GRACE PETROLEUM CORP. | MCGILL-PHILLIPS #34-4 | 14S | 16W | 34 | Lamar | AL |
| 3378 | PRUET PRODUCTION CO. | HERRON 20-15 #1 | 17S | 15W | 20 | Lamar | AL |
| 3387 | TERRA RESOURCES, INC. | EMMETT WILSON 29-5 #1 | 17S | 13W | 29 | Fayette | AL |
| 3503 | PACIFIC ENTERPRISES OIL CO. | CONNER #18-10 | 15S | 13W | 18 | Fayette | AL |
| 3514 | GRACE PETROLEUM CORP. | CUNNINGHAM REED #20-10 | 13S | 12W | 20 | Fayette | AL |
| 3586 | ANDERMAN OPERATING CO. /MOON AND HINES | GILMER 14-14 #1 | 14S | 15W | 14 | Lamar | AL |
| 3670 | JOHNSON, L.W. & ASSOC., INC. | G.A. BOYLES 34-1 #3 | 8S | 14W | 34 | Franklin | AL |
| 3772 | MOON-HINES-TIGRETT OPERATING CO. | SHELTON 6-13 #1 | 12S | 13W | 6 | Marion | AL |

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|---|---|---|---|---|---|---|---|
| 3790 | TRE'J EXPLORATION, INC. | U.S. PIPE & FOUNDRY 25-4 #1 | 7S | 14W | 25 | Franklin | AL |
| 3811 | CARLESS RESOURCES, INC. | HOLLOWAY 2-16 #1 | 18S | 11W | 2 | Tuscaloosa | AL |
| 3928 | MOON-HINES-TIGRETT OPERATING CO. | FINE 33-7 #1 | 13S | 15W | 33 | Lamar | AL |
| 4014 | TXO PRODUCTION CORP. | ROBINSON 28-16 #1 | 17S | 15W | 28 | Lamar | AL |
| 4026 | CARLESS RESOURCES, INC. | FAUCETT ET AL 36-2 #1 | 18S | 11W | 36 | Tuscaloosa | AL |
| 4036 | TRE'J EXPLORATION, INC. | FARRIS 34-12 #1 | 9S | 10W | 34 | Winston | AL |
| 4085 | CARLESS RESOURCES, INC. | TAYLOR 23-16 #1 | 18S | 11W | 23 | Tuscaloosa | AL |
| 4109 | PETRUS OPERATING CO., INC. | RODEN ESTATE ET AL 34-7 #1 | 14S | 10W | 34 | Fayette | AL |
| 4190 | PRUET PRODUCTION CO. | WILLIAMS 13-15 #1 | 17S | 16W | 13 | Lamar | AL |
| 4224 | ENERGY THREE, INC. | J.C. JENKINS 20-6 #1 | 15S | 10W | 20 | Fayette | AL |
| 4324 | MOON-HINES-TIGRETT | JAKE LUNDY #36-13 | 10S | 16W | 36 | Marion | AL |
| 4414 | TRE'J EXPLORATION, INC. | CHANDLER-KNIGHT 27-15 #1 | 10S | 13W | 27 | Marion | AL |
| 4425 | PACIFIC ENTERPRISES OIL CO. | HODGES ESTATE #26-13 | 16S | 12W | 27 | Fayette | AL |
| 4536 | BEST EXPLORATION, INC. & MORROW OIL & GAS CO. | GULF STATES PAPER CORP. 22-6 #1 | 18S | 13W | 22 | Pickens | AL |
| 4623 | DENBURY ONSHORE, LLC | BLACK EST. 24-15 #1 | 14S | 14W | 24 | Lamar | AL |
| 4818 | GOLDEN BUCKEYE PET. CORP. | 31 ELMORE 23-8 | 18S | 16W | 23 | Pickens | AL |

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|---|---|---|---|---|---|---|---|
| 4821 | MOON-HINES-TIGRETT OPERATING CO. | ROBERTS 26-11 #1 | 11S | 16W | 26 | Marion | AL |
| 4818 | GOLDEN BUCKEYE PETROLEUM CORP. | ELMORE #23-8 | 18S | 16W | 23 | Pickens | AL |
| 4821 | MOON-HINES-TIGRETT OPERATING CO. | ROBERTS 26-11 #1 | 11S | 16W | 26 | Marion | AL |
| 5271 | MWJ PRODUCING CO. | PENNY #9-3 | 12S | 11W | 8 | Marion | AL |
| 5287 | BROWNING & WELCH, INC. | W. LELAND ESTELL 15-16 | 12S | 14W | 15 | Lamar | AL |
| 5304 | VICTORY RESOURCES, INC. | JONES-BANNISTER 9-10 | 11S | 13W | 9 | Marion | AL |
| 5373 | TERRA RESOURCES, INC. | J.C. SHEPHERD 9-1 #1 | 17S | 11W | 9 | Fayette | AL |
| 5449 | TERRA RESOURCES, INC. | BARNES ESTATE #35-13 | 14S | 13W | 35 | Fayette | AL |
| 5255 | SANFORD RESOURCES CORP. | W.A. AUSTIN 9-13 #1 | 14S | 15W | 9 | Lamar | AL |
| 5606 | BROWNING & WELCH, INC. | CARLESS RESOURCES 4-4 #1 | 17S | 11W | 4 | Fayette | AL |
| 5726 | ANDERMAN/SMITH OPERATING CO. | THOMAS 11-6 #1 | 17S | 16W | 11 | Lamar | AL |
| 15004 | EHRMAN, ROBERT V. | FIRST NATIONAL BANK #1 | 11S | 9W | 3 | Winston | AL |
| 15005 | SINCLAIR OIL AND GAS COMPANY | J.T. HARRIS NO. 1 | 11S | 9W | 30 | Winston | AL |

**A-2: MISSISSIPPI Wells**

| WELL # | WELL OPERATOR | WELL NAME | T | R | Sec. | COUNTY | STATE |
|---|---|---|---|---|---|---|---|
| 37 | PRUET & HUGHES COMPANY AND PELTO OIL COMPANY | #1 SULLIVAN 23-4 | 12S | 18W | 23 | Monroe | MS |
| 44 | LOUISANA LAND AND EXPL. CO. | AVIS CUNNINGHAM #1 | 12S | 17W | 18 | Monroe | MS |
| 76 | GUERNSEY PETROLEUM CORP. | #1 VELMA HAMELY | 13S | 7E | 7 | Monroe | MS |
| 81 | MAGNOLIA PETROLEUM CO. | #1 BERTHA PIERCE | 13S | 7E | 22 | Monroe | MS |
| 86 | SANTA FE MINERALS | #1 J.R. SCRIBNER 25-1 | 13S | 19W | 25 | Monroe | MS |
| 113 | SHELL OIL COMPANY AND FEAZEL | MRS LEE HARRINGTON #1 | 14S | 6E | 25 | Monroe | MS |
| 128 | SHELL OIL CO. | DALRYMPLE #1 | 14S | 19W | 1 | Monroe | MS |
| 130 | PRUET &HUGHES COMPANY | #1 MC ALLISTER UNIT 36-7 | 14S | 19W | 36 | Monroe | MS |
| 200 | SHELL OIL CO. | WILLIS #1 | 15S | 18W | 18 | Monroe | MS |
| 273 | PRUET &HUGHES COMPANY AND QUITAINE OIL CORPERATION | #1 CRUMP UNIT 1-6 | 16S | 18W | 1 | Monroe | MS |
| 372 | PREUT PRODUCITON CO. | #1 WEYERHAUSER 1-6 | 15S | 17W | 1 | Monroe | MS |
| 373 | TRIAD OIL & GAS CO., INC. | WISE HEIRS #1 | 15S | 17W | 10 | Monroe | MS |
| 438 | BARIA &MASON PRUET PRODUCTION COMPANY | COLEMAN 34-6 | 15S | 18W | 34 | Monroe | MS |
| 451 | LOUSIANA LAND & EXPLORATION CO. | #1BEASLEY 36-14 | 12S | 6E | 36 | Monroe | MS |
| 478 | HUGHES EASTERN PETROLEUM, LTD. | #1 SLONE 21-5 | 12S | 18W | 21 | Monroe | MS |

|  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|
| 482 | ANDERMAN-SMITH OPERATING CO. | TUBB 20-11 | 12S | 18W | 20 | Monroe | MS |
| 530 | PRUET & HUGHES COMPANY - AQUITAIN OIL AMERADA HESS | SANDERS 22-4 | 16S | 18W | 22 | Lowndes | MS |
| 540 | PRUET & HUGHES COMPANY | PARKER 6-2 #1 | 17S | 18W | 6 | Lowndes | MS |
| 544 | PURET & HUGHES COMPANY AND AMERADA HESS CORPORATION | #1 LIVINGSTON 11-6 | 17S | 18W | 11 | Lowndes | MS |
| 546 | BROWING & WELCH INC. | #1 RALPH WILLIAMSON 1-11 | 17S | 17W | 1 | Lowndes | MS |
| 549 | BROCK EXPLORATION CORP | #1 LED WRIGHT | 17S | 17W | 7 | Lowndes | MS |
| 561 | PRUET PROD. CO. BARIA &MASON | GATES 5-9 | 17S | 18W | 5 | Lowndes | MS |
| 593 | BOW VALLEY PET. INC. | #1 G.D. HOLLIMAN 12-16 | 16S | 18W | 12 | Lowndes | MS |
| 597 | ELF AQUITAINE OIL &GAS | RALPH E. WILLIAMSON #1-33 | 15S | 17W | 33 | Lowndes | MS |
| 607 | PRUET PRODUCTION CO. & LANDER-STETART-HILDERBRAND | CONNER-MEYERS 20-3 | 16S | 17W | 20 | Lowndes | MS |
| 611 | BARIA & MASON MUNOCO PRUET PRODUCTION CO. | #1 SIZEMORE 28-11 | 16S | 17W | 28 | Lowndes | MS |
| 726 | LOUSIANA LAND & EXPLORATION CO. | CARNATHAN 23-4 | 12S | 5E | 23 | Chickasaw | MS |
| 729 | THE CARTER OIL CO. | T.G. ABERNATHY #1 | 12S | 5E | 29 | Chickasaw | MS |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 738 | LOUSIANA LAND & EXPLORATION CO. | #1 MABEL NEAL | 13S | 4E | 34 | Chickasaw | MS |
| 757 | BARIA & MASON MUNOCO PRUET PRODUCTION CO. | #1 S.A. FARR 11-11 | 14S | 3E | 11 | Chickasaw | MS |
| 801 | MICHIGAN OIL CO. | #1 ANDERSON 6-11 | 12S | 5E | 6 | Chickasaw | MS |
| 806 | TUCKER OPPERATING CO. | #1 ANDERSON 14-13 | 13S | 4E | 14 | Chickasaw | MS |
| 826 | GETTY OIL COMPANY | NO. 1 HENRY BENEKA 6-1 | 15S | 3E | 6 | Chickasaw | MS |
| 930 | V.B. BOTTOMS | DELANEY #1 | 10S | 10E | 34 | Itawamba | MS |
| 944 | KERR MC GEE CORPERATION | #1 WILSON | 11S | 10E | 24 | Itawamba | MS |
| 946 | PRUET PRODUCTION CO. | #1 WILSON | 11S | 10E | 29 | Itawamba | MS |
| 976 | GETTY OIL COMPANY | #1 OMER PEARSON 6-10 | 9S | 9E | 6 | Itawamba | MS |
| 982 | C. DALE. ARMOUR | O.R. SMITH-H. BENSON #1 | 10S | 9E | 10 | Itawamba | MS |
| 983 | GRAGG DRILLING CO& LANCER PROD. CO. | #1 BARNES UNIT #1 | 10S | 9E | 14 | Itawamba | MS |
| 1008 | KERR MC GEE CORPERATION | #1 FREDRICK | 11S | 10E | 11 | Itawamba | MS |
| 1109 | LOUSIANA LAND & EXPLORATIONCO. | #1 wax 26-3 | 10S | 3E | 26 | Pontotoc | MS |
| 1159 | LOUSIANA LAND & EXPLORATION CO. | D.L. WARD 27-8 NO 2 | 11S | 4E | 27 | Pontotoc | MS |
| 1251 | PRUET PROD. CO. BARIA & MASON | #1 WEYERHAEUSER 26-2 | 16S | 7E | 26 | Clay | MS |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1262 | SHELL OIL COMPANY AND FEAZEL | #1 JAMES C. FOSTER ET AL 29-3 | 16S | 6E | 29 | Clay | MS |
| 1262m | BROWNING & WELCH INC. | J.A. WIYGUL #1 | 12S | 6E | 2 | Monroe | MS |
| 1443 | MOON-HINES-TIGRETT OPERATING CO. | VAUGHAN 22-8 #1 | 11S | 5E | 22 | Lee | MS |
| 1508 | MC ALESTER FUEL CO. | #A-1 W.P SUDDUTH | 19S | 15E | 6 | Oktibbeha | MS |
| 2543 | BROWNING & WELCH-KENAI OIL &GAS | #1 G.B. LILLEY 6-3 | 16S | 6E | 6 | Monroe | MS |
| 2545 | PRUET PRODUCTION CO. - BARIA & MASON - MUNOCO | NO. 1 RICHARD C. BRYAN<br>8-14 | 16S | 7E | 8 | Monroe | MS |
| 10107 | G.C. GRASTY | KENTUCKY LUMBER CO. #1 | 10S | 10E | 7 | Itawamba | MS |
| 14233 | PHILLIPS PETROLEUM CO. | CRAWFORD #1 | 14S | 2E | 33 | Chickasaw | MS |

## A-3: Pearce Wells

| WELL # | WELL OPERATOR | WELL NAME | T | R | Sec. | COUNTY | STATE |
|---|---|---|---|---|---|---|---|
| 905 | MOON-HINES & H. BEST | #1 HECKMAN | 9S | 10E | 31 | Itawamba | MS |
| 910 | MOON-HINES & H. BEST | #1 REEVES-BOWEN | 10S | 9E | 1 | Itawamba | MS |
| 929 | W.A. WEGMAN& STRAHAN | #1 W.A. DE LANEY | 10S | 10E | 23 | Itawamba | MS |
| 930 | V.B. BOTTOMS | DELANEY #1 | 10S | 10E | 34 | Itawamba | MS |
| 998 | MOON-HINES-TIGRETT OPERATING CO. | # 1 STONE EXT. 4-5 | 10S | 10E | 4 | Itawamba | MS |
| 999 | MOON-HINES-TIGRETT OPERATING CO. | #1 CLARK 12-12 | 10S | 10E | 12 | Itawamba | MS |
| 1001 | MOON-HINES-TIGRETT OPERATING CO. | 9-1 J.H. STONE UNIT | 10S | 10E | 9 | Itawamba | MS |
| 1003 | MOON-HINES-TIGRETT OPERATING CO. | 13-9 DELANEY | 10S | 10E | 13 | Itawamba | MS |
| 1004 | MOON-HINES-TIGRETT OPERATING CO. | #1 MURPHEE 11-3 | 10S | 10E | 11 | Itawamba | MS |
| 1008 | KERR MC GEE CORPERATION | #1 FREDRICK | 11S | 10E | 11 | Itawamba | MS |
| 1010 | MOON-HINES-TIGRETT OPERATING CO. | #1 HIDEN 11-1 | 11S | 10E | 12 | Itawamba | MS |
| 1521 | CONN ENGINEERING SERVICES | HAMILTON GAS UNIT 23-7 #1 | 11S | 14W | 23 | Marion | AL |

|  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|
| 1536 | CONN ENGINEERING SERVICES | HAMILTON GAS UNIT 22-6 #1 | 11S | 14W | 22 | Marion | AL |
| 1838 | MCMORAN EXPLORATION | H.W. MATTHEWS 25-1 | 11S | 14W | 25 | Marion | AL |
| 2122 | SHENANDOAH OIL CORP. | BIRMINGHAM TRUST NATIONAL BANK 15-2 #1 | 12S | 12W | 15 | Marion | AL |
| 2143 | BURNS, R.L. CORP. | PEARCE 4 #1 | 13S | 11W | 4 | Marion | AL |
| 3119 | CHERRY, CHARLES L. & ASSOC., INC. | STRICKLAND 8-12 #1 | 11S | 12W | 8 | Marion | AL |
| 3166 | CHERRY, CHARLES L. & ASSOC., INC. | ROBERT CROW 15-5 #1 | 11S | 13W | 15 | Marion | AL |
| 3514 | GRACE PETROLEUM CORP. | CUNNINGHAM REED #20-10 | 13S | 12W | 20 | Fayette | AL |
| 3903 | JOHNSON, L.W. & ASSOC. | UNIVERSAL PETROLEUM 1-15 #12 | 9S | 15W | 1 | Marion | AL |
| 4096 | TRE'J EXPLORATION, INC. | WILLIAMS 10-9 #1 | 9S | 15W | 10 | Marion | AL |
| 4317 | ALAGASCO ENERGY CO., INC.-HAWKEYE OIL & GAS | CANTRELL 7-13 #1 | 10S | 13W | 7 | Marion | AL |
| 4323 | ALAGASCO ENERGY CO., INC. | CHAMPION 10-14 #2 | 10S | 14W | 10 | Marion | AL |
| 4344 | GUERNSEY PETROLEUM CORP. | GALBREATH 6-9 #1 | 10S | 14W | 6 | Marion | AL |
| 4351 | ALAGASCO ENERGY CO., INC.-HAWKEYE OIL & GAS, INC. | ROGERS #32-4 | 9S | 14W | 32 | Marion | AL |
| 4406 | ALAGASCO ENERGY CO., INC. | CASEY 6-14 #2 | 11S | 14W | 6 | Marion | AL |

|  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|
| 4414 | TRE'J EXPLORATION, INC. | CHANDLER-KNIGHT 27-15 #1 | 10S | 13W | 27 | Marion | AL |
| 4456 | TRE'J EXPLORATION, INC. | BARRETT-WILLIAMS 10-12 #1 | 11S | 14W | 10 | Marion | AL |
| 4460 | ALAGASCO ENERGY CO., INC. | STATE OF ALABAMA 16-9 #1 | 10S | 13W | 16 | Marion | AL |
| 4467 | HAWKEYE OIL & GAS, INC. | HAYES 4-13 #1 | 12S | 13W | 4 | Marion | AL |
| 4472 | ALAGASCO ENERGY CO., INC.HAWKEYE OIL & GAS | BEDFORD 19-9 #1 | 9S | 15W | 19 | Marion | AL |
| 4487 | ALAGASCO ENERGY CO. INC. | ALLEN 22-4 #1 | 9S | 15W | 22 | Marion | AL |
| 4541 | TRE'J EXPLORATION, INC. | PENNY B. LONG 5-12 #1 | 11S | 12W | 5 | Marion | AL |
| 4678 | TRE'J EXPLORATION, INC. | W.A. JONES #1-11 | 11S | 14W | 1 | Marion | AL |
| 4697 | TRE'J EXPLORATION, INC. | BEDFORD ESTATE 2-1 #1 | 9S | 15W | 2 | Marion | AL |
| 5084 | MOON-HINES-TIGRETT OPERATING CO., INC. | HOWELL 5-1 #1 | 11S | 13W | 5 | Marion | AL |
| 5086 | HAWKEYE OIL & GAS, INC. | BURROW 1-4 #1 | 11S | 15W | 1 | Marion | AL |
| 5131 | ENERGY RECOVERY GROUP, LLC | MCPOLAND ET AL 7-16 #1 | 13S | 10W | 7 | Walker | AL |
| 5187 | HAWKEYE OIL & GAS, INC. | PEARCE TRUST #8-12 | 9S | 15W | 8 | Marion | AL |
| 5208 | HAWKEYE OIL & GAS, INC. | PALMER #36-5 | 10S | 15W | 36 | Marion | AL |
| 5248 | HAWKEYE OIL & GAS, INC. | WIGINTON 23-14 #1 | 10S | 15W | 23 | Marion | AL |
| 5270 | SUNEX PRODUCTION, INC. | MCPOLAND ET AL 8-5 #1 | 13S | 10W | 8 | Walker | AL |
| 5271 | MWJ PRODUCING CO. | PENNY #9-3 | 12S | 11W | 9 | Marion | AL |
| 5292 | HAWKEYE OIL & GAS, INC. | TAYLOR #9-14 | 10S | 15W | 9 | Marion | AL |
| 5304 | VICTORY RESOURCES, INC. | JONES-BANNISTER 9-10 | 11S | 13W | 9 | Marion | AL |
| 5440 | HAWKEYE OIL & GAS, INC. | PEARCE TRUST 21-2 #1 | 10S | 15W | 21 | Marion | AL |
| 5560 | HAWKEYE OIL & GAS, INC. | MCCLENDON 9-5 #1 | 10S | 15W | 9 | Marion | AL |

# APPENDIX B

# KEY

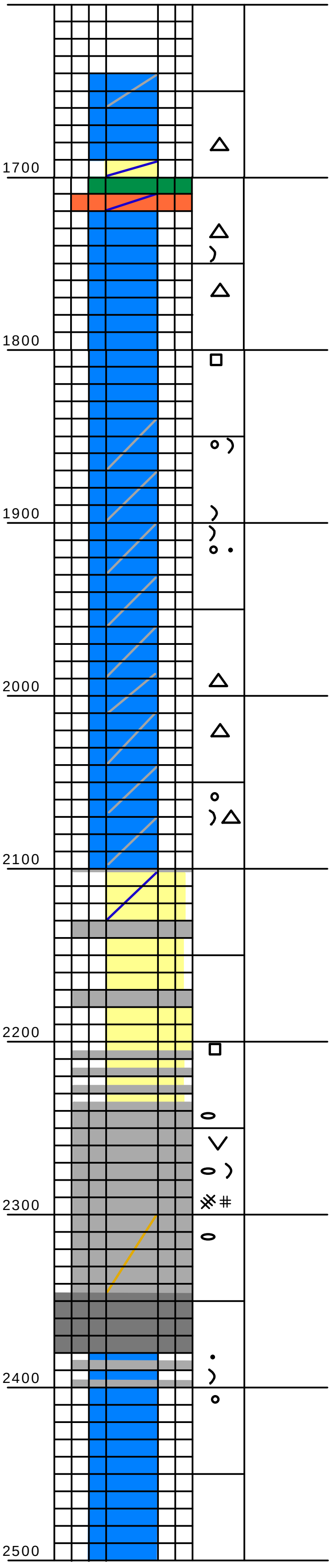
🟧 Siltstone
🟨 Sandstone
🟦 Limestone
🟪 Dolomite
⬜ Light gray shale
▨ Medium gray shale
⬛ Dark gray shale
🟩 Claystone

# Carbonaceous
V Glauconite
□ Pyrite
V Mica
• Pellets
∘ Ooids
) Fossils
ʖ Molluskan fossils
△ Chert
⬭ Siderite
▱ Interclasts/ripups

/ Calcareous
/ Sandy
/ Silty
/ Argillaceous

Color description of limestone units corresponds to Munsell color divisions:

Light olive gray (5Y 6/1)
Olive gray (5Y 4/1)
Light gray (N7)
Medium light gray (N6)
Medium gray (N5)
Medium dark gray (N4)
Dark gray (N3)

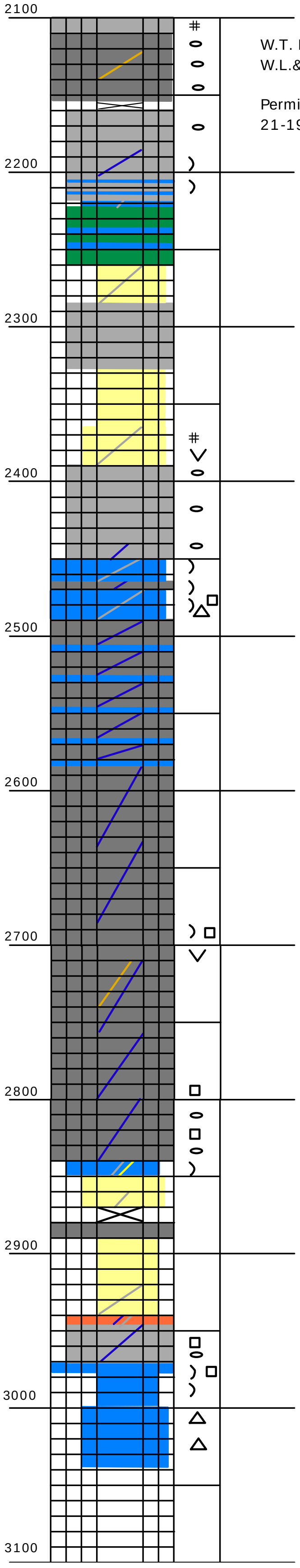


Superior Oil Co.
Moss-McCormack #1

Permit #18
14S-9W-14

Permit No. 18
SUPERIOR OIL CO.
MOSS & MCCORMACK #1
Walker County, Alabama
14S, 9W, 14
Described by C.A. Kidd

| Depth (feet) | Lithology | Description |
|---|---|---|
| 1680-1700 | Limestone | light to medium gray, argillaceous, shaley, rare ooids |
| 1700-1705 | Sandstone | light gray, very fine grained (0.125 mm), calcareous |
| 1705-1710 | Claystone | green and maroon |
| 1710-1720 | Siltstone | light gray, calcareous |
| 1720-1840 | Limestone | light to medium gray, rare shell fragments, rare pyrite, chert |
| 1840-1890 | Limestone | light to medium gray, pellets, shell fragments, packstone |
| 1890-1910 | Limestone | medium gray, argillaceous, packstone, fossils: crinoids and shell fragments |
| 1910-1930 | Limestone | light to medium gray, pellets (0.25-0.75 mm), argillaceous, packstone, fossils: crinoids and shell fragments |
| 1930-1990 | Limestone | medium gray, argillaceous, micrite |
| 1990-2040 | Limestone | as above, chert |
|  | Shale | medium gray |
| 2040-2070 | Limestone | light to medium gray, argillaceous, pellets, wackestone, rare shell fragments |
| 2070-2090 | Limestone | as above |
|  | Shale | medium gray |
| 2090-2130 | Sandstone | light gray to tan, fine grained (0.14-0.20 mm), slightly calcareous, argillaceous, quartzarenite |
| 2130-2140 | Shale | medium gray |
| 2140-2145 | No Sample |  |
| 2145-2170 | Sandstone | as above |
| 2170-2180 | Shale | medium gray |
|  | Sandstone | as above, hematitic cement? |
| 2180-2205 | Sandstone | light gray to white, very fine to fine grained (0.125-.020 mm), quartzarenite, friable |
| 2205-2240 | Sandstone | as above |
|  | Shale | interbedded, medium gray, pyrite, sparsely carbonaceous |
| 2240-2300 | Shale | medium gray, micaceous, carbonaceous, plant fragments, shell fragment |
| 2300-2325 | Shale | medium gray, silty laminae |
| 2325-2335 | No Sample |  |
| 2335-2345 | Shale | as above |
| 2345-2380 |  |  |
| 2380-2400 | Shale | medium gray, silty, micaceous |
|  | Limestone | light gray, argillaceous, pelloids, wack/packstone |
| 2400-2440 | Limestone | light gray, ooids, packstone/grainstone |



W.T. Durant
W.L.&F. Ogden #1

Permit #432-A
21-19S-5W

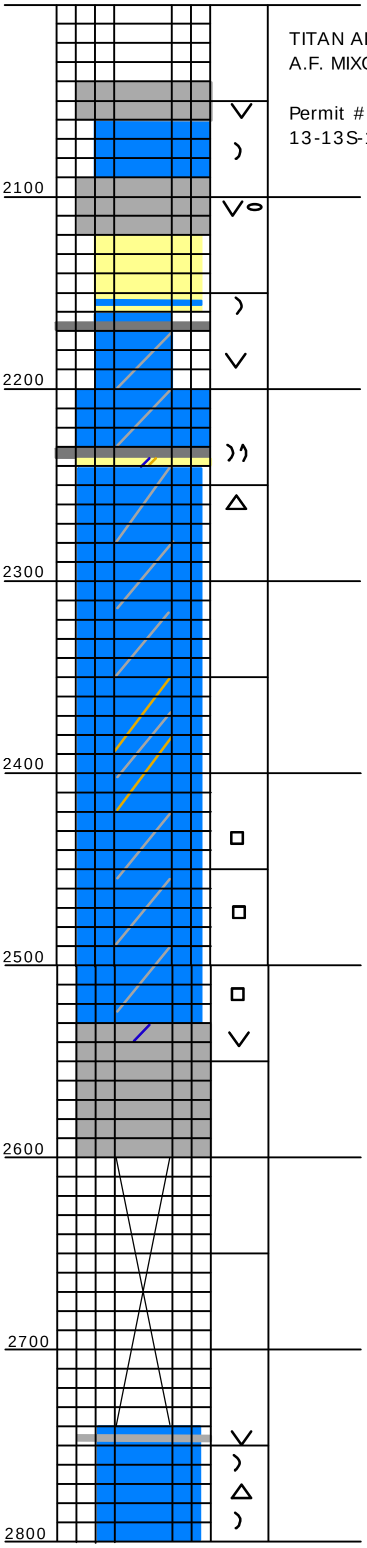
Permit No. 432-A
W.T. Durant
No. 1 W.L. & F. Ogden
14S-15W-6
Lamar County, Alabama
Described by C.A. Kidd

| Depth (feet) | Lithology | Description |
|---|---|---|
| 2100-2105 | Limestone | light gray/tan, micrite, fossils: crinoids, shell fragments |
| 2105-2111 | Shale | medium gray, silty laminae, rare carbonaceous, waxy |
| 2111-2145 | Shale | dark gray, siderite, silty |
| 2145-2155 | Limestone | dark gray, fine crystalline, argillaceous, fossils: crinoids and brachiopods |
| 2155-2170 | Shale | medium gray, siderite |
| 2170-2175 | No Sample | |
| 2175-2187 | Shale | medium gray, slightly calcareous, siderite |
| 2187-2202 | Shale | medium gray, calcareous, abundant fossils: crinoid stems, gastropod, pelecypod, bryozoan |
| 2202-2218 | Shale | medium gray and |
| | Limestone | fine crystalline, argillaceous |
| 2218-2222 | Limestone | light gray, fine crystalline, argillaceous, bioclastic wackestone |
| 2222-2260 | Claystone | maroon and green, with interbeds of limestone (as above) |
| 2260-2285 | Sandstone | white to light gray, fine (0.16-0.2mm), quartzarenite, argillaceous, well sorted and rounded, friable |
| 2285-2327 | Shale | medium gray |
| 2327-2364 | Sandstone | white, fine, quartzarenite, well sorted and rounded, friable |
| 2364-2390 | Sandstone | light gray, v. fine to fine, carbonaceous, micaceous, argillaceous |
| 2390-2450 | Shale | medium gray, rare silty laminae, siderite, mica, calcareous |
| 2450-2464 | Limestone | dark gray, fine crystalline, argillaceous, abundant fossils: brachiopods, fish dermal plates |
| 2464-2470 | Shale | dark gray, rare shell fragments, calcareous |
| 2470-2490 | Limestone | dark gray, very fine to medium crystalline, shell fragments, pyrite, brown chert |
| 2490-2585 | Shale | dark gray, calcareous and |
| | Limestone | dark gray, fine crystalline, argillaceous, fossils: mollusk and crinoids |
| 2585-2685 | Shale | dark gray, calcareous |
| 2685-2710 | Shale | dark gray, pyrite, rare shell fragment, mica |
| 2710-2840 | Shale | dark gray, calcareous, silty, mica, pyrite and siderite (2794 ft.) |
| 2840-2850 | Limestone | medium gray, medium-coarse crystalline, argillaceous, quartzose, bioclastic packstone, fossils: gastropod and crinoids |

|  |  |  |
|---|---|---|
| 2850-2870 | Sandstone | white to light gray, fine (0.2mm), argillaceous, calcareous, subangular, <5% lithics, friable |
| 2870-2880 | No Sample |  |
| 2880-2890 | Shale | dark gray |
| 2890-2940 | Sandstone | white, very fine-medium grained (0.125-0.25mm), slightly calcareous, quartzarenite, subangular, poor sorting, friable |
| 2940-2945 | Siltstone | medium gray, argillaceous, calcareous |
| 2945-2960 | Shale | medium gray, slightly calcareous, pyrite, silty laminae, siderite |
| 2960-2978 | Limestone | dark gray, micrite, shell fragments, pyrite |
| 2978-3000 | Limestone | light gray to white, fine-coarse crystalline, bioclastic packstone |
| 3000-3020 | Limestone | light medium gray, fine crystalline |
|  | Chert | light to blue gray |

TITAN ALABAMA COMPANY
A.F. MIXON #1

Permit #1687
13-13S-15W



Permit No. 1687
Titan Alabama Company
A.F. Mixon #1
Lamar County, Alabama
13S, 15W, 13
Described by Geological Survey of Alabama

### Mississippian-Bangor Limestone

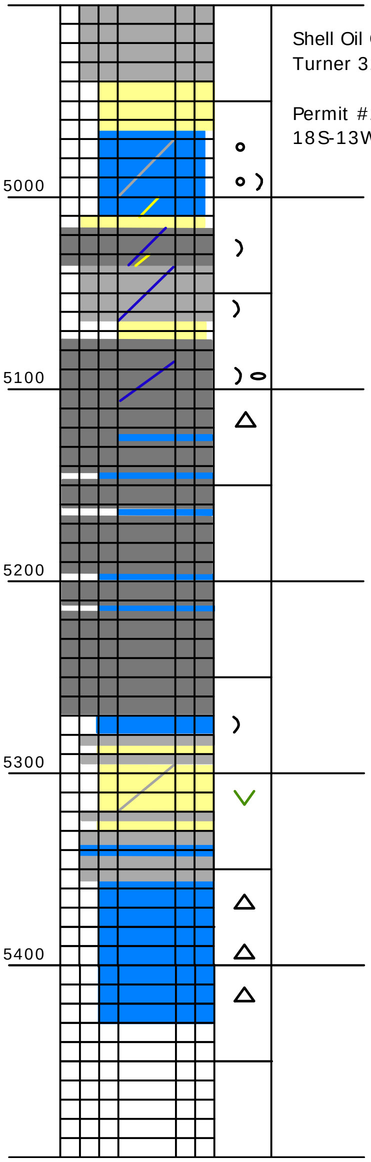
| | | |
|---|---|---|
| 2170-2200 | Limestone | pale-yellowish-brown to brownish-gray, coarsely crystalline to sublithographic, argillaceous |
| | Shale | dark-gray; very finely micaceous |
| 2200-2230 | Limestone | dusky-yellowish-brown (10YR2/2) to medium-dark- to brownish-gray, very finely crystalline to sublithographic, argillaceous, bioclastic in part |

### Bangor Limestone- Floyd Shale undifferentiated

| | | |
|---|---|---|
| 2230-2240 | Shale | medium-dark-gray, fossiliferous, pelecypods and ostracods |
| | Sandstone | light-olive to light-brownish-gray, very fine-grained, subangular, silty, calcareous, tightly packed |
| | Limestone | same. |
| 2240-2350 | Limestone | same, very argillaceous, some chert, light-brownish-gray, dense at 2260-2290. |
| 2350-2420 | Limestone | dark-gray, finely crystalline, very argillaceous, silty, shaley. |
| 2420-2530 | Limestone | same; and shale, medium-dark-gray, pyritiferous. |
| 2530-2540 | Shale | medium-light-to medium-dark-gray, very finely micaceous, slightly calcareous; .and limestone, same, sparse |
| 2540-2600 | Shale | same; and sparse limestone, dusky-yellowish-brown, finely crystalline, argillaceous, shaley. |
| 2600-2740 | No samples. | |

### Tuscumbia Limestone

| | | |
|---|---|---|
| 2740-2750 | Shale | medium-light-, medium-dark-and brownish-gray, very finely micaceous |
| | Limestone | pinkish-gray to white, sublithographic to finely crystalline, dense, bioclastic in part, crinoid columnals; and chert, light-gray to white, dense. |
| 2750-2800 | Limestone | pinkish-gray to pale-yellowish-brown, medium crystalline to sublithographic, bioclastic in part; |
| | Chert | light-gray to white, dense; and shale, same, cavings. |



Shell Oil Company
Turner 32-10

Permit #1792
18S-13W-32

Permit No. 1792
Shell Oil Company
C.E. Turner 32-10
Pickens County, Alabama
18S, 13W, 32
Described by Jack T. Kidd

### Floyd Shale ?

| | | |
|---|---|---|
| 5080-5085 | Shale | medium dark gray, greenish gray and grayish red, same. |
| 5085-5105 | Shale | medium dark gray and greenish gray, calcareous and fossiliferous in part; siderite. |
| 5105-5110 | Shale | same; trace of chert, brownish black (5 YR 2/1). |
| 5110-5125 | Shale | same. |
| 5125-5130 | Shale | dark gray, otherwise same; trace of limestone, brownish gray. |
| 5130-5145 | Shale | same. |
| 5145-5150 | Shale | same; trace of limestone, pale yellowish brown and very light gray. |
| 5150-5160 | Shale | dark gray, small amount of greenish gray. |
| 5160-5270 | Shale | same; trace of limestone, brownish gray. |

### "Lewis"-"Bethel" equivalent

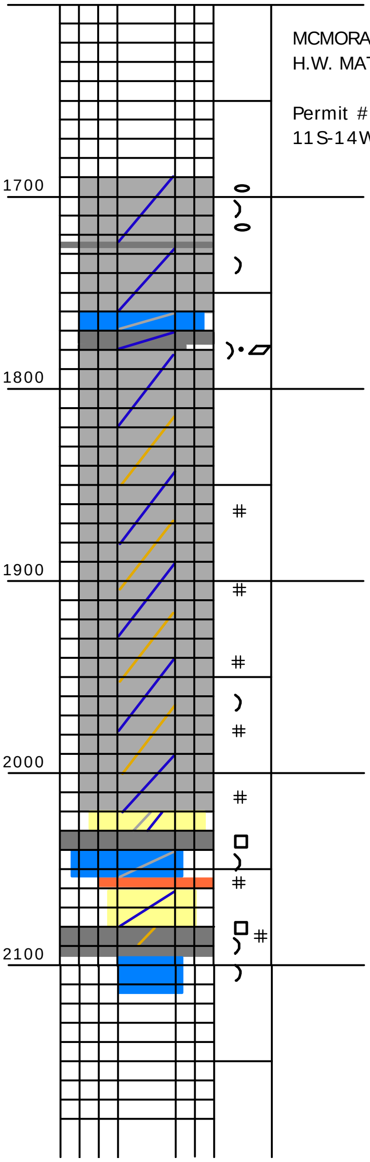
| | | |
|---|---|---|
| 5270-5280 | Limestone | brownish gray, dense to crystalline, crinoidal;<br>shale, same; trace of sandstone, light gray, very fine. |
| 5280-5285 | Limestone | same, with slight increase in sandstone. |
| 5285-5290 | Sandstone | light gray, very fine to fine; shale, dark gray. |
| 5290-5295 | Shale | same; limestone, brownish gray; sandstone, same. |
| 5295-5305 | Sandstone | light brownish gray, very fine to fine, quartzose, argillaceous in part; shale, same. |
| 5305-5320 | Sandstone | light gray to light brownish gray, very fine to fine, quartzose, calcareous, argillaceous, glauconitic. |
| 5320-5325 | Sandstone | same; shale, dark gray, some greenish gray. |
| 5325-5330 | Shale | same; sandstone, same; trace of limestone, light brown. |
| 5330-5335 | Sandstone | same; shale, same. |
| 5335-5345 | Shale | same; sandstone, same; limestone, brownish gray, dense to crystalline. |
| 5345-5355 | | Shale limestone, and sandstone, same; cavings. |

### Tuscumbia-Fort Payne Undifferentiated

| | | |
|---|---|---|
| 5355-5360 | Limestone, | brownish gray, very fine crystalline to sublithographic; chert, brownish gray to light bluish gray (5 B 7/1); shale, medium dark gray and greenish gray, may be cavings. |
| 5360-5385 | Limestone | and chert, same; samples contaminated by shale covings. |
| 5385-5425 | Limestone | same; chert, brownish gray, dense; shale covings. |
| 5425-5430 | Limestone | brownish gray, same; chert, brownish gray, same; trace of glauconitic limestone. |

MCMORAN EXPLORATION CO.
H.W. MATTHEWS 25-1

Permit # 1838
11S-14W-25

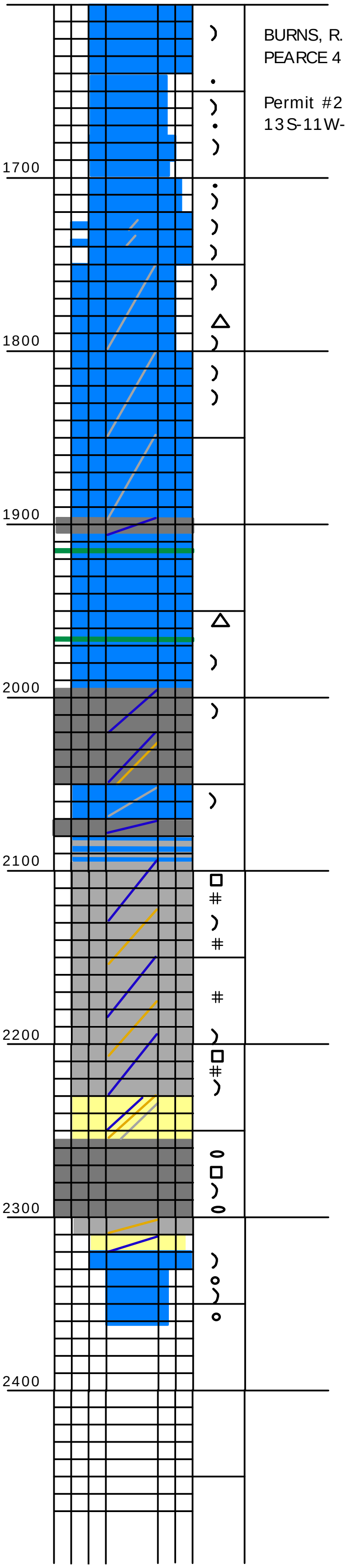


Permit No. 1838
MCMORAN EXPLORATION CO.
H.W. MATTHEWS 25-1
Marion County, Alabama
11S, 14W, 25
Described by C.A. Kidd

| Depth (feet) | Lithology | Description |
|---|---|---|
| 1690-1730 | Shale | medium gray, calcareous, siderite, carbonaceous, sulfur, pyrite, fossils: crinoid stems, shell fragments (mollusk), gastropods |
| 1730-1760 | Shale | dark gray/black, very fissile, sulfur |
| 1760-1770 | Limestone | medium gray, fine crystalline, wackestone, fossil: crinoid |
| 1770-1780 | Shale | medium gray, calcareous |
|  | Shale | as above, black pellets, carbonaceous rip-ups,<br>fossils: crinoids and shell fragments |
| 1780-2020 | Shale | medium gray, silty, very calcareous, sparsely carbonaceous (after 1850 ft.), abundant carbonaceous material (2010-2020 ft.), pyrite, shell fragment (1960-1970 ft.) |
| 2020-2030 | Shale | as above |
|  | Sandstone | brown, very fine (0.14-0.16 mm), argillaceous, calcareous, quartzarenite |
|  | Shale | dark gray/black, sulfur |
| 2030-2040 | Shale | black, sulfur, pyrite |
| 2040-2055 | Limestone | dark gray, course crystalline, weathers red, argillaceous, ooids, packstone, fossils: crinoids, gastropods, shell fragments, bryozoans |
| 2055-2060 | Siltstone | white/light gray, carbonaceous |
| 2060-2080 | Sandstone | white, calcareous, carbonaceous, 5%>lithics, (after 2070 ft.) shell fragments, pyrite, carbonaceous rip-ups |
|  | Shale | (after 2070 ft.) dark gray, sharp contact with sandstone |
| 2080-2095 | Shale | dark gray, coaly stringers, calcareous, pyrite, rare silty laminae |
|  | Shale | medium gray, calcareous, silty, fossils: bryozoans, brachiopods |
|  | Shale | dark gray/black |
| 2095-2115 | Limestone | olive gray, argillaceous, very fossiliferous, packstone |

BURNS, R.L. CORP.
PEARCE 4 #1

Permit #2143
13S-11W-4



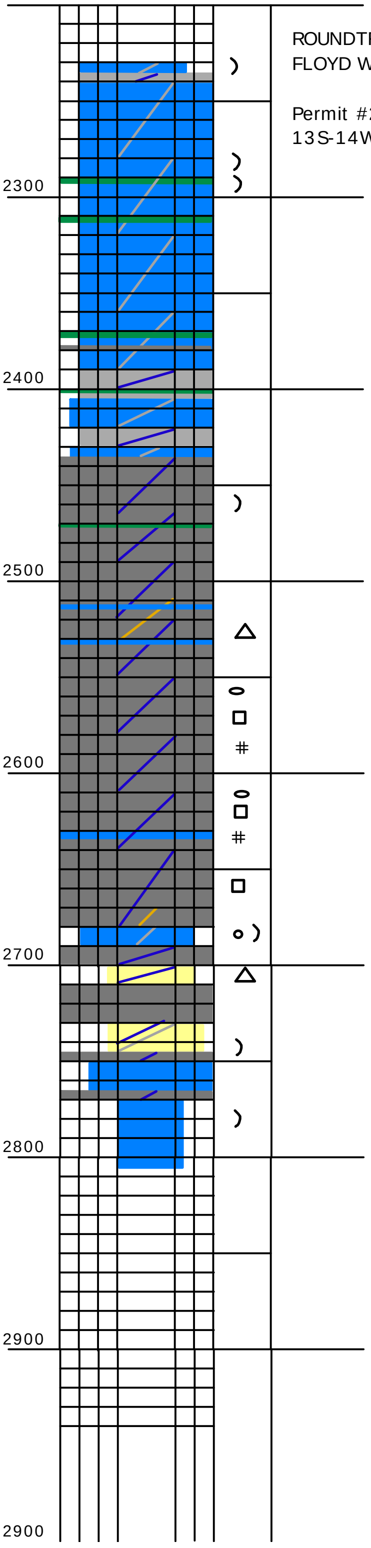
Permit No. 2143
BURNS, R.L. CORP.
PEARCE 4 #1
Marion County, Alabama
13S, 11W, 4
Described by C.A. Kidd

| Depth (feet) | Lithology | Description |
|---|---|---|
| 1600-1640 | Limestone | light olive gray, fine crystalline, micrite, fossils: crinoids |
| 1640-1675 | Limestone | light olive gray, coarse crystalline, pellets, packstone, fossils: crinoids |
| 1675-1690 | Limestone | light gray, fine crystalline, packstone, fossils: shell fragments and bryozoans |
| 1690-1700 | Limestone | light olive gray/olive gray, coarse crystalline, pellets, bioclastic, packstone |
| 1700-1720 | Limestone | light gray, fine crystalline, packstone, fossils: crinoids and gastropods |
| 1720-1750 | Limestone | olive gray/medium gray, fine to medium crystalline, wacke/packstone, fossils: crinoids and shell fragments |
| 1750-1800 | Limestone | medium gray, medium crystalline, bioclastic, packstone, rare blue chert, fossils: crinoids |
|  | Shale | (1750 ft.) dark gray, calcareous |
| 1800-1895 | Limestone | medium gray, fine crystalline, wackestone, fossils: crinoids, brachiopod shell fragments |
| 1895-1905 | Shale | dark gray/black, calcareous |
| 1905-1995 | Limestone | medium gray, fine crystalline, micrite, rare brown chert, rare shell fragments |
|  | Claystone | maroon (at 1915 ft.) |
| 1995-1050 | Shale | medium dark gray, calcareous, siderite, sulfur, pyrite, sparse fossils: crinoids, shell fragments |
| 2050-2070 | Limestone | medium gray, fine-medium crystalline, micrite, rare shell fragments |
| 2070-2080 | Shale | medium dark gray, calcareous, slightly silty, sparse shell fragments |
| 2080-2100 | Limestone | medium gray, fine-medium crystalline, few pellets, micrite/wackestone |
|  | Shale | as above |
| 2100-2190 | Shale | medium gray, silty, calcareous, slightly carbonaceous, fossils: abundant (2090-2095 ft.) crinoids, clams, gastropods; rare (after 2100 ft.) shell fragments, ammonite cephalopod |
| 2190-2230 | Shale | medium gray, silty, calcareous, carbonaceous, pyrite, sulfur fossils: (rare) shell fragments, bryozoans |
|  | Limestone | light olive gray, medium crystalline, micrite |
| 2230-2255 | Sandstone | medium gray, very fine (0.125 mm), argillaceous, calcareous |

| | | |
|---|---|---|
| 2255-2300 | Shale | dark gray, siderite, pyrite, rare shell fragments |
| 2300-2310 | Shale | medium gray, silty, carbonaceous, sulfur, rare shell fragments |
| 2310-2320 | Sandstone | light gray, very fine (0.14-0.16 mm), calcareous, argillaceous, carbonaceous |
| 2320-2330 | Limestone | light olive gray, fine crystalline, wackestone, fossils: shell fragments, crinoids |
| 2330-2350 | Limestone | white/light gray, oolitic, fossiliferous, packstone |

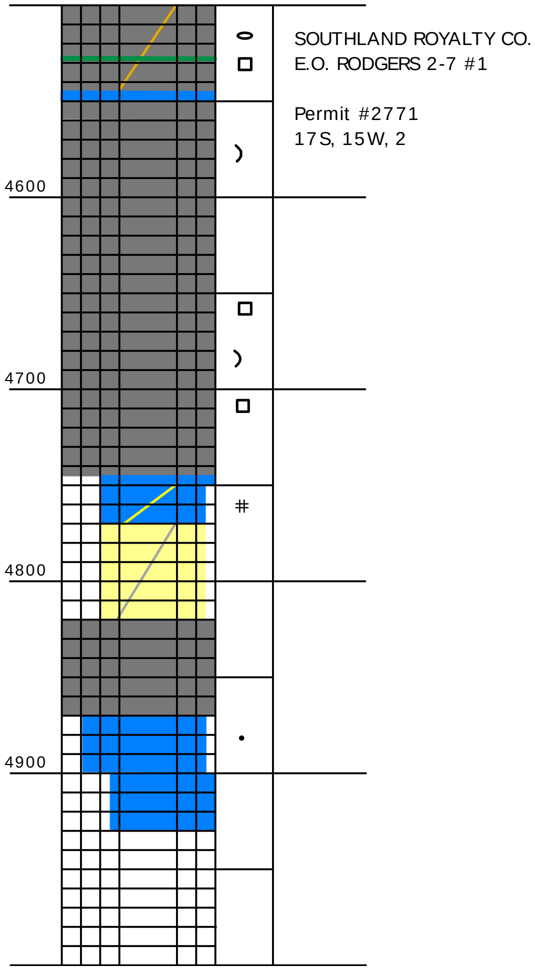
ROUNDTREE & ASSOCIATES, INC.
FLOYD WHITE 7-12 #1

Permit #2482
13S-14W-7



Permit No. 2482
ROUNDTREE & ASSOCIATES, INC.
FLOYD WHITE 7-12 #1
Lamar County, Alabama
13S, 14W, 17
Described by C.A. Kidd

| Depth (feet) | Lithology | Description |
|---|---|---|
| 2230-2235 | Limestone | light medium gray, fine crystalline, packstone, fossils: crinoids, bryozoans, shell fragments |
| 2235-2240 | Shale | medium gray, calcareous |
| | Claystone | maroon and green |
| 2240-2270 | Limestone | light medium gray, fine crystalline, micrite/wackestone, fossils: crinoids and shell fragments |
| | Claystone | maroon and green |
| 2270-2300 | Limestone | medium gray, fine crystalline, packstone, rare pyrite, fossils: shell fragments and bryozoans |
| 2300-2390 | Limestone | medium gray, fine crystalline, micrite |
| | Claystone | maroon and green (thin beds at 2300 ft. and 2370 ft.) |
| | Shale | black, (very thin bed at 2380 ft.) |
| 2390-2400 | Shale | medium gray, calcareous, slightly silty, rare shell fragments |
| 2400-2405 | Claystone | maroon and green |
| 2405-2430 | Limestone | medium dark gray, fine crystalline, micrite |
| 2430-2440 | Shale | medium gray, calcareous |
| 2440-2445 | Limestone | medium dark gray, fine crystalline, micrite |
| 2445-2490 | Shale | dark gray, slightly calcareous, calcite along partings, rare shell fragments |
| | Claystone | maroon and green (2470 ft.) |
| 2490-2550 | Shale | dark gray, calcareous, silty, micaceous |
| | Limestone | interbeds, dark gray, fine crystalline, micrite |
| 2550-2680 | Shale | medium dark gray, calcareous, siderite, sulfur, carbonaceous, pyrite (2640 ft.), siderite (2250-2620 ft.), silty (2680 ft.), fossils: rare gastropods and shell fragments |
| | Limestone | medium dark gray, fine crystalline, micrite (2635 ft.) |
| 2680-2690 | Limestone | medium gray, fine crystalline, bioclastic, packstone, ooids (with quartz nuclei), shell fragments |
| 2690-2700 | Shale | dark gray, calcareous |
| 2700-2710 | Sandstone | light gray, very fine to fine (avg. 0.2 mm), calcareous, poorly sorted, quartzarenite |
| 2710-2730 | Shale | dark gray |
| 2730-2745 | Sandstone | tan/light gray, fine (0.2-0.33 mm), quartzarenite, argillaceous, calcareous, shale laminae, shell fragments |
| 2745-2750 | Shale | dark gray, calcareous |
| 2750-2765 | Limestone | light medium gray, fine crystalline, micrite, fossils: crinoids |
| 2765-2770 | Shale | dark gray, calcareous |
| 2770-2800 | Limestone | white/light gray, bioclastic, packstone/grainstone |

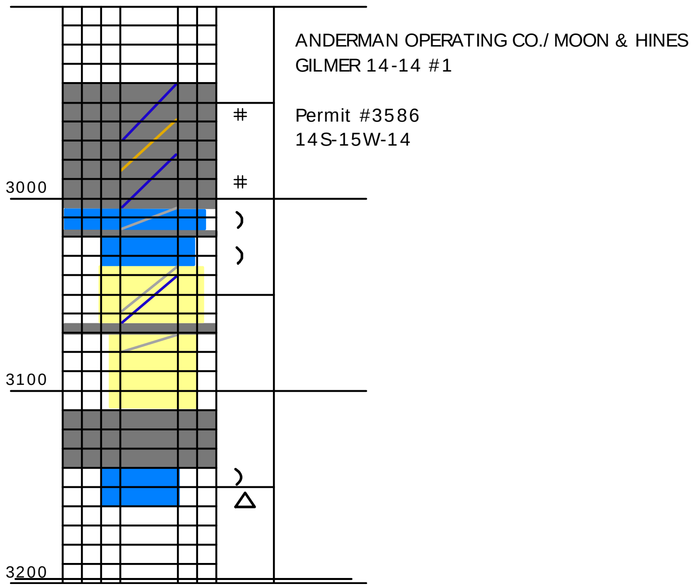


SOUTHLAND ROYALTY CO.
E.O. RODGERS 2-7 #1

Permit #2771
17S, 15W, 2

Permit No. 2771
SOUTHLAND ROYALTY CO.
E.O. RODGERS 2-7 #1
Lamar County, Alabama
17S, 15W, 2
Described by C.A. Kidd

| Depth (feet) | Lithology | Description |
|---|---|---|
| 4500-4560 | Shale | dark gray, siderite, rare coal, pyrite |
| | Limestone | medium gray, micrite (thin bed at 4540 ft.) |
| 4560-4745 | Shale | dark gray/black (after 4650 ft.), rare pyrite, rare brachiopod |
| 4745-4750 | Limestone | light gray, fine crystalline, wackestone, fossil: crinoids |
| 4750-4770 | Limestone | light gray, carbonaceous, sandy (0.16 mm) |
| 4770-4820 | Sandstone | brown, very fine (0.16 mm), very argillaceous |
| 4820-4870 | Shale | dark gray |
| 4870-4900 | Limestone | medium to olive gray, fine-medium crystalline, micrite, few pellets |
| 4900-4930 | Limestone | light olive gray, fine crystalline, micrite, chert |



ANDERMAN OPERATING CO./ MOON & HINES
GILMER 14-14 #1

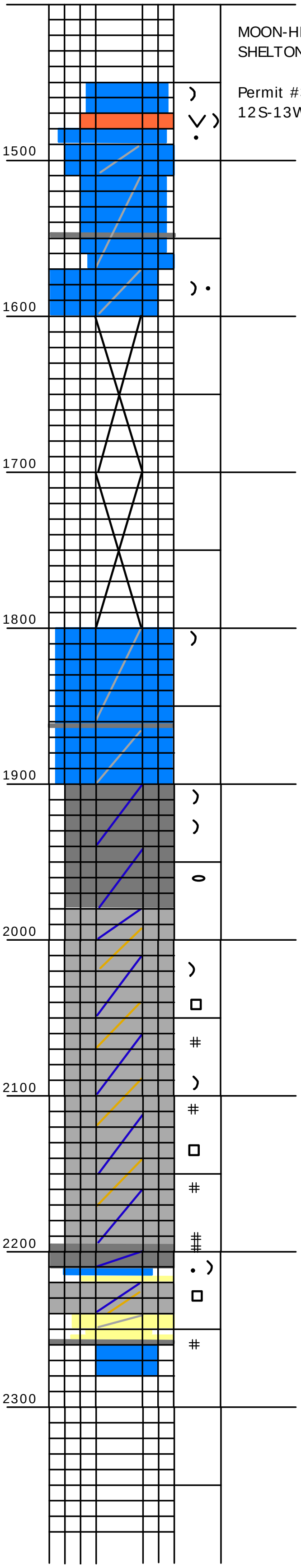
Permit #3586
14S-15W-14

Permit No. 3586
ANDERMAN OPERATING CO./MOON & HINES
GILMER 14-14 #1
Lamar County, Alabama
14S, 15W, 14
Described by C.A. Kidd

| Depth (feet) | Lithology | Description |
|---|---|---|
| 2940-3005 | Shale | Dark gray, slightly calcareous, silty, few laminae, rare carbonaceous fragments |
| | Limestone | few interbeds, (2980-3000 ft.) light olive gray, fine crystalline, micrite |
| 3005-3015 | Limestone | dark gray, coarse crystalline, bioclastic, wack/packstone, fossils: brachiopods |
| 3015-3020 | Shale | dark gray |
| 3020-3035 | Limestone | medium light gray, bioclastic, argillaceous, packstone, fossils: brachiopods and crinoids |
| | Shale | dark gray |
| 3035-3065 | Sandstone | light gray, very fine to fine (0.16-0.25mm), very argillaceous, slightly calcareous, quartzarenite, <2% lithics, sharp contact with shale, rare carbonaceous material |
| 3065-3070 | Shale | dark gray, sharp contact with sandstone |
| 3070-3110 | Sandstone | light gray/white, fine to medium (0.33-0.5mm), quartzarenite, subrounded, finer and more argillaceous up-section |
| 3110-3140 | Shale | dark gray |
| 3140-3160 | Limestone | light gray/white, coarse crystalline, bioclastic, packstone, chert (milky), ooids/pellets, abundant fossils |

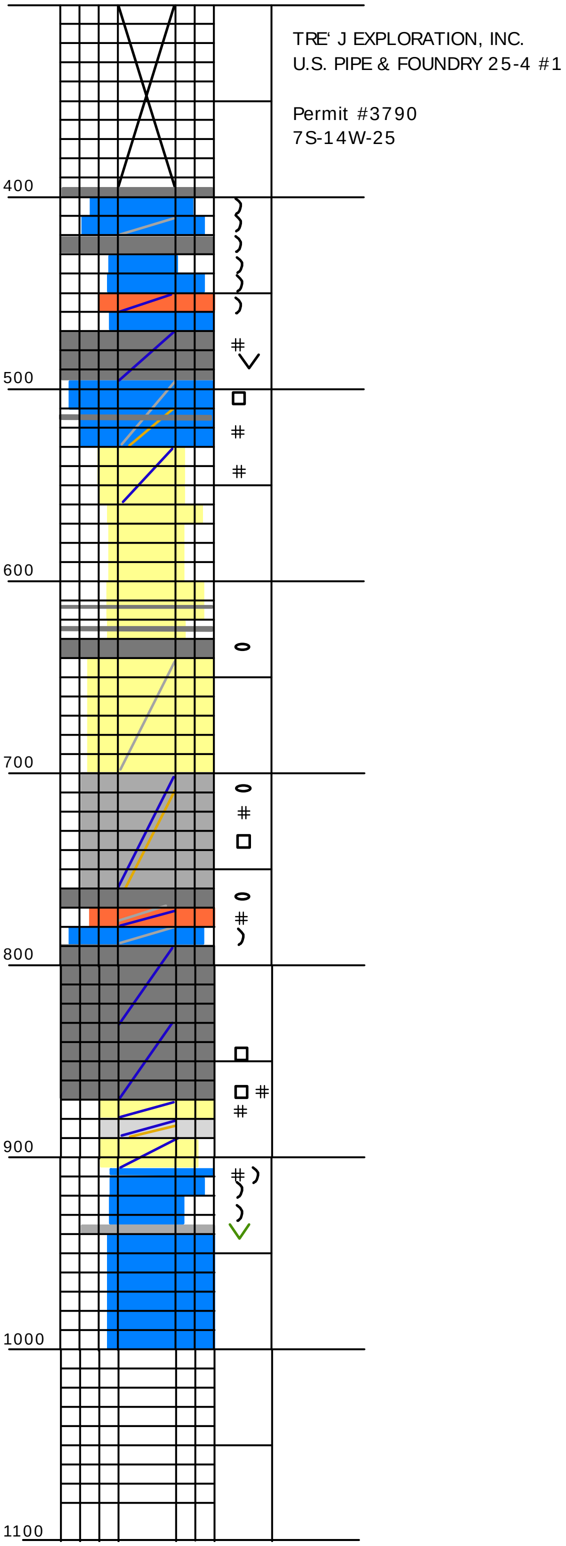
MOON-HINES-TIGRETT OPERATING CO., INC.
SHELTON 6-13 #1

Permit #3772
12S-13W-6



Permit No. 3772
MOON-HINES-TIGRETT OPERATING CO., INC.
SHELTON 6-13 #1
Marion County, Alabama
12S, 13W, 6
Described by C.A. Kidd

| Depth (feet) | Lithology | Description |
|---|---|---|
| 1450-1470 | Limestone | light olive gray, fine-medium crystalline, bioclastic, packstone, fossils: shell fragments and crinoids |
| 1470-1480 | Siltstone | light green gray, micaceous, feldspathic? |
| 1480-1510 | Limestone | medium dark gray, fine crystalline, black pellets, wackestone |
| 1510-1560 | Limestone | light olive gray, fine crystalline, micrite |
|  | Shale | dark gray/black, rare coal (1550 ft.) |
| 1560-1570 | Limestone | white/light olive gray, fine crystalline, pellets?, micrite |
| 1570-1600 | Limestone | dark gray, medium crystalline, packstone, argillaceous, black pellets, crinoids |
| 1600-1800 | No Sample |  |
| 1800-1900 | Limestone | dark gray, fine crystalline, argillaceous, micrite, rare brachiopod shell |
|  | Shale | (1860 ft.) dark gray, calcareous |
| 1900-1980 | Shale | medium/dark gray, calcareous, siderite, fossils (decrease in abundance with depth): crinoids and stems, bryozoans, gastropods, shell fragments |
| 1980-2000 | Shale | medium gray, calcareous, silty |
|  | Limestone | dark gray, medium-coarse crystalline, black pellets, packstone, fossils: crinoids |
| 2000-2195 | Shale | medium gray, silty calcareous, sparsely carbonaceous, rare coal (2170 ft.), rare pyrite, rare shell fragments, rare bryozoans (2055 ft.) |
| 2195-2200 | Shale | black, carbonaceous |
| 2200-2210 | Shale | dark gray, calcareous |
| 2210-2215 | Limestone | light gray, fine crystalline, packstone, black pellets, crinoids |
| 2215-2220 | Sandstone | light gray, very fine (0.16 mm), argillaceous, calcareous |
| 2220-2240 | Shale | medium gray/green gray, calcareous, silty, carbonaceous, pyrite |
| 2240-2257 | Sandstone | brown, very fine (0.16mm), argillaceous, quartzarenite |
|  | Sandstone | (2245 ft.) white, fine (0.33 mm), friable |
| 2257-2260 | Shale | black, very fissile, carbonaceous |
| 2260-2280 | Limestone | white/light gray, sandy, packstone |



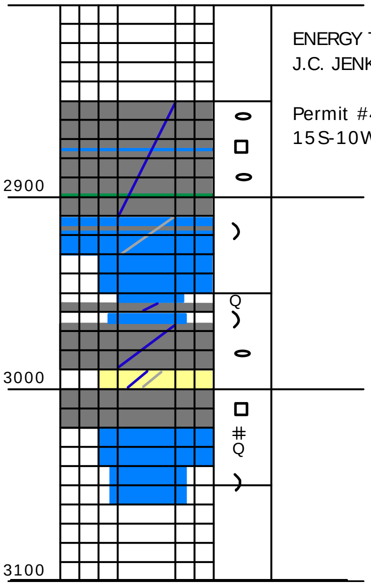
TRE' J EXPLORATION, INC.
U.S. PIPE & FOUNDRY 25-4 #1

Permit #3790
7S-14W-25

Permit No. 3790
TRE'J EXPLORATION, INC.
U.S. PIPE & FOUNDRY 25-4 #1
Franklin County, Alabama
7S, 14W, 25
Described by C.A. Kidd

| Depth (feet) | Lithology | Description |
|---|---|---|
| 300-395 | No Samples | |
| 395-400 | Shale | medium dark gray |
| | Limestone | medium dark gray, medium crystalline, packstone, argillaceous, fossils: bryozoans, shell fragments, crinoids, gastropods |
| 400-410 | Limestone | as above |
| | Limestone | light olive gray, fine crystalline, micrite |
| 410-420 | Limestone | medium gray, medium crystalline, bioclastic, packstone, fossils: crinoids, shell fragments, bryozoans |
| 420-430 | Shale | medium dark gray, sparse fossils: crinoids and gastropods |
| 430-440 | Limestone | medium gray, medium crystalline, pack/grainstone, very abundant fossils: bryozoans and crinoids |
| 440-450 | Limestone | light olive gray, fine crystalline, wackestone, fossils: bryozoans and crinoids |
| 450-460 | Siltstone | medium gray, calcareous, rare crinoids |
| 460-470 | Limestone | light olive gray, medium crystalline, micrite |
| 470-495 | Shale | dark gray, calcareous, carbonaceous, micaceous |
| 495-510 | Limestone | medium dark gray, fine crystalline, argillaceous, micrite |
| | Shale | dark gray, calcareous, micaceous, pyrite |
| 510-530 | Limestone | medium gray, fine crystalline, silty, carbonaceous, micrite, rare shell fragments |
| 530-550 | Sandstone | light gray/white, fine to medium (0.33-0.5 mm), calcareous, friable, moderately sorted, subrounded, rare crinoids |
| 550-560 | Sandstone | medium gray, very fine (0.2 mm), very argillaceous, calcareous, carbonaceous |
| 560-630 | Sandstone | light gray/tan, very fine to medium (0.16-0.5 mm), calcareous, poor sorting, friable, rare shell fragments, coarsens upward, shale interbeds in lower part of unit |
| 630-640 | Shale | dark gray, siderite |
| 640-700 | Sandstone | medium gray, very fine (0.125 mm), silty, argillaceous, carbonaceous (680 ft.), calcareous (660 ft.) |
| 700-760 | Shale | medium gray, siderite, slightly calcareous, silty, micaceous, sparsely carbonaceous |
| 760-770 | Shale | dark gray, siderite |
| 770-780 | Siltstone | medium gray, sandy, argillaceous, slightly calcareous, carbonaceous |
| 780-790 | Limestone | dark gray, fine crystalline, wackestone, shell fragments |
| 790-870 | Shale | dark gray, calcareous, rare sulfur and pyrite |

| | | |
|---|---|---|
| | Shale | black (860 ft.), pyrite, carbonaceous |
| 870-880 | Sandstone | tan/light gray, very fine (<0.125 mm), argillaceous, calcareous, sparsely carbonaceous |
| 880-890 | Shale | light medium gray, calcareous |
| 890-905 | Sandstone | tan/light gray, very fine to fine (0.16-0.25 mm), calcareous, friable, subrounded, moderate sorting |
| 905-910 | Limestone | light gray, fine crystalline, micrite, sparsely carbonaceous, fossils: bryozoans |
| 910-920 | Limestone | light olive gray, fine crystalline, wackestone, |
| 920-935 | Limestone | light olive gray, fine crystalline, packstone, fossils: bryozoans and crinoids |
| 935-940 | Shale | medium gray, calcareous, micaceous, glauconite? |
| 940-1000 | Limestone | light olive gray, fine crystalline, micrite |



ENERGY THREE, INC.
J.C. JENKINS 20-6 #1

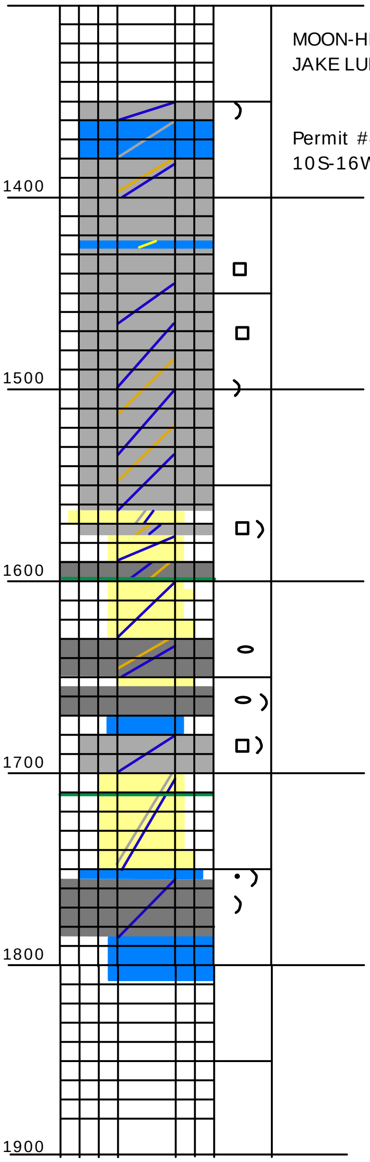
Permit #4224
15S-10W-20

Permit No. 4224
ENERGY THREE, INC.
J.C. JENKINS 20-6 #1
Fayette County, Alabama
15S, 10W, 20
Described by C.A. Kidd

| Depth (feet) | Lithology | Description |
|---|---|---|
| 2850-2910 | Shale | dark gray, calcareous, siderite, rare pyrite |
| | Limestone | few thin interbeds, light gray, fine crystalline, micrite |
| | Clay | maroon and green, (2 foot bed at 2900 ft.) |
| 2910-2930 | Limestone | dark gray, medium crystalline, bioclastic, wackestone, fossils: crinoids |
| 2930-2950 | Limestone | light olive gray, medium crystalline, bioclastic, wackestone |
| 2950-2955 | Limestone | white, sandy, packstone |
| 2955-2960 | Shale | dark gray, calcareous, rare siderite |
| 2960-2965 | Limestone | light olive gray, coarse crystalline, bioclastic, packstone, fossils: crinoids |
| 2965-2990 | Shale | dark gray, calcareous, siderite |
| 2990-3000 | Sandstone | brown, very fine (0.125-0.16 mm), argillaceous, calcareous, quartzarenite |
| 3000-3020 | Shale | dark gray/black, sulfur, pyrite |
| 3020-3025 | Limestone | light olive gray, fine crystalline, micrite, rare carbonaceous |
| 3025-3060 | Limestone | white, sandy, packstone |

MOON-HINES-TIGRETT OPERATING CO., INC.
JAKE LUNDY #36-13

Permit #4324
10S-16W-36



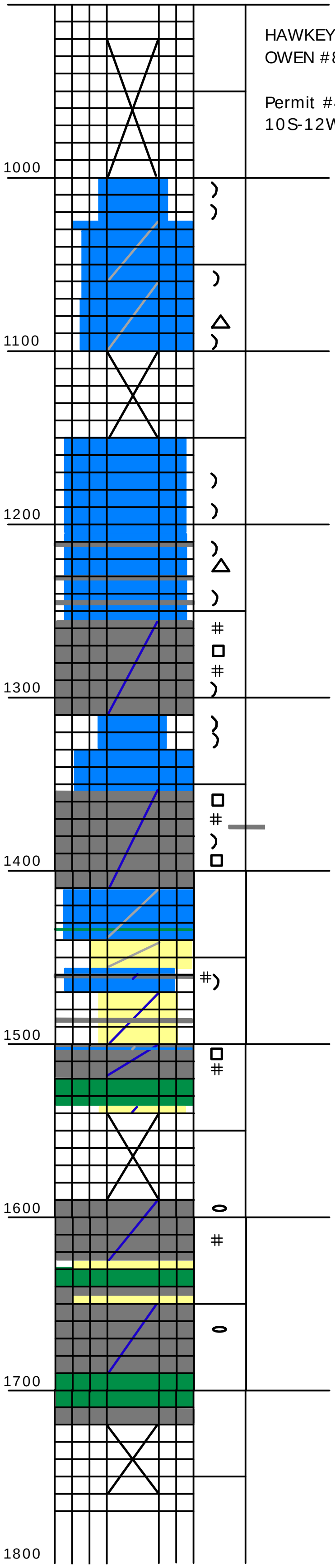
Permit No. 4324
MOON-HINES-TIGRETT OPERATING CO., INC.
JAKE LUNDY #36-13
Marion County, Alabama
10S, 16W, 36
Described by C.A. Kidd

| Depth (feet) | Lithology | Description |
|---|---|---|
| 1350-1355 | Shale | medium gray, calcareous, sparse shell fragments |
| 1355-1380 | Limestone | medium gray, fine crystalline, micrite |
| 1380-1400 | Shale | medium gray, calcareous, silty |
| 1400-1445 | Shale | medium gray, pyrite (1440-1450 ft.) |
| 1445-1465 | Shale | medium gray, calcareous |
| 1465-1563 | Shale | medium gray, calcareous, silty, pyrite (1470 ft.), fossil: tiny shell (mollusk?) (1500 ft.) |
| 1563-1570 | Sandstone | dark gray/black, calcareous, very fine (0.125-0.16 mm), argillaceous |
|  | Sandstone | tan/light gray, calcareous, slightly coarser |
| 1570-1575 | Shale | medium gray, calcareous, pyrite, silty, fossils: crinoid and coral? |
| 1575-1590 | Sandstone | light gray/white, very fine to fine (0.14-0.25 mm), friable, slightly calcareous, quartzarenite, carbonaceous, 3% lithics, argillaceous |
| 1590-1600 | Shale | dark gray, slightly calcareous, pyrite, fossil: crinoids |
| 1600-1620 | Sandstone | as above |
| 1620-1630 | Sandstone | white, fine (0.2-0.33 mm), slightly calcareous, quartzarenite |
| 1630-1650 | Shale | dark gray, calcareous, siderite, silty (1630-1635 ft.), siderite, very thin green claystone layer |
| 1650-1655 | Sandstone | white, fine (0.2-0.25 mm), quartzarenite, slightly argillaceous, slightly carbonaceous |
| 1655-1670 | Shale | as above, rare shell fragments |
| 1670-1680 | Limestone | white/light gray, ooids, grainstone, rare shell fragments |
|  | Limestone | light olive gray, fine crystalline, micrite |
| 1680-1700 | Shale | medium gray calcareous, rare pyrite, rare shell fragments |
|  | Claystone | green, carbonaceous |
| 1700-1755 | Sandstone | tan, argillaceous, very slightly calcareous, quartzarenite, friable, subangular, grain size by depth:<br>1700 ft. (0.16-0.125 mm), 1710 (0.16-0.33 mm),<br>1730 ft. (0.16-0.25mm), 1740 ft. (0.25-0.5 mm) |
| 1750-1755 | Shale | medium gray, fine crystalline, packstone, black pellets, sparse fossil fragments |
| 1755-1785 | Limestone | medium dark gray, fine crystalline, rare coal, sparsely carbonaceous, calcareous, fossils: rare shell fragments and crinoids |

|  |  |  |
|---|---|---|
| 1785-1800 | Limestone | white/light gray, fine crystalline, patchy argillaceous, micrite |

HAWKEYE OIL & GAS, INC.
OWEN #8-11

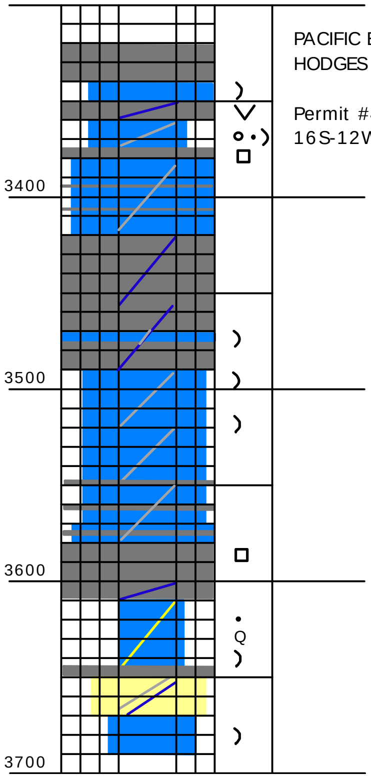
Permit #4361
10S-12W-8



Permit No. 4361
HAWKEYE OIL & GAS, INC.
OWEN #8-11
Marion County, Alabama
10S, 12W, 8
Described by C.A. Kidd

| Depth (feet) | Lithology | Description |
|---|---|---|
| 920-1000 | No Sample | |
| 1000-1025 | Limestone | medium gray to light olive tray, coarse crystalline, bioclastic, argillaceous, packstone, fossils: crinoids and columnals, bryozoan, brachiopod, clam |
| 1025-1030 | Limestone | medium gray, very argillaceous, rare bioclastic, micrite |
| 1030-1070 | Limestone | medium gray, medium crystalline, bioclastic, packstone, fossils: crinoids, bryozoans |
| | Limestone | white, abundant ooids, grainstone |
| | Claystone | maroon and green |
| 1070-1100 | Limestone | medium dark gray, fine-medium crystalline, argillaceous, wack/packstone, fossils: crinoids and brachiopods |
| 1100-1150 | Limestone | light gray, argillaceous, wackestone, fossils: brachiopod |
| | Shale | dark gray, micaceous |
| 1150-1215 | Limestone | medium dark gray, fine-medium crystalline, bioclastic, packstone, rare blue chert, fossils: bryozoans, brachiopods, crinoids |
| 1215-1255 | Limestone | as above |
| | Shale | dark gray |
| 1255-1310 | Shale | dark gray, calcareous, carbonaceous, pyrite, very fissile, fossil: bryozoan |
| 1310-1355 | Limestone | medium and olive gray, coarse crystalline, argillaceous, packstone, abundant fossils: bryozoans, crinoids, and brachiopods |
| 1355-1410 | Shale | dark gray, calcareous, pyrite, carbonaceous, rare silty laminae, sharp contact with limestone, fossil: rare brachiopod |
| 1410-1440 | Limestone | medium dark gray, fine crystalline, micrite/wackestone and |
| | Shale | dark gray |
| | Claystone | maroon and green (1430-1440 ft.) |
| 1440-1455 | Sandstone | tan, very fine (0.125-0.16mm), very argillaceous, friable |
| 1455-1470 | Limestone | medium dark gray, medium crystalline, bioclastic, few black pellets, packstone, fossils: bryozoans and crinoids |
| 1470-1500 | Sandstone | white/tan, fine (0.25 mm), argillaceous, calcareous, friable |
| | Shale | dark gray, calcareous |
| 1500-1520 | Shale | dark gray, calcareous, carbonaceous, pyrite and |
| | Limestone | medium dark gray, packstone, fossil: bryozoans |
| 1520-1535 | Claystone | maroon and green |

|  |  |  |
|---|---|---|
| 1535-1540 | Sandstone | white, very fine (0.16 mm), calcareous, rare carbonaceous, friable |
| 1540-1590 | No sample |  |
| 1590-1610 | Shale | dark gray, slightly calcareous, siderite, rare carbonaceous |
| 1610-1625 | Shale | dark gray with sand <0.125 mm (sample powdered) |
| 1625-1640 | Claystone | maroon and green |
| 1640-1660 | Shale | as above. |
| 1660-1690 | Shale | dark gray, siderite, calcareous |
|  | Sandstone | brown, very fine (<0.125 mm), calcareous, argillaceous, silty |
| 1690-1710 | Claystone | maroon and green |
| 1710-1720 | Shale | dark gray |
| 1720+ | No sample |  |



PACIFIC ENTERPRISES OIL CO. (USA)
HODGES ESTATE #26-13

Permit #4425
16S-12W-27

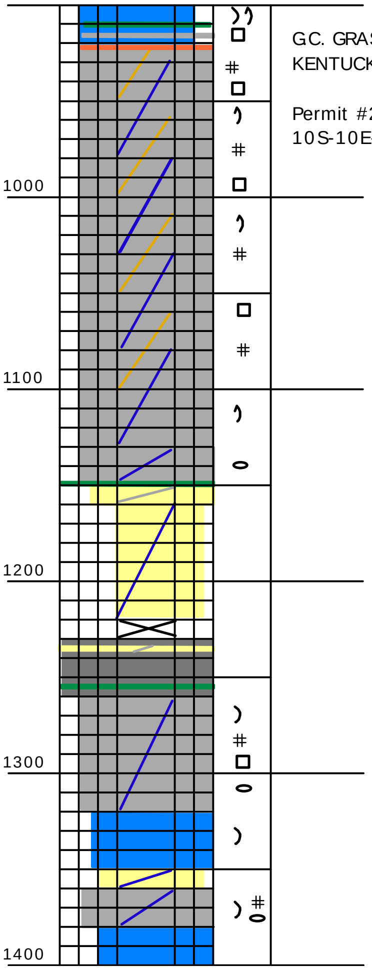
Permit No. 4425
PACIFIC ENTERPRISES OIL CO. (USA)
HODGES ESTATE #26-13
Fayette County, Alabama
16S, 12W, 27
Described by C.A. Kidd

| Depth (feet) | Lithology | Description |
|---|---|---|
| 3320-3340 | Shale | dark gray |
| 3340-3350 | Limestone | brown/red, micrite, bioclastic, crinoids |
| 3350-3360 | Shale | dark gray, calcareous, mica in partings |
| 3360-3375 | Limestone | medium gray, argillaceous, pack/grainstone, black pellets, fossils: shell fragments, gastropods, crinoids |
| 3375-3380 | Shale | dark gray/black, pyrite |
| 3380-3420 | Limestone | medium dark gray, fine crystalline, micrite, argillaceous |
| 3420-3490 | Shale | dark gray, calcareous |
|  | Limestone | thin bed at 3470 ft., medium dark gray, medium crystalline, packstone, crinoids |
| 3490-3570 | Limestone | medium dark gray, fine crystalline, argillaceous, micrite |
|  | Shale | gradational, shale content increases down section, dark gray, pyrite, rare shell fragment |
| 3570-3580 | Limestone | medium dark gray, medium crystalline, micrite |
| 3580-3600 | Shale | dark gray/black, sulfur, pyrite, very fissile |
| 3600-3610 | Shale | dark gray, calcareous |
| 3610-3650 | Limestone | white, sandy (0.33 mm), packstone, grapestone, shale rip-ups, black pellets and ooids, fossils: shell fragments and crinoids |
|  | Limestone | medium gray, micrite |
|  | Shale | dark gray (5 foot bed at 3650 ft.) |
| 3650-3670 | Sandstone | medium gray/tan, very fine to fine (0.16-0.25 mm), argillaceous, subangular, quartzarenite, calcareous, moderate sorting |
| 3670-3690 | Limestone | white/light gray, sandy, bioclastic, packstone |

Well No. 81
Magnolia Petroleum
No 1 Pierce
Monroe County, Mississippi
13S, 7E, 22
Described by W.A. Thomas

| Depth (feet) | Lithology | Description |
|---|---|---|
| 2855-2960 | Sandstone | gray to white, fine grained, angular, slightly calcareous, quartzose, aggregates |
| | Shale | dark medium gray (interbedded) |
| 2960-2970 | Shale | dark medium gray |
| 2970-2995 | Sandstone | light brown and gray white, fine grained, angular, vitreous, slightly calcareous, quartzose, brown oil stain, aggregates |
| 2995-3020 | Shale | dark gray, siderite |
| 3020-3116 | Shale | dark gray black |
| 3116-3126 | Sandstone | medium light gray, fine grained, angular, vitreous, fossils (brachiopods, bryozoans, crinoid columnals) rare mica, coarse crystalline calcite fracture and vug fillings, very calcareous, in part quartz grains apparently float in calcite cement |
| 3126-3128 | No Sample | |
| 3128-3138 | Sandstone | medium light gray and light gray, fine grained, angular, vitreous, rare fossil fragment, calcareous, calcite fracture filling |
| | Shale | medium gray, carbonaceous in part, rare mica, occurs as < 3 mm thick interlaminations within sandstone, horizontal laminae |
| 3138-3150 | Sandstone | light gray brown, fine grained, angular, vitreous, slightly calcareous, brown oil stain<br>(3140-3141) rare carbonaceous laminae<br>(3141-3142) light gray, very calcareous, fossil (composite)<br>(3142-3145) quartzose, hard<br>(3145-3146) carbonaceous clay laminae<br>(3146-3148) fossil fragment |
| 3150-3154 | Sandstone | medium light gray, fine grained, angular, vitreous, slightly calcareous in part, quartzose, hard, dark gray clay chip < 15mm across;< 3mm thick |
| 3154-3157 | Sandstone | light gray, very fine to fine grained, angular, vitreous, calcareous, irregular carbonaceous clay laminae <3 mm thick |
| 3157-3158 | No Sample | |
| 3158-3170 | Sandstone | light gray, very fine to fine grained, angular, vitreous, calcareous, rare carbonaceous clay laminae, quartzose, aggregates |

| | | |
|---|---|---|
| 3170-3275 | Shale | dark gray black, siderite |
| 3275-3297 | Limestone | light medium gray, micrite and biomicrite, rare biosparite, medium to coarse bioclastic, rare oolite, fossil fragments (brachiopods and crinoid columnals) |
| 3297-3303 | Sandstone | medium light gray, fine to medium grained, angular, vitreous, quartzose, interlaminated with clay shale, medium gray, carbonaceous in part, avg. 3 mm thick |
| 3303-3306 | Sandstone | light gray, very fine to fine grained, angular, vitreous, quartzose, clay laminae |
| 3306-3307 | No Sample | |
| 3307-3314 | Sandstone | like, 3303-3306 |
| 3314-3332 | Sandstone | light gray and very light tan, fine to medium grained, angular, vitreous, quartzose, rare carbonaceous laminae, rare glauconite? |
| 3332-3334 | No Sample | |
| 3334-3343 | Shale | dark gray, calcareous, fossil and fragments (brachiopods, crinoid columnals), calcite |
| 3343-3344 | No Sample | |
| 3344-3365 | Shale | like 333-3343 |
| 3365-3369 | Limestone | light medium gray, biosparite, argillaceous in part, fossil (crinoid columnals), coarse bioclastic |
| 3369-3371 | Limestone | light gray, biomicrite, fine bioclastic |

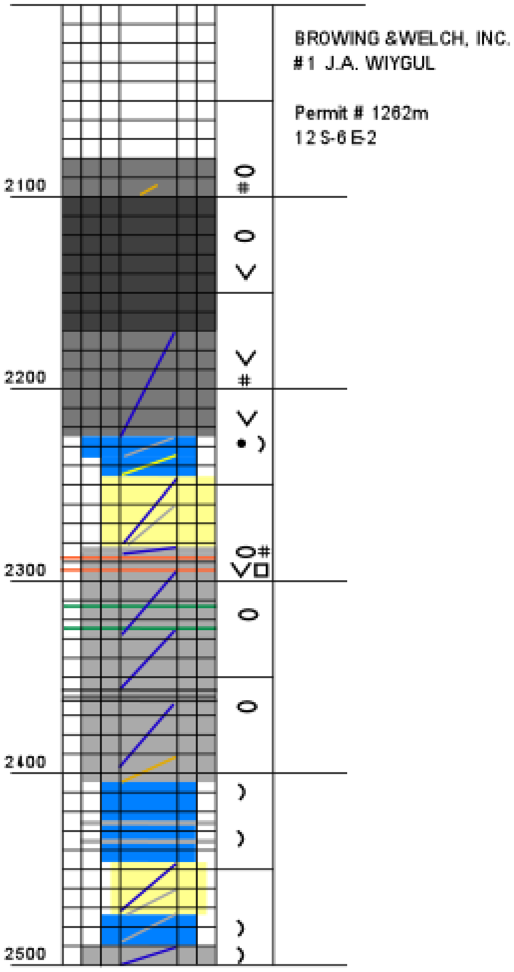


G.C. GRASTY
KENTUCKY LUMBER CO. #1

Permit #2093
10S-10E-7

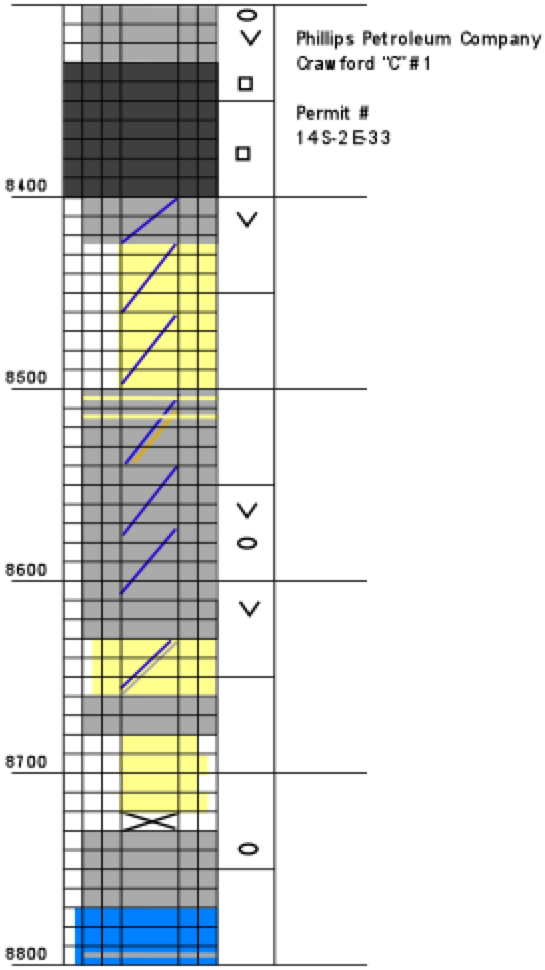
Well No. 10107m
G.C. Grasty
Kentucky Lumber Co. #1
Itawamba County, Mississippi
10S, 10E, 7
Described by C.A. Kidd

| Depth (feet) | Lithology | Description |
|---|---|---|
| 900-920 | Limestone | medium gray, fine crystalline, sparsely silty, bioclastic, packstone, shell fragments |
| | Shale | medium gray, silty, calcareous, carbonaceous, pyrite, fossils: mollusk, crinoid, shell fragments |
| | Siltstone | medium gray |
| | Claystone | thin bed, maroon and green (910-920 ft.) |
| 920-1130 | Shale | medium gray, calcareous, silty, carbonaceous, pyrite, sparse fossils: mollusk, shell fragments, echinoderm? |
| 1130-1150 | Shale | medium gray, calcareous, siderite |
| | Claystone | maroon and green (1150 ft.) |
| 1150-1160 | Sandstone | light gray/brown, very fine to fine grained (0.16-0.25 mm), slightly calcareous, argillaceous, friable |
| 1160-1220 | Sandstone | white, very fine (0.16 mm at 1160ft.) to fine (0.25 mm, at 1180 ft.), quartzarenite, sparsely carbonaceous, slightly calcareous |
| 1220-1230 | No Sample | |
| 1230-1260 | Shale | dark gray, carbonaceous, coaly, sulfur, pyrite |
| | Sandstone | as above |
| | Claystone | maroon and green |
| 1260-1320 | Shale | dark gray, siderite, slightly calcareous, carbonaceous, pyrite, sparse fossils: bryozoans and shell fragments |
| 1320-1350 | Limestone | medium to light olive gray, fine crystalline, micrite/wackestone, rare shell fragments |
| 1350-1360 | Sandstone | tan, fine (0.2-0.25 mm) slightly calcareous, argillaceous matrix |
| 1360-1380 | Shale | medium gray, calcareous, sparsely carbonaceous, siderite, shell fragments |
| | Limestone | thin bed, medium gray, medium crystalline, micrite |
| 1380-1400 | Limestone | light olive gray, fine to medium crystalline, micrite |


BROWING &WELCH, INC.
#1 J.A. WIYGUL
Permit # 1262m
12 S-6 E-2
2100
2200
2300
2400
2500

Well No. 1262m
Browning & Welch Inc.
J.A. Wiygul #1
Monroe County, Mississippi
12S, 6E, 2
Described by C.A. Kidd

| Depth (feet) | Lithology | Description |
|---|---|---|
| 2080-2110 | Shale | medium dark gray, siderite, silty laminae, micaceous, sparsely carbonaceous, very silty (2100-2110 ft.) |
| 2110-2170 | Shale | black, sparse sulfur, sparsely coaly, sparse siderite, laminated, very fine mica |
| 2170-2225 | Shale | medium dark gray, calcareous, silty, sparsely carbonaceous |
| | Siltstone | medium gray, calcareous |
| 2225-2235 | Limestone | medium gray, fine crystalline, packstone, pellets, crinoids |
| | Shale | as above, with very rare coal |
| 2235-2245 | Limestone | light gray, packstone, sandy, fossils: shell fragments and bryozoans |
| 2245-2283 | Sandstone | white/tan, slightly calcareous, very fine (0.16-0.2mm), friable, more argillaceous down section |
| | Shale | few interbeds, dark gray, rare carbonaceous and sulfur |
| 2283-2285 | Shale | medium gray, calcareous, siderite, slightly carbonaceous, fine mica in partings |
| 2285-2300 | Shale | medium gray, siderite, slightly carbonaceous |
| | Siltstone | thin interbeds, medium gray, argillaceous, sparse pyrite |
| 2300-2405 | Shale | medium gray, siderite, slightly calcareous, thin coaly intervals (2330-2350 ft.), rare pyrite (after 237 0ft.), silty (2390-2405 ft.) |
| | Claystone | green, thin interbeds (2300-2320 ft.) |
| 2405-2425 | Limestone | light gray/light olive gray, fine crystalline, bioclastic wackestone/packstone |
| | Shale | interbedded, medium dark gray, silty |
| 2425-2445 | Limestone | light gray/light olive gray/medium gray, fine crystalline, wackestone/packstone, bioclastic, fossils: crinoid stems and shell fragments |
| 2445-2472 | Sandstone | white/light gray, fine-very fine (0.16-0.25mm), calcareous, quartzarenite, friable, becomes more argillaceous down section |
| | Shale | thin interbeds, medium dark gray, carbonaceous plant fragments, rare sulfur |
| 2472-2490 | Limestone | light olive gray, packstone, bioclastic, fossils: bryozoans and crinoids |
| 2490-2500 | Shale | medium gray, slightly calcareous, siderite, pyrite, fossils: bryozoans and crinoids columnals |


Phillips Petroleum Company
Crawford "C" #1
Permit #
14S-2E-33
8400
8500
8600
8700
8800

Well No. 14233m
Phillips Petroleum Company
Crawford “C” #1
Chickasaw County, Mississippi
14S, 2E, 33
Described by C.A. Kidd

| Depth (feet) | Lithology | Description |
|---|---|---|
| 8300-8330 | Shale | medium gray, micaceous, siderite |
| 8330-8400 | Shale | gray black to black, pyrite |
| 8400-8425 | Shale | medium gray, slightly calcareous, micaceous |
| 8425-8500 | Sandstone | white, very fine grained (0.16 mm), calcareous, quartzarenite, subrounded, friable |
| 8500-8540 | Shale | medium gray, calcareous, slightly silty |
| | Sandstone | few interbeds, brown, very fine grained, argillaceous |
| 8540-8610 | Shale | medium gray, slightly calcareous, rare carbonaceous, fine mica, siderite |
| 8610-8630 | Shale | medium gray, fine mica |
| 8630-8660 | Sandstone | light to medium gray, very fine grained (0.16 mm), very calcareous, sparsely carbonaceous |
| | Sandstone | thin bed, white, cleaner, slightly coarser (0.2 mm) |
| 8660-8680 | Shale | medium gray |
| 8680-8720 | Sandstone | white to light gray, alternates between fine and very fine (0.16 to 0.25mm), quartzarenite, subangular, friable |
| 8720-8730 | No sample | |
| 8730-8770 | Shale | medium gray, siderite |
| 8770-8800 | Limestone | dark gray, fine crystalline, micrite |

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